



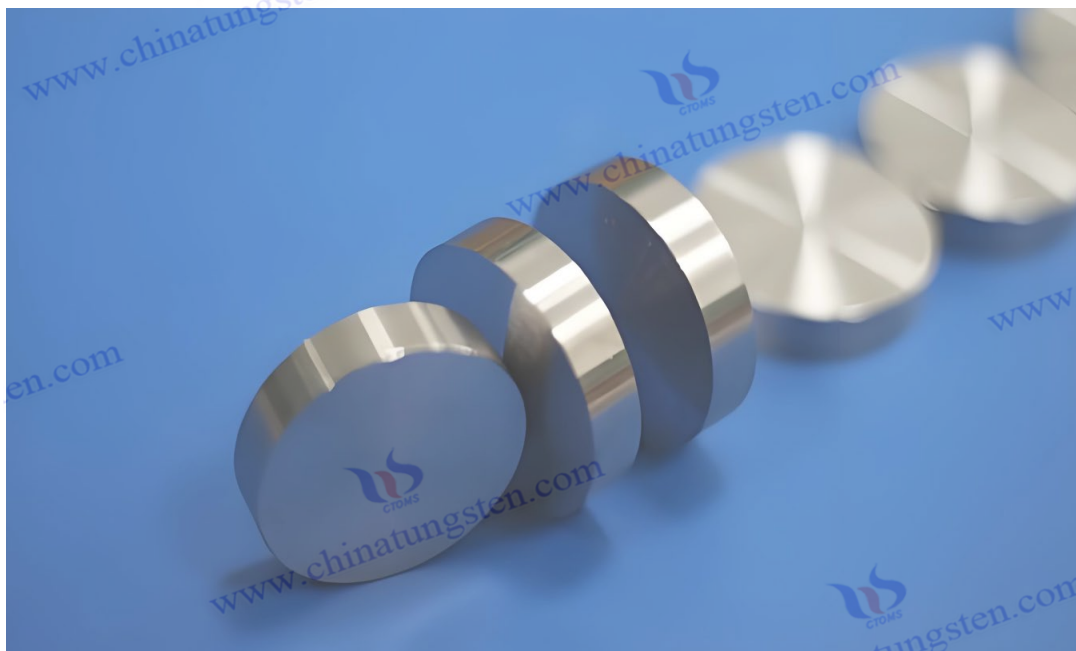
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Tungsten Alloy Counterweight Core Q&A 50 Questions

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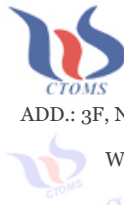
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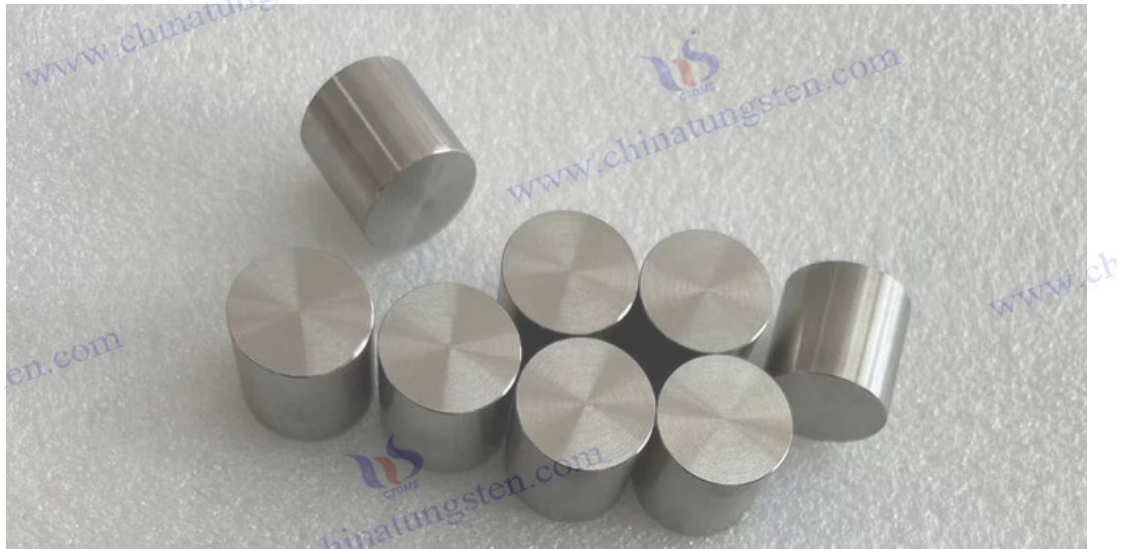
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Tungsten Alloy Counterweight High-Traffic Core Q&A 50 Questions

I. Basic Knowledge About High-Density Tungsten Alloy Counterweights

What is a high-density tungsten alloy counterweight?

A high-density tungsten alloy counterweight is a tungsten-based heavy alloy made primarily of tungsten (W, Tungsten) as the main constituent element, with the addition of metals such as nickel (Ni, Nickel), iron (Fe, Iron), and copper (Cu, Copper), used to provide calculated and controlled mass to mechanical systems, electronic devices, transportation vehicles, aerospace equipment, and precision instruments. It is not entirely the same as a metal block in the ordinary sense. The core task of a counterweight is not simply to increase the weight of a device, but to place a certain mass at a specified position so that the mass distribution of the entire system meets the design requirements. Therefore, counterweight design usually involves parameters such as mass, center of gravity, moment, moment of inertia, dynamic balance, and installation space at the same time. The advantage of high-density tungsten alloys lies precisely in the ability to obtain greater mass with a smaller volume. Public information shows that high-density tungsten alloys in engineering applications can usually reach about 16.5–19.0 g/cm³, and different material systems, tungsten contents, and manufacturing processes will cause differences in actual density.

From the perspective of product form, high-density tungsten alloy counterweights can be processed into cylinders, discs, rings, blocks, plates, special-shaped parts, perforated counterweights, threaded counterweights, embedded counterweights, and so on. The actual shape is usually not determined by the material itself, but by the installation space and mass distribution requirements of the equipment.



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Why are tungsten alloys particularly suitable for counterweights?

The core advantages of high-density tungsten alloys used for counterweights can be summarized as high density, small volume, and precision machinability. The density of ordinary steel is usually about 7.8 g/cm³, while high-density tungsten alloys can reach about 17–18.5 g/cm³ or even higher. Therefore, under the same mass condition, the volume of a tungsten alloy counterweight can be significantly reduced. For example, for a counterweight with a mass of 1 kg, if the material density is 18 g/cm³, its theoretical volume is approximately:

$$V = m/\rho = 1000/18 \approx 55.6 \text{ cm}^3$$

If steel with a density of about 7.85 g/cm³ is used, then: $V \approx 1000/7.85 \approx 127.4 \text{ cm}^3$

When achieving the same mass, the volume difference between the two is more than double. This is the most important engineering value of tungsten alloy counterweights: when the internal space of a device is limited, there is no need to add a very large steel counterweight block in order to obtain sufficient mass.

What does high density actually mean?

Density is the first basic parameter for understanding tungsten alloy counterweights. Density ρ (Density, density) is defined as the mass possessed by a unit volume of material, and its basic relationship is $\rho = m/V$, where m (Mass, mass) represents the counterweight mass, and V (Volume, volume). For counterweight design, it can be further obtained:

$$m = \rho V$$

That is to say, when the volume has already been determined, increasing the material density can increase the counterweight mass; conversely, when the target mass is determined, increasing the density can reduce the required volume. For example:

A 10 g tungsten alloy counterweight has a volume of about 0.556 cm³ at a density of 18 g/cm³;

A 100 g counterweight has a volume of about 5.56 cm³;

A 1 kg counterweight has a volume of about 55.6 cm³.

This type of calculation is very important for product design, because engineers usually do not first decide how large a counterweight block should be, but first know how much mass needs to be added, then reversely calculate the material volume, and then design the final structure according to the equipment space.

High-density tungsten alloy and pure tungsten are not the same material. Many people who come into contact with tungsten counterweights for the first time easily confuse pure tungsten with tungsten alloy. Pure tungsten (W, Tungsten) has a very high melting point, density, and high-temperature stability, but pure tungsten material has relatively high processing difficulty and brittleness problems. Therefore, the industrial counterweight field widely uses tungsten heavy alloys rather than directly using pure tungsten. Tungsten heavy alloys form a composite material system through tungsten particles and binder phase metals, allowing the material to maintain high density while obtaining mechanical



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properties and processing properties more suitable for engineering manufacturing. At present, common counterweight material systems mainly include:

W-Ni-Fe (Tungsten-Nickel-Iron, tungsten-nickel-iron);

W-Ni-Cu (Tungsten-Nickel-Copper, tungsten-nickel-copper).

Public product information shows that both types of materials are used in counterweight scenarios such as vibration motors, mobile phones, electric toothbrushes, massage equipment, golf, fishing gear, and vehicles.

What are the characteristics of W-Ni-Fe counterweights?

W-Ni-Fe (Tungsten-Nickel-Iron, tungsten-nickel-iron) is a very common type of material in high-density tungsten alloy counterweights. Its basic structure can be understood as a high proportion of tungsten particles forming the main mass basis, while nickel and iron form the binder phase. Through powder metallurgy (PM, Powder Metallurgy) and liquid-phase sintering and other processes, a material with relatively high density and relatively good comprehensive mechanical properties can be formed. W-Ni-Fe is usually suitable for counterweight structures with certain requirements for strength, toughness, and machinability, such as automotive counterweights, aviation counterweights, industrial rotor balancing parts, and precision machinery counterweights. In addition, W-Ni-Fe usually has a certain degree of magnetism. Therefore, if the counterweight is installed near magnetic sensors, magnetic compasses, or equipment highly sensitive to magnetic fields, it is not enough to consider only density; the magnetic properties of the material also need to be evaluated.

What are the characteristics of W-Ni-Cu counterweights?

W-Ni-Cu (Tungsten-Nickel-Copper, tungsten-nickel-copper) uses nickel and copper as the main binder phase. Compared with W-Ni-Fe, one of the important characteristics of W-Ni-Cu is that it usually has a lower magnetic response or approximately non-magnetic characteristics, so it is more valuable in certain equipment sensitive to magnetic field interference. Public technical information also uses it in scenarios such as gyroscopes and magnetically sensitive equipment. Therefore, W-Ni-Fe and W-Ni-Cu are not simply a question of which is better, but are selected according to the application environment. If the main considerations are mechanical strength, toughness, cost, and conventional structural counterweights, W-Ni-Fe is often an important candidate material; if the equipment has strict requirements for magnetic properties, W-Ni-Cu may be more suitable.

Is higher density always better?

High density can indeed further reduce counterweight volume, but as tungsten content increases, the material's mechanical properties, processing difficulty, cost, and sintering process requirements will also change. For example, when there is only a very small space inside the equipment, a material of 18.0–18.5 g/cm³ may have obvious value; but if the installation space is sufficient, then bearing higher material and processing costs in order to



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increase from 17.5 g/cm³ to 18.5 g/cm³ may not have equivalent engineering benefits. Therefore, what high-density counterweights truly need to optimize are: target mass, installation space, material density, structural dimensions, mechanical strength, processing accuracy, magnetic properties, surface treatment, cost, and service environment. In other words, a reasonable counterweight design usually seeks a material that satisfies all engineering requirements, rather than simply pursuing the highest density.

What is the difference between tungsten alloy counterweights and steel counterweights?

The greatest advantages of steel counterweights are usually low price, mature supply, and convenient processing. However, the density of steel is significantly lower than that of high-density tungsten alloys. When equipment space is limited, if steel is used to achieve the same mass, a larger counterweight volume may be required. The main advantage of tungsten alloys is the ability to concentrate more mass in a limited space. This is especially important for automotive engines, rotating machinery, aviation control surfaces, drones, robot joints, and precision instruments, because many systems do not simply need a weight, but require that this weight must be installed in a specific small space. Information in the aerospace field also clearly emphasizes the value of tungsten heavy alloys in control surface counterweights, rotating system balancing, and space-constrained mass distribution.

What is the difference between tungsten alloy counterweights and lead counterweights?

Lead (Pb, Lead) is also a traditional high-density counterweight material, but the density of tungsten alloys is usually significantly higher than that of lead. Therefore, under the same mass condition, tungsten alloys can further reduce volume. In addition, in modern engineering design, material environmental protection, safety, mechanical properties, and service environment also need to be comprehensively considered. Some automotive counterweight fields are looking for lead replacement solutions, and high-density tungsten alloys have therefore become one of the material choices. Automotive application information points out that tungsten alloys can achieve greater mass in limited space and are used in scenarios such as wheel balancing, engine crankshafts, and transmission systems. However, lead will not be completely replaced by tungsten alloys in all applications. For ordinary, low-cost counterweight products that are not sensitive to space, material price is still an important factor.

What a counterweight truly controls is the center of gravity, not simply weight.

This is one of the most important concepts for understanding high-density tungsten alloy counterweights. If a mechanical system itself already has a certain mass, then the purpose of adding an additional counterweight block is usually not simply to make it heavier, but to change the mass distribution of the entire system.

The most basic center-of-gravity relationship can be understood as: $x_c = \sum m_i x_i / \sum m_i$
where x_c represents the position of the system's center of gravity, m_i represents the mass



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of the i -th mass unit, and x_i represents the coordinate of that mass unit relative to the reference position. Therefore, adding the same 100 g counterweight at different positions produces completely different changes in the center of gravity. This is also why tungsten alloy counterweights often use small cylinders, thin sheets, ring parts, or local embedded structures, rather than simply being made into a large iron block.

Counterweights also involve moments.

In rotating systems, merely knowing the counterweight mass is not enough; the position of the counterweight relative to the axis of rotation must also be considered. The moment can be expressed as: $M=F \times r$. Here M (Moment, moment) represents the rotational effect, F (Force, force) represents the applied force, and r (Radius, moment arm) represents the distance from the mass or applied force to the center of rotation. In some counterweight systems, a smaller tungsten alloy mass only needs to be installed at a position farther from the axis of rotation to produce a greater balancing effect; if space requirements place the counterweight close to the axis center, then a higher-density material is needed to provide sufficient mass. This is the important connection between high-density materials and precision rotating machinery.

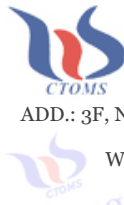
Why is tungsten alloy used in dynamic balancing?

If the mass of a rotating component is unevenly distributed, periodic centrifugal force will be generated during high-speed rotation. Automotive crankshafts, transmission shafts, industrial rotors, machine tool spindles, fan rotors, aero-engine components, and gyroscope rotors may all have similar problems.

Tungsten alloy counterweights can be installed at designed positions to make the mass distribution of the rotating system more uniform by adding or adjusting local mass, thereby reducing vibration. For example, when an automotive engine crankshaft rotates at high speed, if the counterweight is insufficient or incorrectly positioned, obvious vibration may occur, further affecting bearings, the engine block, and other related components. Related automotive application information uses tungsten alloy counterweights in crankshafts, transmission shafts, wheel balancing, and mass distribution of high-performance vehicles.

Why are industrial rotors particularly suitable for high-density counterweights?

Industrial rotors usually have two characteristics: high rotational speed and limited installation space. When the rotational speed increases, even a very small mass deviation may form obvious dynamic imbalance. Therefore, counterweight parts must not only have accurate mass, but also accurate position and geometric dimensions. For high-speed spindles, industrial robot joints, centrifuges, pumps, fans, compressors, and other rotating systems, tungsten alloy rings, cylindrical counterweights, and eccentric counterweights can all become design solutions. Tungsten alloy ring-shaped balancing parts can also perform dynamic balancing by changing the mass distribution and moment of inertia of rotating



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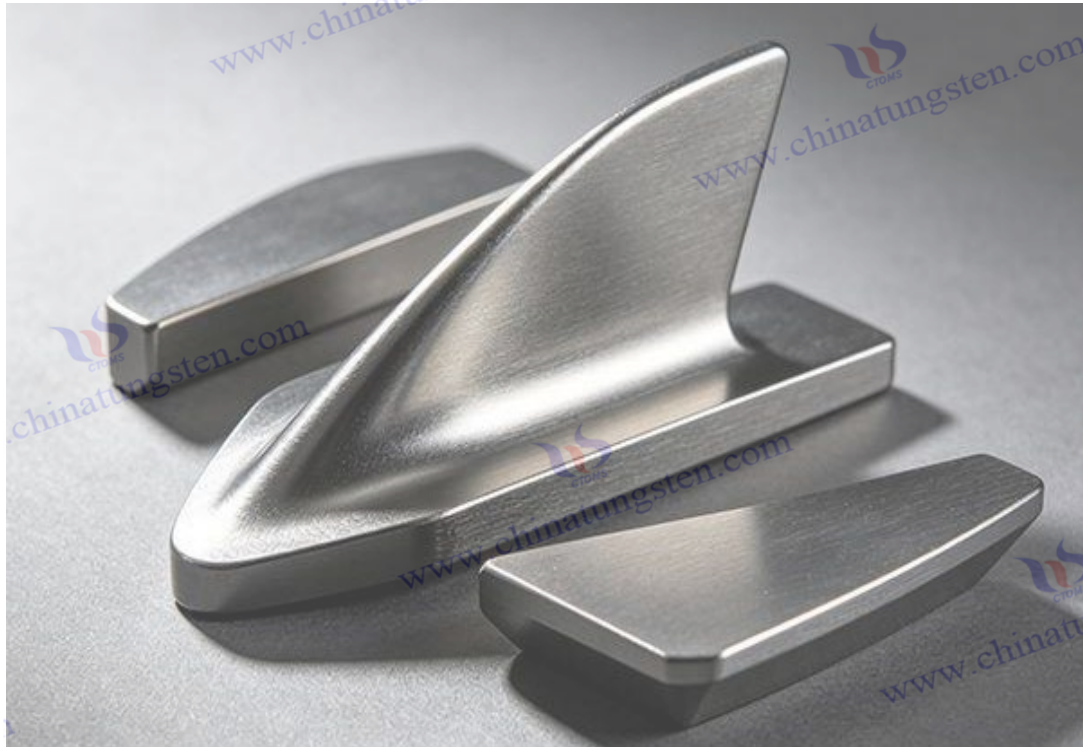
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components.

Why does the aerospace field particularly value tungsten alloy counterweights?

Aerospace equipment is very sensitive to weight distribution and space utilization. Aircraft elevators, ailerons, rudders, flaps, and other control surfaces all need to consider aerodynamic balance and mass distribution. If the counterweight volume is too large, it will not only affect the structural layout, but may also increase system weight and space occupation. Tungsten alloys can provide greater mass in limited space, so they can be used for aircraft control surface counterweights, helicopter rotor balancing, engine rotating components, and spacecraft mass distribution adjustment. Related aerospace information shows that the key applications of high-density tungsten alloys include control surface counterweights, gas turbine rotor balancing, spacecraft attitude control, and inertial systems.



Why is there so much attention on tungsten alloy counterweights in the automotive field?

Counterweights in the automotive field are not limited to traditional tire balancing weights. High-density tungsten alloys can be used for engine crankshaft counterweights, driveshaft counterweights, wheel hub balancing components, racing chassis ballast, suspension mass adjustment, and vibration-damping structures for some cameras, radar, and LiDAR (Light Detection and Ranging) devices. For racing cars, ballast also involves front-to-rear axle load distribution and the vehicle's center-of-gravity position. For high-speed rotating components, counterweights are more responsible for dynamic balancing. For vehicle-mounted sensors, counterweights may be used to change system inertia and



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suppress vibration, thereby helping maintain the sensor's operational stability. Relevant automotive materials also describe high-density tungsten alloys as suitable for scenarios such as crankshafts, driveshafts, wheel hub balancing, and sensor vibration damping.

Why do drones need high-density counterweights?

Drones are characterized by compact structures, sensitivity to mass, and many rotating components. In drone systems, counterweights may be used to: adjust the aircraft's center of gravity, balance the rotor system, stabilize the gimbal, adjust the inertia of camera equipment, reduce structural vibration, and compensate for local mass differences. Especially in gimbal systems, there are complex torque relationships among the mass of the camera itself, the lens position, and the rotation axes. If counterweight needs to be added without significantly increasing structural dimensions, high-density tungsten alloys offer clear advantages.

Why do mobile phones and micro vibration devices use tungsten alloy counterweights?

In micro devices such as mobile phones, electric toothbrushes, massage devices, and vibration motors, the size of counterweights is usually subject to very strict limitations. The eccentric mass block in a vibration motor needs to generate a certain centrifugal force while not occupying too much internal space. For rotating vibration structures, this can be simply understood as:

$$F = m\omega^2r$$

Here, F (Centrifugal Force) is related to the mass m (Mass), the angular velocity ω (Angular Velocity), and the eccentric radius r (Radius). When the structural dimensions cannot continue to increase, increasing the density of the counterweight material allows a greater mass to be obtained within a limited volume. This is also an important reason why high-density tungsten alloys are used in micro products such as mobile phones, vibration motors, electric toothbrushes, and massage devices.

Why do golf clubs use tungsten alloy counterweights?

Golf clubs are a fairly typical consumer-grade application of high-density counterweights. Club designers can install tungsten alloy counterweights at specific positions on the club head and adjust the club's center of gravity and inertia characteristics by changing the mass distribution. Because tungsten alloys have high density, a relatively large mass can be added within a very limited structural space. Public application materials show that tungsten alloys are used for golf club head counterweights to adjust the center-of-gravity position and mass distribution.



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How are high-density tungsten alloy counterweights manufactured?

High-density tungsten alloys are usually not directly melted and cast into final products like ordinary steel; instead, powder metallurgy routes are widely used. A typical process can be summarized as: preparation of tungsten powder and other alloy powders → batching → mixing → pressing and forming → debinding or pretreatment → liquid-phase sintering → blank inspection → machining → surface treatment → dimensional and weight inspection → final inspection. The powder metallurgy route is particularly suitable for materials with high tungsten content because tungsten itself has an extremely high melting point, and traditional melting and casting processes make it difficult to directly obtain the desired composition and microstructure. Some sources also point out that tungsten alloys can achieve good dimensional stability and mechanical properties through powder metallurgy processes such as liquid-phase sintering, and then undergo precision machining.

Why is machining still required after sintering?

Sintering can form the basic shape of a counterweight, but many precision counterweights cannot rely solely on sintering to reach their final dimensions. For example, products may require: hole diameter accuracy, outer diameter accuracy, thickness tolerance, flatness, coaxiality, threads, chamfers, slots, mounting steps, and specific surface roughness. Therefore, sintered tungsten alloy blanks usually still require subsequent processes such as turning, milling, drilling, grinding, and thread machining. Public product information shows that tungsten alloy counterweights can be turned, milled, drilled, and threaded after sintering, and can undergo surface treatments such as nickel plating, zinc plating, or



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coating as needed.

Why is tungsten alloy relatively difficult to machine?

Although tungsten alloy is easier to machine than pure tungsten, it is still an engineering material with high density and high hardness. Machining mainly faces problems such as tool wear, large cutting forces, a narrow window of machining parameters, concentrated heat, and control of dimensional stability. Therefore, the rigidity of the machining equipment, tool material, tool geometry parameters, cutting speed, feed rate, and cooling method all affect the final quality. For precision counterweights, the machining difficulty is not only about achieving the dimensions, but also about ensuring that the quality and dimensions of each batch remain consistent.



Why do counterweights need weight tolerance control?

For ordinary static counterweights, weight error may not be sensitive. However, for high-speed rotating components, weight error directly affects dynamic balance. For example, a rotor may require multiple counterweight parts to jointly achieve balance. If each counterweight part has a relatively obvious mass deviation, the final combined mass distribution may deviate from the design value. Therefore, in engineering procurement, in addition to material density, requirements may also include the actual weight of individual parts, weight tolerance, batch consistency, and dynamic balance test data. For high-precision counterweights, the final evaluation criterion is not simply the material name, but whether the finished product truly meets the equipment's mass distribution requirements.



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Why are counterweight drawings very important?

Tungsten alloy counterweights are usually custom parts. A complete engineering drawing should at least clarify, as much as possible, the material grade or material system, target density, external dimensions, hole positions, threads, dimensional tolerances, geometric tolerances, surface roughness, surface treatment, and weight requirements. If the counterweight is used in a rotating system, the mounting datum, axis of rotation, balancing requirements, and allowable unbalance should also be further specified. For purchasers, simply telling a supplier that a 100 g tungsten alloy counterweight is needed is usually not enough for an accurate quotation. This is because the same weight can be designed into completely different structures such as cylinders, rings, blocks, and eccentric parts, and the mold, sintering, and machining costs of different structures may differ significantly.

How should the cost of tungsten alloy counterweights be understood?

The price of tungsten alloy counterweights is usually higher than that of ordinary steel counterweights, mainly due to material costs and manufacturing costs. Factors affecting the final price include: tungsten content, material density, W-Ni-Fe or W-Ni-Cu material system, raw material prices, product size, single-piece weight, mold cost, sintering process, amount of machining, dimensional tolerances, surface treatment, inspection requirements, order quantity, and packaging and transportation. Especially for small-batch custom products, even if the product itself is very light, fixed costs such as molds, process development, programming, fixtures, and inspection may still need to be borne. Therefore, the final product price of tungsten alloy counterweights cannot be judged simply by the price per kilogram of material.

How should a suitable high-density tungsten alloy counterweight be selected?

In actual projects, material selection can follow the logic below: first determine how much mass needs to be added, then determine the installation space; based on the space, work backward to determine the required material density, and then determine the W-Ni-Fe or W-Ni-Cu material system; subsequently determine the structural form, installation method, and machining accuracy; and finally comprehensively evaluate cost, surface treatment, and batch size. If space is very limited, focus should be placed on density; if mechanical loads must be borne, focus should be placed on strength and toughness; if magnetically sensitive components are nearby, focus should be placed on magnetic properties; if the product requires a large amount of machining, focus should be placed on machinability and machining cost; if it is used in a high-speed rotating system, special attention should be paid to weight tolerance, coaxiality, geometric accuracy, and dynamic balance. This selection method is more reasonable than simply comparing 17.5 g/cm³, 18.0 g/cm³, and 18.5 g/cm³. The core value of high-density tungsten alloy counterweights can be summarized as one engineering logic.

From the perspective of the entire material system and application scenarios, high-density



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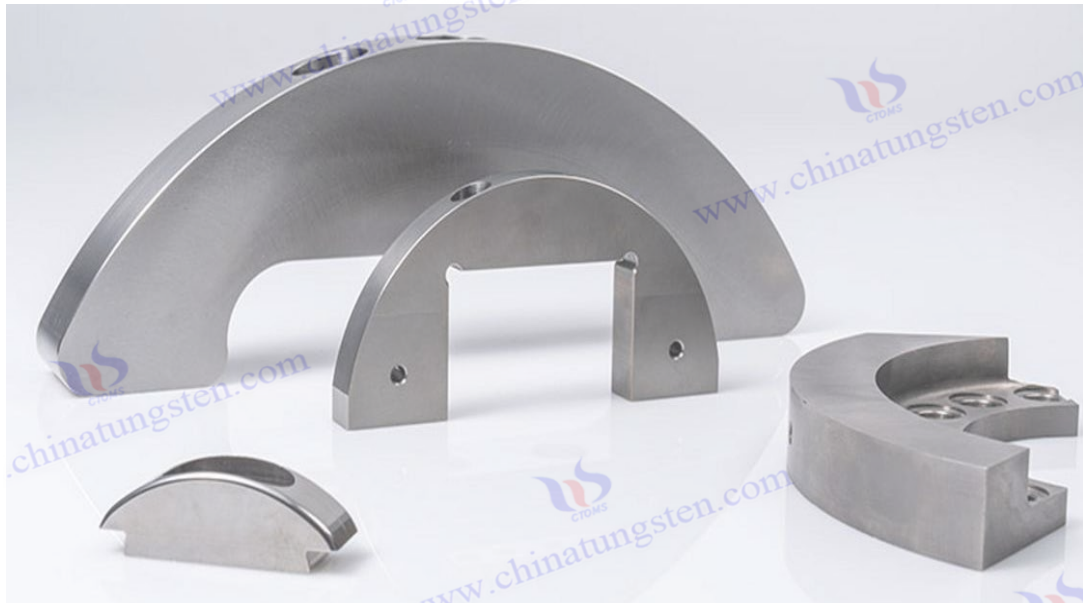
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tungsten alloy counterweights actually solve a very specific problem: how to accurately place the required mass within a limited space. Therefore, their value can be further broken down as follows: high density solves the volume problem, miniaturized structures solve the space problem, precision machining solves the dimensional problem, precise weight control solves the quality problem, a reasonable installation position solves the center-of-gravity problem, and dynamic balance solves the rotational vibration problem. Although applications such as aerospace, automobiles, racing cars, industrial rotors, drones, mobile phone vibration motors, and golf club heads appear very different, the underlying engineering logic is basically the same, namely, achieving compact mass configuration through high-density materials and precisely controlling mass distribution according to the equipment's motion state and structural requirements.





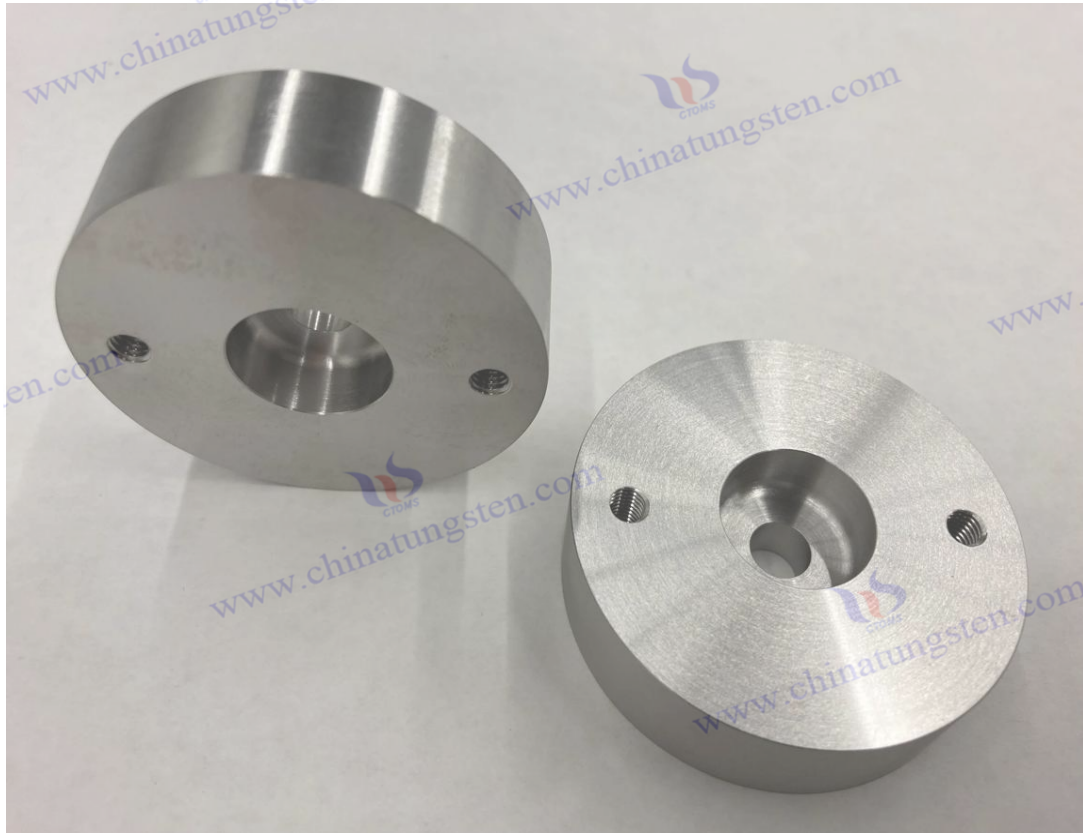
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Q1 What Is a Tungsten Alloy Counterweight?

A tungsten alloy counterweight is a type of functional metal component made from a high-density tungsten-based heavy alloy (Tungsten Heavy Alloy), with tungsten (W, Tungsten) as the main constituent element and with the addition of metals such as nickel (Ni, Nickel), iron (Fe, Iron), and copper (Cu, Copper), manufactured according to specific mass, dimensions, center of gravity, moment of inertia, and installation requirements, and used to adjust the mass distribution, center-of-gravity position, rotational inertia, or dynamic balance state of equipment or structures. Unlike an ordinary metal block in the general sense, the core of a tungsten alloy counterweight is not simply to increase the weight of equipment, but to precisely configure a specified mass to a designated position within a limited space. Therefore, a tungsten alloy counterweight simultaneously belongs to the cross-disciplinary field of materials engineering, mechanical design, precision machining, and mass balance control as a functional component.

I. High Density Is the Most Basic Material Characteristic of Tungsten Alloy Counterweights

The most prominent feature of tungsten alloy counterweights is high density. The density of common engineering-grade high-density tungsten alloys is usually about 16.5–19.0 g/cm³, with the specific value depending on tungsten content, binder phase composition, powder characteristics, and sintering process. The density of some commonly used counterweight



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materials can reach about 17.0–18.5 g/cm³. The basic relationship among density ρ (Density), mass m (Mass), and volume V (Volume) is $\rho=m/V$, which can also be written as $m=\rho V$ and $V=m/\rho$. This means that, when the target mass is the same, the higher the material density, the smaller the volume required. For example, when designing a 1 kg counterweight: if a tungsten alloy with a density of 18.0 g/cm³ is used, its theoretical volume is approximately: $V=1000/18.0\approx 55.6$ cm³.

If ordinary steel with a density of about 7.85 g/cm³ is used, its volume is approximately: $V=1000/7.85\approx 127.4$ cm³. In other words, to achieve the same 1 kg counterweight mass, the space required by high-density tungsten alloy is significantly smaller than that required by ordinary steel. This is precisely one of the most important engineering values of tungsten alloy counterweights: obtaining the required mass with a smaller structural size when the internal space of equipment is limited.

II. A Tungsten Alloy Counterweight Is Not Equal to a Pure Tungsten Counterweight

From the material name, there is an obvious difference between a tungsten alloy counterweight and a pure tungsten counterweight. Pure tungsten (W, Tungsten) itself has very high density, melting point, and high-temperature performance, but its material processing and forming are relatively difficult. In engineering, tungsten heavy alloys are usually formed by adding metals such as nickel, iron, and copper to maintain high-density characteristics while improving the material's comprehensive mechanical properties, sintering performance, and processing adaptability. At present, the material systems commonly used in the counterweight field include W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). W-Ni-Fe usually has good strength, toughness, and comprehensive mechanical properties, so it is often used in automobiles, aerospace, industrial machinery, rotating components, and general precision counterweights. W-Ni-Cu uses nickel and copper as the main binder phase and has advantages in certain applications with requirements for magnetic properties, electrical conductivity, or specific processing methods. Therefore, a tungsten alloy counterweight is actually a material system, not a single fixed-grade material.

III. The Real Function of a Tungsten Alloy Counterweight Is to Adjust Mass Distribution

The most basic engineering purpose of counterweight design is to change the mass distribution of a system. For example, if a certain component of mechanical equipment has a shifted center of gravity due to structural asymmetry, a tungsten alloy counterweight can be added at a designated position to return the overall center of gravity to the design position.

The system center-of-gravity position can be expressed as: $x_c = \sum m_i x_i / \sum m_i$, where x_c is the system center-of-gravity coordinate, m_i is the mass of the i -th mass unit, and x_i is the position of that mass unit relative to the reference coordinate. This means that a tungsten



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alloy counterweight of the same mass, if installed at different positions, will produce different effects on the entire system. For example, for the same 100 g counterweight: if installed close to the rotating shaft, the change in mass distribution produced is relatively small; if installed far from the rotating shaft, it can produce a more obvious mass and inertia adjustment effect. Therefore, the design of a tungsten alloy counterweight cannot provide only a weight value; it must also determine the position of the counterweight, the installation direction, and its relationship to the reference plane.

IV. In Rotating Machinery, Tungsten Alloy Counterweights Also Perform a Balancing Function

For crankshafts, rotors, main shafts, fans, pumps, compressors, centrifuges, and other high-speed rotating components, tungsten alloy counterweights are often used to improve dynamic balance. When a rotating system has mass eccentricity, as the rotational speed increases, the periodic centrifugal force generated by unbalance increases rapidly. Under idealized conditions, centrifugal force can be expressed as: $F=m\omega^2r$, where F (Centrifugal Force) represents the centrifugal effect generated by rotation, m (Mass) represents the eccentric mass, ω (Angular Velocity) represents the angular velocity of rotation, and r (Radius) represents the distance from the eccentric mass to the rotating shaft. Because centrifugal force is proportional to the square of angular velocity, high-speed rotating equipment is very sensitive to counterweight mass, installation position, and machining accuracy.

This is also one of the reasons why tungsten alloys are particularly suitable for high-speed rotating counterweights: by utilizing their high-density characteristics, the required mass can be configured within a smaller space, while the actual dimensions and position of the counterweight can be controlled through precision machining.

V. Why Tungsten Alloy Counterweights Are Suitable for Equipment with Limited Space

This is one of the core advantages that distinguishes tungsten alloy counterweights from ordinary steel counterweights. Suppose a certain piece of equipment needs to add 500 g of mass, but only about 30 cm³ of installation space can be provided internally. When a tungsten alloy with a density of 18 g/cm³ is used: $V=500/18\approx27.8$ cm³. Theoretically, it can meet the space requirement. If steel with a density of 7.85 g/cm³ is used: $V=500/7.85\approx63.7$ cm³.

At this time, even if the weight is exactly the same, the volume of the steel counterweight may exceed the installation space provided by the equipment. Therefore, in products such as mobile phone vibration motors, drone gimbals, automotive rotating components, aviation control surfaces, precision instruments, and micro actuators, high-density tungsten alloys have obvious space utilization advantages.



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VI. Typical Structural Forms of Tungsten Alloy Counterweights

There is no fixed external shape for tungsten alloy counterweights; rather, they are designed according to the specific equipment structure. Common forms include cylindrical counterweights, disc-shaped counterweights, ring-shaped counterweights, block-shaped counterweights, plate-shaped counterweights, spherical or nearly spherical counterweights, eccentric counterweights, perforated counterweights, threaded counterweights, embedded counterweights, and complex special-shaped counterweights. Among them, ring-shaped counterweights are particularly suitable for rotating systems and can be installed near shafts, rotors, flywheels, or other rotating components to achieve balance or inertia adjustment by changing mass distribution.

Block-shaped and plate-shaped counterweights are often used in aerospace, automobiles, and large machinery. Miniature cylinders, discs, or eccentric blocks are often used in mobile phones, electric toothbrushes, massage equipment, and other micro vibration mechanisms.

VII. How Tungsten Alloy Counterweights Are Usually Manufactured

High-density tungsten alloys are usually manufactured by powder metallurgy (PM, Powder Metallurgy) processes, rather than the simple melting and casting route common for ordinary steel. A typical production process can be summarized as: preparation of tungsten powder and other metal powders → batching → mixing → press forming → debinding or pretreatment → liquid-phase sintering → blank inspection → mechanical machining → surface treatment → dimension and weight inspection → finished product inspection. The powder metallurgy route is suitable for manufacturing high-tungsten-content materials because tungsten has an extremely high melting point, and directly using ordinary melting and casting processes to manufacture high-tungsten-content alloys presents great difficulties. Sintered tungsten alloy blanks usually also require further processing. Depending on the product structure, methods such as turning, milling, drilling, grinding, and thread machining can be used.

For complex structures, special processing methods such as electrical discharge machining (EDM, Electrical Discharge Machining) may also be used.

VIII. Why Tungsten Alloy Counterweights Require Precision Machining

A counterweight does not need only to reach the target weight. For example, for a tungsten alloy counterweight used in a high-speed rotor, even if the mass is completely correct, if the hole position is offset, the mounting surface is tilted, or the outer diameter is not concentric with the rotating shaft, new unbalance may still be generated. Therefore, counterweight products usually need to simultaneously control: mass tolerance, external dimension tolerance, hole diameter tolerance, hole position accuracy, coaxiality, circular runout, flatness, perpendicularity, surface roughness, and mounting datum. For high-precision rotating components, single-plane balancing, two-plane balancing, or



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dynamic balancing testing may also be required. This shows that a tungsten alloy counterweight is actually a typical precision functional part, not merely a piece of high-density metal.

IX. Application Fields of Tungsten Alloy Counterweights

Because tungsten alloys have high density and good dimensional designability, their application fields are very wide. In the aerospace field, they can be used for aircraft control surface counterweights, rotor balancing, engine rotor counterweights, inertial systems, and spacecraft mass distribution adjustment. In the automotive and racing fields, they can be used for crankshafts, drive shafts, wheel hub balancing, racing car mass distribution, and some sensor damping structures. In the industrial machinery field, they can be used for high-speed main shafts, industrial rotors, centrifuges, fans, pumps, compressors, and robot joints.

In the consumer electronics field, they can be used for mobile phone vibration motors, electric toothbrushes, massage equipment, and other micro eccentric vibration mechanisms. In the sports field, they can be used for golf clubs, fishing gear, and other small equipment requiring concentrated mass. In the precision instrument field, they can be used for gyroscopes, inertial systems, precision motion mechanisms, and some instruments requiring mass compensation.

X. Why for High-Density Tungsten Alloy Counterweights, Higher Density Is Not Always Better

Although higher density can further reduce volume, engineering material selection cannot consider density alone. For example, if a piece of equipment needs a 1 kg counterweight and has 100 cm³ of installation space, then materials with densities of 17.5 g/cm³, 18.0 g/cm³, or 18.5 g/cm³ may all be able to meet the requirements in terms of space. At this time, the space benefit brought by further increasing density may be limited, but material costs, processing costs, and manufacturing difficulty may increase. Conversely, if the equipment has only 50 cm³ of installation space, then a material with a density of 17.5 g/cm³ may already find it difficult to meet the target mass, while a material with a density of 18.5 g/cm³ may have obvious value. Therefore, the truly reasonable material selection logic is: target mass → available space → required density → material system → mechanical properties → processing requirements → balancing accuracy → cost. It is not simply choosing the material with the highest density.

XI. The Essential Difference Between Tungsten Alloy Counterweights and Traditional Counterweight Materials Such as Steel and Lead

From an engineering perspective, the characteristics of several materials can be understood as different combinations of performance. The advantages of steel counterweights are usually lower price, mature material supply, and convenient processing,



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but their density is relatively low. Lead (Pb, Lead) has relatively high density and good formability, but modern engineering applications need to further consider factors such as environmental protection, safety, and mechanical properties. The main advantages of tungsten alloys are concentrated in high density, small volume, and strong engineering designability, making them particularly suitable for scenarios with limited space, high mass concentration, and precision balancing. Therefore, tungsten alloys do not necessarily have to replace steel or lead in all counterweight applications, but rather demonstrate their material value when space, mass, balance, and performance requirements reach a certain level.

XII. From the Perspective of Product Definition, a Tungsten Alloy Counterweight Is Actually a Comprehensive Design Result

A truly meaningful high-density tungsten alloy counterweight ultimately needs to answer several questions at the same time: How much mass is needed? How much installation space is needed? Where is the counterweight installed? Is what needs to be changed the static center of gravity or dynamic balance? Does it involve rotational inertia? Does the material need to be W-Ni-Fe or W-Ni-Cu? What density must be achieved? What are the dimensional tolerances? Are holes, grooves, threads, or mounting steps required? Is surface treatment required? What kind of weight and balance testing is ultimately required? Therefore, the essence of a tungsten alloy counterweight can be summarized as: high-density tungsten-based material + precise mass + specified spatial position + precise geometric structure + mass distribution control. It is precisely because of this that high-density tungsten alloy counterweights usually belong to functional components designed according to application requirements, rather than ordinary metal materials sold simply by weight. From an engineering application perspective, tungsten alloy manufacturers such as CTIA GROUP usually develop counterweight parts around material grades, target density, product structure, sintering process, precision machining, and final inspection. This integrated capability from material to finished product is especially important for customized counterweight projects in aerospace, automobiles, industrial rotors, and precision instruments.



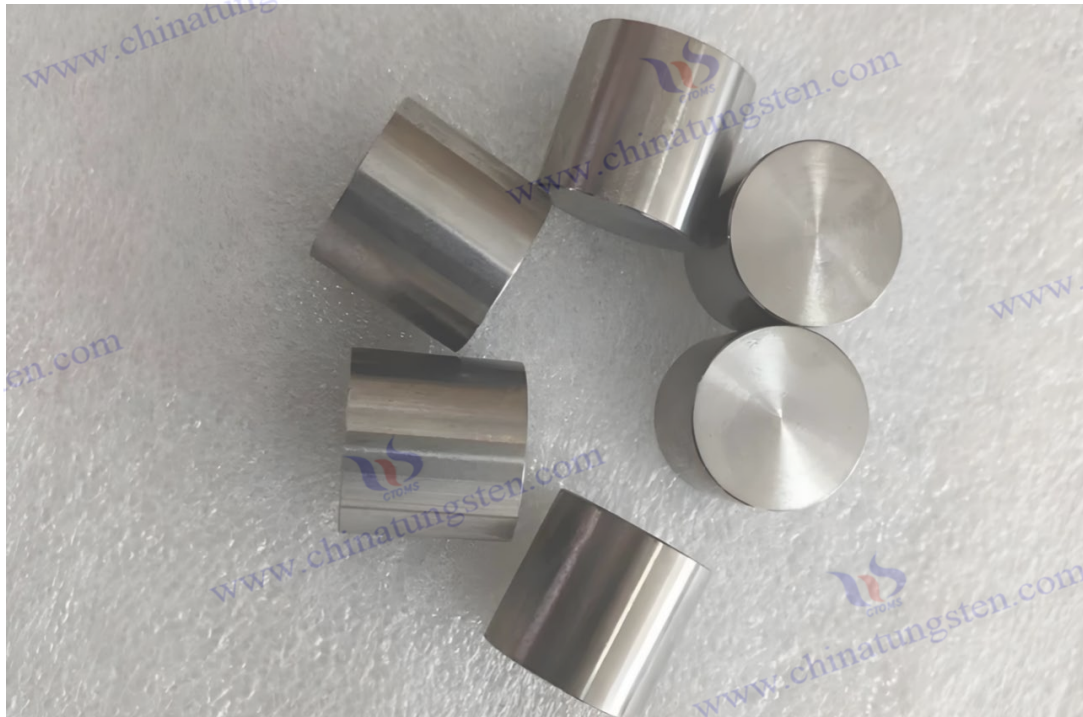
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Q2 In Which Fields Are Tungsten Alloy Counterweights Mainly Used?

The core of the application of tungsten alloy counterweights can be summarized in one sentence: to provide a relatively large concentrated mass within a limited installation space, and, by precisely controlling the position, weight, and geometric dimensions of the counterweight, to achieve center-of-gravity adjustment, mass balancing, rotational inertia control, dynamic balancing, vibration suppression, or inertia regulation. High-density tungsten alloys usually adopt systems such as W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper), with engineering application densities commonly around 17–18.5 g/cm³, and there are also higher or lower density grades. Because their mass per unit volume is far higher than that of steel, they are particularly suitable for scenarios with requirements for space, mass distribution, or balancing accuracy in aerospace, automobiles and racing cars, industrial rotating machinery, precision instruments, drones, consumer electronics, sports equipment, and marine and energy equipment. Public engineering materials also list aerospace, automobiles, industrial machinery, sports equipment, oil and gas equipment, and other fields as important application directions for tungsten heavy alloy counterweights.

Aerospace Field

Aerospace is one of the most typical application fields for high-density tungsten alloy counterweights. During flight, aircraft need to strictly control mass distribution, center-of-gravity position, and the aerodynamic balance of flight control surfaces. Ailerons,



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elevators, rudders, flaps, and other control surfaces may all require the installation of balance counterweights. Because the internal space of these structures is limited, if lower-density materials are used, a larger counterweight volume may be required, thereby increasing structural design difficulty. Tungsten alloys can provide a relatively large mass within a smaller space, so they can be used for static counterweights and dynamic balance counterweights for aircraft control surfaces, and can also be used for mass balancing of helicopter rotors, propellers, and other rotating components. Aerospace technical materials also extend the application of tungsten heavy alloys to engine gas turbine rotor balancing, vibration control, and systems such as spacecraft reaction wheels and momentum wheels. The characteristic of aerospace counterweights is not simply the pursuit of weight, but the requirement to provide very precise mass at a specified position. For example, counterweights on aircraft control surfaces need to simultaneously consider counterweight mass, installation position, axis of rotation, structural connection method, and loads under flight conditions. For such products, material batch stability, dimensional tolerances, weight tolerances, corrosion protection, connection reliability, and environmental adaptability usually also need to be considered.

Automotive and Racing Fields

Automobiles are another important application field for tungsten alloy counterweights. Counterweight needs in traditional automobiles and high-performance automobiles mainly include crankshaft balancing, drivetrain balancing, wheel hub balancing, and local mass distribution adjustment. Racing cars have even stricter requirements for counterweights because the total vehicle mass, front-to-rear axle load distribution, left-to-right mass distribution, and center-of-gravity position all affect the vehicle's dynamic characteristics. High-density tungsten alloys can be used for crankshaft counterweights, chassis counterweights, racing ballast blocks, and balancing components of some rotating mechanisms. Related material materials show that typical applications of tungsten heavy alloys include racing crankshafts and chassis counterweights. For example, when a racing car needs to add a certain amount of mass, if ordinary steel blocks are used, they may occupy a relatively large chassis space; if high-density tungsten alloys are used, the same mass can be configured within a smaller volume. For high-speed rotating components such as crankshafts, tungsten alloy counterweights also perform a dynamic balancing function. Their design needs to comprehensively consider rotation radius, counterweight mass, crankshaft speed, installation position, and allowable unbalance amount.

Industrial Rotating Machinery Field

Industrial rotating machinery is a field very suitable for tungsten alloy counterweights to exploit their high-density advantages. Typical equipment includes: industrial motor rotors, machine tool spindles, fan rotors, pumps, compressors, centrifuges, turbine rotors, flywheels, and various high-speed rotating actuators. If a rotating component has mass eccentricity, it will generate periodic centrifugal force during high-speed operation. Under



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idealized conditions, centrifugal force can be expressed as $F=m\omega^2r$, where F (Centrifugal Force) represents the centrifugal effect generated by unbalance, m (Mass) represents the eccentric mass, ω (Angular Velocity) represents the angular velocity of rotation, and r (Radius) represents the eccentric distance. Because centrifugal force is related to the square of angular velocity, the higher the equipment speed, the higher the sensitivity to mass distribution is usually. Therefore, industrial rotor counterweights must not only focus on material density, but also control the actual weight, installation position, hole position, coaxiality, circular runout, and dynamic balancing accuracy of the counterweight.

Precision Instruments and Inertial Systems

High-density tungsten alloys are also widely used in precision equipment that is highly sensitive to mass distribution and inertia. Examples include gyroscopes, inertial measurement units, inertial navigation systems, precision rotating mechanisms, measuring instruments, and some optical equipment. For gyroscopes or other inertial elements, the position of mass affects rotational inertia. Rotational inertia I (Moment of Inertia) is related to mass distribution. Therefore, for the same total mass, if it is distributed at different radius positions, the inertial characteristics of the system may also differ. The high-density characteristics of tungsten alloys enable designers to configure a relatively large mass within a limited space, thereby achieving inertia adjustment while avoiding excessive expansion of the counterweight structure. Related materials use tungsten heavy alloys in scenarios such as gyroscopes, inertial navigation systems, and precision instruments.

Drones and Aerial Robots

Drone counterweights are a relatively typical high-density miniaturized application in recent years. Drones themselves need to strictly control mass, but some equipment also requires local mass compensation. Examples include: drone gimbals, camera components, lens modules, rotor systems, flight control mechanisms, and special mission payloads. Especially for gimbal structures, the center of mass of the camera and lens may deviate from the axis of rotation, and counterweights are needed to improve the center-of-gravity position so that the compensation torque borne by the motor is reduced. If ordinary steel is used to achieve the same mass, the counterweight size may be too large; if high-density tungsten alloy is used, the mass can be concentrated in a very small structural area. Therefore, drone counterweights usually reflect three characteristics: miniaturization, high mass density, and precise mass distribution.

Mobile Phones and Consumer Electronics Products

This is a type of tungsten alloy counterweight application that ordinary consumers are relatively likely to encounter. Some mobile phones, vibration motors, electric toothbrushes, massagers, and other products need to generate vibration through an eccentric rotating mass. For example, in an eccentric vibration mechanism, there is an eccentric distance between the counterweight block and the rotating shaft. When the motor rotates, the



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eccentric mass generates a periodic centrifugal effect. For this structure, a smaller counterweight does not mean a better effect, because mass, eccentric distance, and rotational speed requirements need to be satisfied simultaneously within a very small space. Therefore, high-density tungsten alloys can enable the vibration mechanism to obtain the required eccentric mass within a limited volume. Public product materials directly apply tungsten alloy counterweights to vibration motors, mobile phones, electric toothbrushes, and massage equipment.

Golf and Sports Equipment Field

Sports equipment is also an important application direction for tungsten alloy counterweights. The most typical is golf clubs. A golf club head can change the overall center-of-gravity position, swing weight, and inertia characteristics by adding local tungsten alloy mass. Because tungsten alloy has high density, a relatively large mass can be added within the limited space of the club head. In addition to golf clubs, tungsten alloys can also be used in darts, fishing gear, and other products. The value of tungsten alloys in darts also comes from high density, that is, while maintaining a relatively high mass, the diameter of the dart body can be reduced. Public materials also use tungsten alloy counterweights in golf clubs, darts, and other sports equipment.

Fishing and Underwater Equipment

The high-density characteristics of tungsten alloys also make them suitable for underwater counterweights requiring small volume and high mass. Examples include fishing counterweights, artificial bait counterweights, and ballast parts for some underwater equipment. For fishing equipment, under the same mass, tungsten counterweights can be made smaller than traditional materials such as lead, thereby reducing the impact on the appearance and motion state of the bait. In professional underwater equipment, counterweights perform more functions such as posture adjustment, center-of-gravity control, and stabilization. In addition, downhole tools and logging tools in the oil and gas industry also have counterweight and inertial mass needs, and some high-density tungsten alloy suppliers use them in downhole tools and downhole equipment.

Marine Engineering and Shipbuilding Field

The principle of counterweights in large ships and marine equipment is the same as that in small electronic products, but the scale is different. Typical uses include: ship ballast, center-of-gravity adjustment for marine equipment, stabilization of deep-sea instruments, counterweights for underwater robots, and posture control for subsea equipment. Tungsten alloys have very high density, so they can add a relatively large mass within a limited space. However, in conventional ballast scenarios for large ships, low-cost solutions such as steel, iron ore, and water ballast are often more economical. The situations in which tungsten alloys truly have value are usually special equipment with limited space, requiring local concentrated mass, or requiring precise center-of-gravity adjustment.



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Oil, Natural Gas, and Downhole Tools

Oil and gas downhole tools are a relatively specialized but very representative application of tungsten alloy counterweights. Downhole equipment usually faces problems such as narrow space, high pressure, complex environment, and the need to precisely control tool posture. For example, logging tools, measurement-while-drilling tools, and other downhole instruments may require high-density mass blocks for center-of-gravity control, tool stabilization, and local inertia adjustment. High-density tungsten alloys can provide a relatively large mass without significantly increasing the outer diameter of the tool, so they are suitable for typical space-limited structures such as downhole tools. Related tungsten heavy alloy application materials also list downhole logging sinker bars, that is, downhole logging sinker bars or counterweight parts, as an application direction.

Medical Equipment and Precision Motion Equipment

Tungsten alloys in the medical field are more widely known for radiation shielding, but some medical equipment also has counterweight and mass balancing needs. For example, medical imaging equipment, radiotherapy equipment, and precision motion mechanisms may require local mass adjustment through high-density materials. However, two types of uses need to be distinguished here: when a tungsten alloy is used as a counterweight, it uses its high density to adjust mass distribution; when a tungsten alloy is used as a shielding part, it mainly uses its attenuation ability against X-rays and γ (Gamma) rays. Although both use high-density tungsten alloys, their engineering purposes are not the same. Specific parts in medical equipment need to have material grades and structures determined separately according to equipment design.

Robots and Automation Equipment

Industrial robots, collaborative robots, and precision automation mechanisms also have counterweight needs. Robot joints, end effectors, and motion mechanisms generate inertial loads in different directions during movement. If the mass distribution is unreasonable, it may increase the load on drive motors and reduction mechanisms. By configuring high-density tungsten alloys at appropriate positions, the center of gravity and rotational inertia of the mechanism can be adjusted so that the mass distribution better conforms to mechanical design requirements. In particular, robotic arm joints, precision rotating platforms, and small high-speed actuators often need to achieve mass adjustment within very limited installation space, which is exactly a scenario relatively suitable for high-density tungsten alloys.

Different Application Fields Actually Correspond to Different Counterweight Functions

If classified from the perspective of engineering function rather than industry name, tungsten alloy counterweights mainly undertake the following types of tasks: in aerospace, mainly control surface balancing, center-of-gravity adjustment, and inertia control; in automobiles and racing cars, mainly crankshaft balancing, chassis mass distribution, and



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local ballast; in industrial machinery, mainly rotor dynamic balancing and vibration control; in drones, mainly gimbal, rotor, and payload center-of-gravity adjustment; in consumer electronics, mainly eccentric vibration; in precision instruments, mainly inertia adjustment and mass compensation; in sports equipment, mainly center-of-gravity and swing characteristic adjustment; in marine and oil and gas equipment, mainly ballast, posture stabilization, and center-of-gravity control. Therefore, although these products are ultimately all called tungsten alloy counterweights, their actual design purposes are not completely the same.

Why These Fields Tend to Use Tungsten Alloys

These industries may seem to have no direct connection, but they generally share a common engineering problem: they want to obtain a relatively large mass without wanting the counterweight to occupy too much space. Tungsten alloys happen to be able to solve this contradiction. For example, when 1 kg of counterweight is required, the theoretical volume of 18 g/cm³ tungsten alloy is about 55.6 cm³, while 7.85 g/cm³ steel requires about 127.4 cm³. For large equipment, this volume difference is sometimes not important; but for aircraft control surfaces, drone gimbals, mobile phone vibration mechanisms, high-speed rotors, and precision instruments, it may directly affect whether the product structure can be realized. This is also the fundamental reason why tungsten heavy alloys are widely used for high-density counterweights and inertial masses.

How to Judge from an Application Perspective Whether Tungsten Alloy Counterweights Are Suitable

Whether a product is suitable for using tungsten alloys can be judged from several questions. If the equipment installation space is very limited while a relatively large mass is also required, then tungsten alloys have obvious advantages; if the counterweight needs to be installed at a position very close to the rotating shaft and a relatively large mass needs to be obtained through a smaller volume, then tungsten alloys are usually worth prioritizing for evaluation; if the equipment needs to precisely adjust the center of gravity, rotational inertia, or dynamic balance, high-density tungsten alloys are also suitable for consideration. Conversely, if the equipment space is very ample, the mass requirement is not high, the precision requirement is low, and the product is highly cost-sensitive, then low-cost materials such as steel may already be able to meet the demand, and the necessity of using tungsten alloys will be reduced. Therefore, tungsten alloy counterweights are not a universal substitute material for all counterweight products, but an engineering material mainly aimed at high-density, small-volume, precise mass distribution, and high-performance applications.

The main application fields of tungsten alloy counterweights can form a relatively clear industrial chain: aerospace → automobiles and racing cars → industrial rotating machinery → precision instruments and inertial systems → drones and robots → consumer electronics



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→ sports equipment → marine and oil and gas equipment → special medical and precision equipment. Although the product forms in different fields differ greatly, the core needs always revolve around high-density mass configuration, center-of-gravity control, inertia adjustment, dynamic balancing, and space optimization.



Q3 Why Are Tungsten Alloys Suitable for Making Counterweights?

Tungsten alloys (Tungsten Alloy, tungsten-based heavy alloys) are suitable for making counterweights not only because of their high density, but because they can provide a relatively large mass within a limited space while, through alloy composition, density grade, geometric dimensions, and precision machining, enabling relatively precise control of mass distribution, center-of-gravity position, rotational inertia, and dynamic balance. These characteristics are especially important for components that are sensitive to space and mass distribution, such as automotive crankshafts, industrial rotors, aviation control surfaces, drones, and vibration mechanisms.

High Density Can Provide a Large Mass Within a Very Small Volume

This is the most direct advantage of tungsten alloys as counterweight materials. Common tungsten alloy counterweights usually use W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) systems. The density of engineering products is usually about 17–18.5 g/cm³, and the broader density range of tungsten heavy alloys can reach about 16.5–19.0 g/cm³, depending on tungsten content, binder phase composition, and manufacturing process. The actual ranges of different suppliers and grades are not entirely the same. The relationship among density, mass, and volume is: $\rho = m/V$.



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Here, ρ is material density, m is mass, and V is volume. Therefore, when the mass is the same, the higher the density, the smaller the volume required. For example, for a tungsten alloy counterweight with a mass of 1 kg and a density of 18.0 g/cm³, its theoretical volume is approximately: $V=1000/18.0 \approx 55.6$ cm³.

For the same 1 kg of steel, if calculated at about 7.85 g/cm³, the volume is approximately 127.4 cm³. In other words, under the same mass condition, the theoretical volume of an 18.0 g/cm³ tungsten alloy is only about 44% of that of ordinary steel. This is very important for structures with limited installation space, such as the interior of engines, aviation mechanisms, precision rotors, and mobile phone vibration components.

A Smaller Counterweight Can Achieve Center-of-Gravity Adjustment

The role of a counterweight is not simply to add weight; more importantly, it is to place mass in the right position. The center of gravity of a system is determined by both the mass of each component and its location. In simple terms, the overall center of gravity is the mass-weighted average of the positions of all mass units: heavier units pull the center of gravity closer to themselves, while lighter ones have less influence. Tungsten alloys have high density, so the same mass can be made into a smaller volume. This allows designers to install the counterweight in narrower areas closer to the target position, thereby reducing interference with surrounding structures. For example, when an aviation control surface needs mass balancing, a low-density material would require a relatively large counterweight volume; a high-density tungsten alloy, by contrast, can provide the required mass within a smaller installation space, which helps maintain the external dimensions and aerodynamic structural design.

It Is Particularly Valuable for the Dynamic Balancing of Rotating Components

In high-speed rotating components such as crankshafts, rotors, main shafts, centrifugal mechanisms, fans, pumps, and compressors, counterweights also perform a dynamic balancing function. The centrifugal force generated by rotating mass can be approximately expressed as: $F=m\omega^2 r$. Here, F is centrifugal force, m is mass, ω is angular velocity, and r is the distance from the center of mass to the axis of rotation. After the rotational speed increases, the ω^2 term causes mass distribution errors to have a significant effect. Therefore, high-speed rotating equipment not only needs to control counterweight mass, but also needs to control the counterweight position, eccentricity, installation angle, coaxiality, and radial runout. Tungsten alloys can provide a relatively large mass within a relatively small volume, giving counterweight design greater freedom in mass arrangement. For example, in automotive crankshafts and racing components, high-density tungsten alloys can be used to complete mass compensation and dynamic balancing within limited space. Tungsten alloys are also used in high-speed main shafts, rotors, centrifuges, and aviation inertial systems and other occasions with high balancing requirements.



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Rotational Inertia Can Be Adjusted

For high-speed rotating or oscillating systems, counterweights not only affect the center of gravity, but also change rotational inertia. In a simplified case: $I = \sum m_i r_i^2$.

Here, I is rotational inertia, m_i is mass, and r_i is the distance from the mass unit to the axis of rotation. This means that, for the same addition of a 100 g counterweight, placing the mass farther from the axis of rotation versus placing it closer to the axis has different effects on the dynamic characteristics of the system. Tungsten alloys have high density and can concentrate a relatively large mass in a relatively small structure, enabling designers to control the mass concentration region more precisely. For example, inertia wheels, gyroscope mechanisms, balance rings, rotors, and certain actuators may all use this characteristic.

Alloy Composition Can Be Adjusted According to Usage Requirements

Tungsten alloys are not a single material. Actual counterweight products can obtain different densities and mechanical properties by adjusting tungsten content, binder phase composition, and manufacturing process. The W-Ni-Fe (Tungsten-Nickel-Iron) system has a relatively mature application foundation as a high-density heavy alloy; the W-Ni-Cu (Tungsten-Nickel-Copper) system can be selected according to specific structure, processing, and environmental requirements. Therefore, in actual design, the goal is not simply to pursue the highest density, but to comprehensively consider density, strength, ductility, magnetic properties, processing method, dimensional accuracy, service environment, and cost.

Powder Metallurgy Is Suitable for Manufacturing Complex Small Counterweights

Tungsten alloy counterweights usually adopt the powder metallurgy (Powder Metallurgy) route, forming the final product through processes such as powder mixing, pressing, pretreatment or debinding, liquid-phase sintering, subsequent mechanical machining, and inspection. This manufacturing route is particularly suitable for high-density, small-volume, batch-produced counterweight products. For regular products, near-net-shape blanks can be obtained by die pressing; for products with holes, grooves, steps, threads, eccentric structures, or mounting and positioning structures, further mechanical machining can be completed by turning, milling, drilling, grinding, and so on. This enables tungsten alloys to expand from simple cylindrical counterweights to structures such as ring-shaped counterweights, disc-shaped counterweights, block-shaped counterweights, eccentric counterweights, embedded counterweights, and special-shaped counterweights.

It Can Meet the High-Quality Counterweight Needs of Small Electronic Devices

Mobile phones, vibration motors, electric toothbrushes, massage equipment, and other micro electromechanical devices place a special requirement on counterweights: the mass must be large enough, but the occupied space must be very small. Therefore, high-density tungsten alloys are very suitable for making micro eccentric counterweights. For example,



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in a vibration mechanism, the mass of the eccentric mass block, the eccentric distance, and the rotational speed jointly determine the vibration characteristics. Tungsten alloys can provide the required mass at a relatively small size, which helps reduce the volume of the entire vibration component. Related product information also shows that tungsten alloy counterweights have been used in micro products such as vibration motors, mobile phones, electric toothbrushes, and massage equipment.

It Is Suitable for Occasions Sensitive to Space and Mass Control, Such as Aerospace

Aerospace equipment usually attaches great importance to mass distribution, center-of-gravity position, and structural space. High-density tungsten alloy counterweights can be used for flight control surface balance weights, trim weights, anti-flutter counterweights, inertial system counterweights, and other structures requiring concentrated mass. The engineering logic is: increase the specified mass without significantly enlarging the external dimensions of the counterweight, while controlling the center of mass and installation position through precision machining. Aerospace field application materials for tungsten alloys also include counterweight uses such as flight control surfaces, trimming, anti-flutter, and inertial systems.

Mechanical Properties Can Meet Many Structural Counterweight Requirements

Modern tungsten alloys are not simply high-density filling materials. Through material design of systems such as W-Ni-Fe (Tungsten-Nickel-Iron), a combination of strength, ductility, and toughness suitable for structural counterweights can be obtained. This is especially important for counterweights that need to be fixed by screws, press fitting, embedding, clamping, or other methods, because the counterweight not only bears its own gravity, but may also bear vibration, impact, centrifugal loads, and periodic loads.

Precision Machining Can Further Control the Mass and Position of the Counterweight

For ordinary static counterweights, quality control may mainly focus on weight and dimensions; for high-speed dynamic systems, it is also necessary to further control dimensional tolerances, hole positions, coaxiality, circular runout, end-face runout, flatness, surface roughness, and counterweight installation angle. After the high-density characteristics of tungsten alloys are combined with precision mechanical machining, precision counterweight parts with stable mass and consistent dimensions can be formed. For batch products, product dispersion can be further reduced through weighing, grouping, and matching, dimensional inspection, and dynamic balancing testing. CTIA GROUP has long been engaged in the design, manufacturing, and application services of tungsten alloys and high-density tungsten-based heavy alloy products, and can provide customized design according to the density, mass, dimensions, hole positions, shape, and service environment of the counterweight.

Tungsten alloys are suitable for making counterweights essentially because they simultaneously have high density, small volume, designable mass distribution, adjustable



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rotational inertia, selectable material systems, and good precision machining adaptability. For ordinary counterweights, the greatest value is usually obtaining the specified mass with a smaller volume; for high-speed rotating equipment, what is more important is achieving balance through precise control of mass, radius, and installation angle; for aviation, electronics, and micro devices, it is mainly reflected in concentrating a relatively large mass within limited space. Therefore, choosing tungsten alloys is not simply pursuing the higher the density, the better, but rather determining the appropriate tungsten alloy grade and structure according to the target mass, installation space, center-of-gravity position, rotational speed, dynamic balancing requirements, mechanical loads, machining accuracy, and cost.



Q4 What Is the Density of Tungsten Alloy Counterweights Usually?

There is no completely unified fixed value for the density of tungsten alloy counterweights. It depends on tungsten content, the proportion of nickel-iron or nickel-copper binder phase, the powder metallurgy (Powder Metallurgy) process, and the specific material grade. In terms of actual engineering applications, the density of common high-density tungsten alloy counterweights is mostly concentrated at about 17.0–18.5 g/cm³; if different tungsten content grades and a wider range of tungsten heavy alloy products are included in the statistics, about 13.5–19.0 g/cm³ may all appear.

How Should the Common Density Ranges Be Understood?

Actual products can be roughly divided into several density intervals. 13.5–16.0 g/cm³ usually belongs to lower-density tungsten alloy counterweights, in which lower cost or specific mechanical properties are obtained by reducing tungsten content; 16.0–17.0 g/cm³ belongs to the medium-high density grade; 17.0–18.5 g/cm³ is a very common high-density range in engineering counterweights, especially suitable for aerospace, automotive, industrial



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rotors, precision mechanisms, and other applications with relatively high requirements for volume and mass distribution; above 18.5 g/cm³ belongs to a higher density grade, usually requiring relatively high tungsten content and good sintering densification control, and the specific value that can be achieved depends on the material system and the manufacturer's grade design. For example, some W-Ni-Fe (Tungsten-Nickel-Iron) balance counterweight products give a typical density of 17.0–18.5 g/cm³; some high-density tungsten alloy products are advertised as reaching up to 18.5 g/cm³. Some suppliers also give a product range of 13.5–18.2 g/cm³ for ordinary W-Ni-Fe and W-Ni-Cu (Tungsten-Nickel-Copper) counterweights, which shows that one cannot assume that a tungsten alloy counterweight must have a density of around 18.0 g/cm³ just by seeing it.

Why Can the Density of Tungsten Alloys Reach Such High Values?

The theoretical density of tungsten itself is about 19.25 g/cm³, while tungsten alloys are multiphase materials formed by adding binder phases such as nickel, iron, and copper on the basis of tungsten particles. As tungsten content increases, the overall density of the material usually increases; however, the final density is also affected by porosity, sintering densification, composition uniformity, and the specific manufacturing process. Therefore, the actual density of a tungsten alloy counterweight can be understood as an engineering parameter jointly determined by material composition and manufacturing quality, rather than simply being equal to the density of pure tungsten. For high-density counterweights using W-Ni-Fe or W-Ni-Cu, the actual average density can be calculated using: $\rho = m/V$, where ρ is density, m is the actual mass of the counterweight, and V is the actual volume of the counterweight. For regular cylinders, discs, blocks, and other products, the volume can be obtained through dimensional measurement, and then the actual density can be calculated in combination with precise weighing; for complex special-shaped parts, verification is usually required by combining three-dimensional dimensional measurement, the water displacement method, or other density testing methods.

What Does 18.0 g/cm³ Mean?

If the density of a tungsten alloy counterweight is 18.0 g/cm³, then theoretically: 1 [" cm"] ^3=18.0 [" g/cm"] ^3=18.0 " g". Therefore, 1 cm³ of material has a mass of about 18 g, the theoretical volume of a 100 g counterweight is about 5.56 cm³, that of 500 g is about 27.78 cm³, and that of 1 kg is about 55.56 cm³. This is precisely one of the main reasons why high-density tungsten alloys are suitable for counterweights. Compared with steel with a density of about 7.85 g/cm³, when manufacturing the same 1 kg counterweight, the theoretical material volume required by 18.0 g/cm³ tungsten alloy is only about 43.6% of that of steel. If used in space-constrained structures such as mobile phone vibration mechanisms, aviation control surfaces, automotive crankshafts, or high-speed rotors, this volume advantage will directly translate into design freedom.



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Is Higher Density Always Better?

Not necessarily. Counterweight design first needs to meet target mass, installation space, and mass distribution requirements, rather than simply pursuing the highest density. For example, if the design requires a certain part to have a mass of 150 g, and if using 18.5 g/cm³ material makes the volume too small, resulting in difficulties in installation, fixing, or processing, then choosing a 17.5–18.0 g/cm³ grade may instead be more reasonable. In addition, strength, elongation, toughness, magnetic properties, processing performance, corrosion resistance, sintering shrinkage, dimensional tolerance, and cost also need to be considered at the same time. Especially in dynamic balancing applications, the final effect of the counterweight depends not only on density, but also on the position of the center of mass, installation radius, and installation angle. For a rotating system, even if two counterweights have exactly the same mass, different installation positions will produce different moments of inertia.

Volume Differences Corresponding to Different Densities

Taking a 1 kg counterweight as an example, the volume changes produced by different densities can be seen intuitively:

Tungsten Alloy Density Theoretical Volume of 1 kg

13.5 g/cm³ 74.07 cm³

15.0 g/cm³ 66.67 cm³

16.5 g/cm³ 60.61 cm³

17.0 g/cm³ 58.82 cm³

17.5 g/cm³ 57.14 cm³

18.0 g/cm³ 55.56 cm³

18.5 g/cm³ 54.05 cm³

19.0 g/cm³ 52.63 cm³

It can be seen that from 17.0 g/cm³ to 18.5 g/cm³, the theoretical volume of a 1 kg counterweight only decreases from about 58.82 cm³ to about 54.05 cm³. Therefore, once a product has already reached a relatively high density, the volume reduction brought by further increasing density does not produce huge benefits linearly, and whether it is worth paying material and manufacturing costs for higher density needs to be judged in combination with the actual structure.

Different Applications Also Have Different Density Requirements

Aviation balance parts usually use W-Ni-Fe (Tungsten-Nickel-Iron) grades of about 17–18.5 g/cm³; the published specifications of some aviation rotor balance counterweights are about 17.5–18.2 g/cm³, while some product specifications for aerospace inertial systems can reach about 17.8–18.5 g/cm³. For mobile phone vibration motors, golf, fishing gear, and ordinary industrial counterweights, a wider range of W-Ni-Fe or W-Ni-Cu (Tungsten-Nickel-Copper) materials can be selected according to volume limitations, target mass, and cost.



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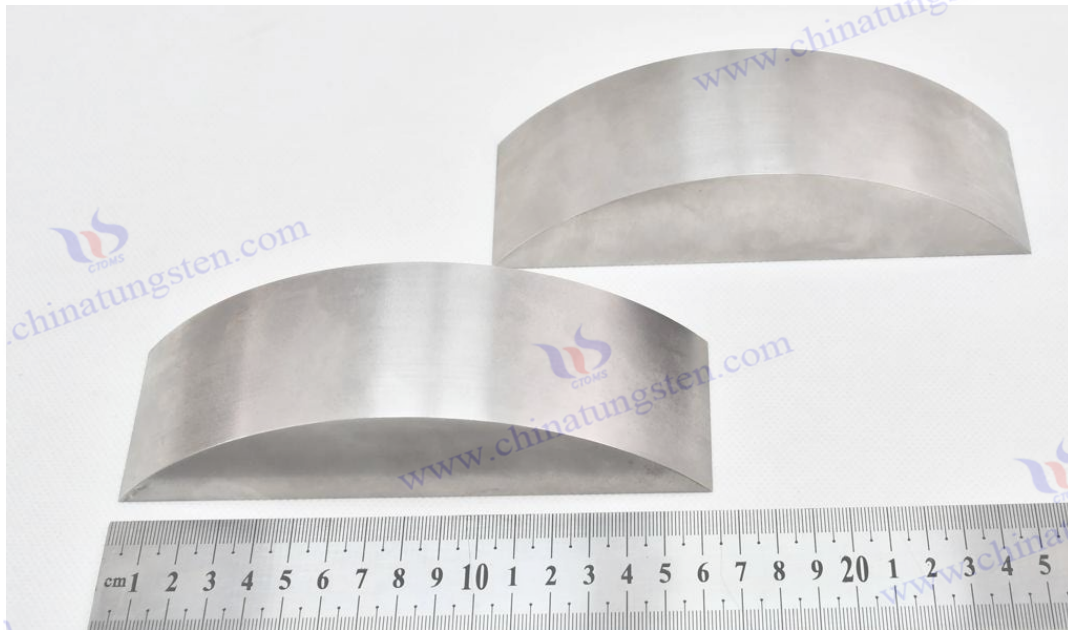
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Which Density Should Be Looked At During Actual Procurement?

For ordinary engineering inquiries, it is not recommended to write only "high-density tungsten alloy"; instead, the target density should be clearly stated, for example, $17.5 \pm 0.2 \text{ g/cm}^3$, $18.0 \pm 0.2 \text{ g/cm}^3$, or an 18.5 g/cm^3 grade, while also specifying the material system, dimensions, tolerances, single-piece weight, surface treatment, and inspection requirements. For high-precision dynamic counterweights, parameters such as weight tolerance, center-of-gravity position, coaxiality, circular runout, and balance grade should be further specified, because qualified material density does not mean that the dynamic balance performance of the final counterweight part is necessarily qualified.

Overall, if a user asks what density tungsten alloy counterweights usually have, about $17\text{--}18.5 \text{ g/cm}^3$ can be used as the most representative range for general engineering and product introductions; if the entire tungsten alloy counterweight product system needs to be described, it can be stated that different grades are about $13.5\text{--}19.0 \text{ g/cm}^3$, and the specific value must be based on the actual alloy composition, grade, and sintering state.



Q5 Why Can Tungsten Alloy Counterweights Reduce Volume?

The most fundamental reason why tungsten alloy counterweights can reduce volume is that tungsten alloys have very high density. When the mass required for a counterweight is fixed, the higher the material density, the smaller the material volume required to achieve the same mass. This characteristic of tungsten alloys makes them particularly suitable for aerospace, automotive, industrial rotors, drones, precision instruments, and micro electronic devices that have limited installation space while also requiring a relatively large counterweight mass. The higher the density, the smaller the volume required for the same



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weight.

The basic relationship among mass, density, and volume is: $\rho = m/V$

It can also be transformed into: $V = m/\rho$

Where V is the counterweight volume, m is the target mass, and ρ is the material density.

When the counterweight mass m is already determined, the volume V is inversely proportional to the density ρ . In other words, if the same 1 kg of mass needs to be added,

using a material with higher density allows a smaller solid volume to be used. The density of common high-density tungsten alloy counterweights is about 17–18.5 g/cm³, while the

density of ordinary carbon steel is about 7.85 g/cm³. Taking 18.0 g/cm³ tungsten alloy and 7.85 g/cm³ steel as an example:

$$V_{\text{"tungsten alloy"}} = 1000/18.0 \approx 55.6 \text{ [" cm"] }^3$$

$$V_{\text{"steel"}} = 1000/7.85 \approx 127.4 \text{ [" cm"] }^3$$

Therefore, when manufacturing the same 1 kg counterweight, 18.0 g/cm³ tungsten alloy theoretically requires only about 55.6 cm³, while steel requires about 127.4 cm³. The volume required by tungsten alloy is about 43.6% of that of steel, and the volume can be reduced by about 56.4%. This is the so-called volume reduction effect brought by high density.

Why Is the Density of Tungsten Alloys Particularly High?

The theoretical density of tungsten (W, Tungsten) is about 19.25 g/cm³, making it one of the materials with very high density among commonly used engineering metals. Tungsten alloys usually use a large amount of tungsten as the main constituent and then add binder phases such as nickel, iron, and copper to form W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) systems.

Although the density of tungsten alloy will be lower than that of pure tungsten after adding the binder phase, the high tungsten content still enables it to reach a density level of about 17–18.5 g/cm³ or even higher. Therefore, the volume reduction of tungsten alloy counterweights is not because the material is compressed by the processing method, but because a unit volume contains more mass.

What Practical Significance Does Volume Reduction Have for Counterweight Design?

What is truly valuable is that it can solve the space limitation problems in many counterweight structures. For example, 1 kg of counterweight needs to be added inside a piece of equipment. If steel is used, about 127 cm³ of material space is required; if 18 g/cm³ tungsten alloy is used, only about 56 cm³ is required. In this way, the counterweight can be designed as a thinner block, a smaller cylinder, a narrower ring, or a more compact special-shaped part. For already highly integrated equipment, reducing the counterweight volume means reducing interference with surrounding parts while leaving more installation space for other components. For rotating components, small volume also means that mass can be more concentrated.



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Tungsten alloy counterweights are not only used to increase mass, but are also often used to control mass distribution. For example, rotating components such as automotive crankshafts, industrial rotors, high-speed main shafts, centrifuges, fans, and pumps all need to control the position of the center of mass. The inertial characteristics in a rotating system can be expressed as: $I = \sum m_i r_i^2$. Where I is the moment of inertia, m_i is a mass unit, and r_i is the distance from that mass unit to the rotating shaft. Because tungsten alloys can concentrate a relatively large mass in a very small space, engineers can arrange the counterweight in a designated area, thereby adjusting the center of gravity and rotational inertia more precisely. For example, a certain rotor needs to add 200 g of mass, and the installation position has only a narrow groove. If a low-density material is used, it may be impossible to place enough mass within the specified space; if high-density tungsten alloy is used, the required mass can be achieved in the same groove. Therefore, the value of tungsten alloy is not only that it makes the counterweight smaller, but also that it makes the mass distribution of the counterweight easier to control.

Tungsten Alloy Counterweights Are Especially Important for Aerospace Equipment

Aircraft, spacecraft, and drones are very sensitive to structural space and mass distribution. Counterweights may need to be installed in wing control surfaces, rudder surfaces, rotors, actuators, or inertial systems. If the counterweight volume is too large, it may increase structural dimensions, affect the aerodynamic shape, occupy installation space for other equipment, or even force designers to change the original structure. With high-density tungsten alloys, the required mass can be obtained within a smaller structural envelope, so they are often used in applications such as flight control surface counterweights, trim weights, anti-flutter counterweights, and inertial systems. Relevant tungsten heavy alloy materials also list aviation control surfaces, trim, and inertial systems as typical applications.

The Effect Is Even More Obvious in Micro Electronic Devices

Products such as mobile phone vibration assemblies, micro motors, electric toothbrushes, and massage equipment have very limited internal space, but eccentric vibration counterweights must still have a certain mass. Suppose a vibration mechanism needs 10 g of eccentric mass:

Using 7.85 g/cm³ steel: $V = 10 / 7.85 \approx 1.27$ [" cm"] ^3

Using 18.0 g/cm³ tungsten alloy: $V = 10 / 18.0 \approx 0.56$ [" cm"] ^3

The volume can be reduced by more than half. For micro motors, this difference may directly affect whether the entire vibration assembly can be further reduced in size. Therefore, tungsten alloy counterweights have already been used in products such as vibration motors, mobile phones, electric toothbrushes, and massage equipment.

Not All Cases Require Pursuing the Highest Density

Although increasing density can reduce volume, engineering design cannot be simply



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understood as the higher the density, the better. For example, if a piece of equipment requires the installation of a 100 g counterweight, and the design space itself is already large enough, then using a 17.0 g/cm³ material may already fully meet the requirements, and there is no need to choose a higher-density, higher-cost material just to further reduce a few cubic centimeters. At the same time, factors such as material strength, toughness, magnetic properties, processing performance, corrosion resistance, sintering shrinkage, dimensional tolerances, and procurement costs also need to be considered.

Especially for precision dynamic balancing parts, the final performance also depends on the counterweight's mass, center-of-gravity position, installation radius, installation angle, and machining accuracy, not just material density.

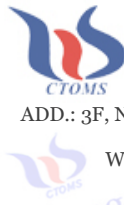
A Simple Ratio Can Be Used for Quick Judgment

If two materials have densities ρ_1 and ρ_2 respectively, then under the condition of the same counterweight mass: $V_1/V_2 = \rho_2/\rho_1$

For example, if steel is 7.85 g/cm³ and tungsten alloy is 18.0 g/cm³, then: $V_{\text{"tungsten alloy"}/V_{\text{"steel"}} = 7.85/18.0 \approx 0.436$

In other words, under the same mass, the theoretical volume of 18.0 g/cm³ tungsten alloy is about 43.6% of that of steel, and this is also the mathematical basis for why high-density tungsten alloys can significantly reduce counterweight volume. From an engineering perspective, the core advantage of tungsten alloy counterweights can be summarized as follows: when the mass requirement remains unchanged, increasing material density can reduce the required volume; after the volume is reduced, the installation freedom within limited space, the degree of mass concentration, and the ability to adjust the center of gravity and inertia can be further improved. Therefore, the real reason why tungsten alloys are suitable for small, high-mass counterweights is that, after combining high density with precision structural design, the same mass and more controllable mass distribution can be achieved in a smaller space.

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Q6 What Is the Difference Between a Tungsten Alloy Counterweight and a Steel Counterweight?

The core difference between a tungsten alloy counterweight and a steel counterweight lies in the different material densities, which further affects the counterweight's volume, mass concentration capability, structural dimensions, dynamic balance design, processing methods, and cost. For a counterweight of the same mass, a tungsten alloy can be made significantly smaller; the advantages of steel are mainly reflected in low material cost, wide supply, mature processing, and better manufacturing economy. Therefore, the two are not simply a question of which is better, but are suitable for different space conditions, performance requirements, and cost objectives.

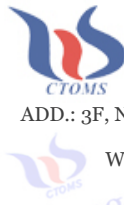
The Most Obvious Difference Between a Tungsten Alloy Counterweight and a Steel Counterweight Is Density

Tungsten alloy counterweights usually adopt W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) systems, with common engineering counterweight densities of about 17–18.5 g/cm³; the density of steel is usually about 7.85 g/cm³. The relationship among mass, density, and volume is: $V=m/\rho$, where V is volume, m is mass, and ρ is density. Suppose both need to manufacture a 1 kg counterweight:

Material Typical Density Theoretical Volume for 1 kg

Tungsten alloy 18.0 g/cm³ 55.6 cm³

Steel 7.85 g/cm³ 127.4 cm³



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Therefore, for the same 1 kg counterweight, the theoretical volume of 18.0 g/cm³ tungsten alloy is only about 43.6% that of steel, meaning the material volume can be reduced by about 56.4%. This is also the greatest advantage of tungsten alloys in space-constrained counterweights. Public product information shows that the density of some tungsten alloy counterweights can reach about 17–18.5 g/cm³, while steel is usually maintained at about 7.85 g/cm³.

The Volume Difference Between Tungsten Alloy Counterweights and Steel Counterweights Directly Affects Structural Design

If there is sufficient space inside the equipment, a steel counterweight can usually meet the requirements; but if the counterweight must be installed in a narrow groove, thin-wall structure, rotor interior, or micro mechanism, the low density of steel may become a limiting factor. For example, if a certain mechanical structure needs to add 500 g of mass, and steel is used, the theoretical volume is approximately: $V_{\text{steel}} = 500 / 7.85 \approx 63.7 \text{ cm}^3$.

If 18.0 g/cm³ tungsten alloy is used: $V_{\text{tungsten alloy}} = 500 / 18.0 \approx 27.8 \text{ cm}^3$.

The difference between the two is about 35.9 cm³. In large equipment, this difference may not be important; but in aviation actuators, automotive crankshafts, drones, mobile phone vibration mechanisms, and high-speed rotors, a space difference of several tens of cubic centimeters may directly affect structural design.

Tungsten Alloys Are More Suitable for High-Mass, Small-Volume Counterweights

Counterweight design often requires adding a certain mass at a fixed position, while the installation space is limited. Tungsten alloys can concentrate a relatively large mass in a relatively small volume, so they are suitable for: automotive crankshaft counterweights, racing car counterweights, aviation control surface counterweights, drone counterweights, high-speed rotor balancing blocks, precision instrument counterweights, mobile phone vibration counterweights, inertial system counterweights, etc. Relevant information shows that high-density tungsten alloys have already been used in automotive crankshaft and transmission system dynamic balancing, wheel hub balancing, and aviation and inertial systems, among other applications. Steel counterweights are more suitable for occasions where installation space is relatively ample, volume requirements are not high, and manufacturing cost needs to be controlled.

For Dynamic Balancing, Both Tungsten Alloy Counterweights and Steel Counterweights Can Be Used

It cannot be simply understood that tungsten alloys can be used for dynamic balancing while steel cannot. In fact, steel is also widely used in various balancing blocks and counterweight parts. What truly affects dynamic balancing is mass distribution, not the material name. The centrifugal force in a rotating system can be approximately expressed



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as: $F = m\omega^2 r$,

where F is centrifugal force, m is mass, ω is angular velocity, and r is the distance from the center of mass of the mass to the rotating shaft. When the mass m , rotational speed ω , and installation radius r are the same, the theoretical centrifugal force generated by tungsten alloy and steel will not automatically change because of the different materials. The difference is that tungsten alloy can obtain the same mass with smaller geometric dimensions, so under conditions of limited structural space, a specified mass can be arranged in positions that are difficult for steel counterweights to enter. For rotational inertia: $I = \sum m_i r_i^2$.

The smaller volume of tungsten alloy also helps concentrate mass at a specific position, thereby obtaining a more flexible inertia design.

Comparing Tungsten Alloy Counterweights and Steel Counterweights, Steel's Cost Advantage Is Usually More Obvious

This is an important difference between tungsten alloys and steel in actual procurement. Steel is a mature bulk engineering material with wide raw material sources, a mature supply chain, and abundant standard grades, so ordinary steel counterweights usually have lower material costs. Tungsten alloys contain a relatively high proportion of tungsten, and tungsten is a high-value metal. At the same time, their powder metallurgy manufacturing, sintering, and subsequent precision machining also increase production costs. Therefore, when installation space is sufficient, mass requirements are not high, and the product is not sensitive to volume, steel counterweights often have obvious economic advantages. When structural space is strictly limited, the higher material cost of tungsten alloys may demonstrate their engineering value by reducing volume, reducing structural modifications, and improving system integration.

The Processing Methods of Tungsten Alloy Counterweights and Steel Counterweights Are Also Different

Steel has mature turning, milling, drilling, grinding, and tapping processes, and a large number of machining enterprises can handle them, so the processing cost and supply difficulty of steel counterweights are usually lower. Although tungsten alloys can also be turned, milled, drilled, ground, and otherwise machined, due to characteristics such as high tungsten content, multiphase structure, and relatively high density, their processing technology needs to be optimized for specific grades. Tool materials, cutting parameters, cooling methods, and machining allowances all affect tool life and dimensional stability. For large-batch, small, structurally repetitive tungsten alloy counterweights, powder metallurgy can obtain blanks close to final dimensions through die pressing and sintering, followed by necessary finishing, thereby reducing a large amount of cutting work.

The Material Properties of Tungsten Alloys and Steel Are Also Different

Comparison Item Tungsten Alloy Counterweight Steel Counterweight



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Density Commonly about 17–18.5 g/cm³ About 7.85 g/cm³

Volume for the same mass Small Large

Miniaturization capability Strong General

Material cost Relatively high Usually relatively low

Supply popularity Relatively low Very high

Mechanical processing Can be processed, but process requirements are relatively high

Mature process

Powder metallurgy adaptability Very suitable Usually not the first choice

High mass concentration Very suitable Requires larger volume

Space-constrained counterweight Obvious advantage May be limited by volume

Ordinary large counterweight Can be used Usually more economical

High-speed dynamic counterweight Can be used Also can be used

Micro vibration counterweight Particularly suitable Easily limited by volume

Magnetic Properties May Also Become a Selection Factor

A steel counterweight is not a single material system, and the magnetic properties of different steel grades vary greatly. Carbon steel and some ferromagnetic steels usually have obvious magnetic response; W-Ni-Fe (Tungsten-Nickel-Iron) tungsten alloys may also exhibit a certain magnetic response, depending on the nickel and iron proportions and microstructure; W-Ni-Cu (Tungsten-Nickel-Copper) usually has magnetic characteristics different from iron-based steels. If magnetic sensors, Hall elements, gyroscopes, or other magnetically sensitive devices are present near the counterweight, the material cannot be selected based only on density. Instead, specific magnetic permeability or magnetic response requirements should be proposed, and actual grade test data should be used as the basis.

Corrosion Resistance Cannot Be Simply Considered as Tungsten Alloys Definitely Being Better Than Steel

The corrosion resistance of steel depends highly on the specific steel grade and surface treatment. For example, there is an obvious difference in corrosion performance between stainless steel and ordinary carbon steel. The W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) systems in tungsten alloys also require surface treatment and protective measures selected according to the service environment. If used for automotive chassis, ships, outdoor equipment, or humid environments, salt spray, humid heat, medium corrosion, and galvanic corrosion should be comprehensively considered, and corrosion resistance cannot be judged only by the material name.

When Is It More Suitable to Choose Tungsten Alloy?

If the requirement is high mass and small volume, or the counterweight must be installed in a narrow space, tungsten alloy usually more easily meets the structural requirements. For example, for the same 1 kg mass, 18.0 g/cm³ tungsten alloy requires only about 55.6 cm³,



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while steel requires about 127.4 cm³.

If the requirement is a large, ordinary, cost-sensitive counterweight, and there is sufficient installation space inside the equipment, then steel can provide a more mature supply chain and lower material cost. If it is used for high-speed rotors or precision balancing systems, then further comparison is needed of mass tolerance, center-of-gravity position, coaxiality, circular runout, installation method, and dynamic balancing grade, and the material cannot be determined based only on density.

The fundamental difference between tungsten alloy counterweights and steel counterweights can be summarized as follows: steel's advantages are more reflected in low cost, easy procurement, and mature processing, while the core advantage of tungsten alloys is the small volume and high mass concentration capability brought by high density. Therefore, tungsten alloys are not intended to comprehensively replace steel counterweights, but rather, under requirements such as limited space, high mass concentration, precision balancing, and miniaturization, to solve the problem of excessive steel volume through higher material density.



Q7 What Is the Difference Between a Tungsten Alloy Counterweight and a Lead Counterweight?

Tungsten alloy counterweights and lead counterweights both belong to the category of high-density counterweight materials. Their basic purpose is to add mass at a limited or



specific position, adjust the center of gravity, balance loads, or change inertia parameters. However, the two differ significantly in density, volume, mechanical strength, machinability, environmental protection and safety, durability, cost, and application scenarios. The most intuitive difference is that the density of lead (Pb, Lead) is about 11.34 g/cm³, while common high-density tungsten alloy counterweights are usually about 17–18.5 g/cm³, and the range of some tungsten heavy alloy products can reach about 16.5–19.0 g/cm³. Therefore, for the same mass, the volume required by tungsten alloy is significantly smaller than that of lead.

(1) Different Densities Determine Different Counterweight Volumes

The volume of a counterweight can be calculated by the following formula: $V=m/\rho$

where V is the counterweight volume, m is the counterweight mass, and ρ is the material density. Suppose a 1 kg counterweight needs to be manufactured in each case:

Material Typical Density Theoretical Volume for 1 kg

Materials	Density	Theoretical Volume
Tungsten alloy	18.0 g/cm ³	55.6 cm ³
Lead	11.34 g/cm ³	88.2 cm ³
Steel	7.85 g/cm ³	127.4 cm ³

Therefore, when an 18.0 g/cm³ tungsten alloy achieves the same mass, its theoretical volume is about 63% of that of lead, meaning that the material volume can be reduced by about 37%. This is also the most direct structural advantage of tungsten alloy relative to lead counterweights. The publicly disclosed specifications of some tungsten alloy counterweight products are 13.5–18.2 g/cm³, while high-density tungsten alloy products can reach about 18.5 g/cm³. For components with limited installation space, such as automobile wheel hubs, aviation control surfaces, drones, precision instruments, and mobile phone vibration components, this difference becomes even more obvious.

(2) Tungsten Alloy Makes It Easier to Achieve Small Volume and Large Mass

Lead is already a common high-density engineering material, but tungsten alloy has higher density, so it can further reduce size under the same mass requirement. For example, if a device needs to install a 500 g counterweight internally:

Lead: $V_{Pb} = 500/11.34 \approx 44.1 \text{ cm}^3$

18.0 g/cm³ tungsten alloy: $V_{WHA} = 500/18.0 \approx 27.8 \text{ cm}^3$

Here WHA (Tungsten Heavy Alloy) usually refers to a high-density alloy with tungsten as the main component and nickel-iron or nickel-copper, etc., as the binder phase. Therefore, tungsten alloy only needs about 63% of the volume of lead to obtain the same mass. For large ship ballast, this volume advantage may not be so prominent because the structural space is usually relatively ample; but for aircraft, automobiles, robot joints, high-speed rotors, and micro electronic devices, volume reduction may directly affect the product structure.



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(3) The Mechanical Strength of Tungsten Alloy Is Significantly Higher Than That of Lead

This is a very important difference between the two materials. Lead is a typical soft metal with low hardness and low strength, and it is prone to plastic deformation when subjected to relatively large mechanical loads or long-term vibration. Tungsten heavy alloy, however, forms a composite structure through tungsten particles and binder phases such as nickel, iron, and copper, and has strength and wear resistance significantly higher than those of lead. Public information on some tungsten alloy products indicates that tensile strength can reach several hundred MPa or even higher, while the mechanical strength of lead is obviously lower. This means that if the counterweight needs to withstand: high-speed rotation, continuous vibration, impact loads, clamping force, threaded connections, press-fit loads, or long-term mechanical friction, tungsten alloy usually has better structural stability. Lead is more suitable for counterweight structures with low mechanical loads, fixed installations, or protection by an outer shell.

(4) Tungsten Alloy Is Not Prone to Obvious Plastic Deformation Like Lead

This point is directly related to mechanical strength. If a lead block is used as a precision counterweight, its shape may change after long-term clamping, collision, vibration, or installation pressure. Once the position of the center of mass changes, it may affect the original balance state. Tungsten alloy has significantly higher strength and hardness and can better maintain geometric dimensions within the normal design load range. For high-speed rotors, this is especially important because once the counterweight shifts or deforms, the rotating system may become unbalanced again.

(5) Tungsten Alloy Is More Suitable for Precision Dynamic Balancing

A counterweight does not merely add mass statically. In automobile crankshafts, drive shafts, high-speed main shafts, centrifuges, fans, pumps, compressors, and aviation rotating components, counterweights need to participate in dynamic balancing. The centrifugal force generated by rotating mass can be approximately expressed as: $F = m\omega^2 r$, where F is centrifugal force, m is counterweight mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft. If the position of the counterweight changes, r may change, thereby affecting dynamic balance. Tungsten alloy has relatively high mechanical stability and can be machined into precision parts such as cylinders, discs, rings, blocks, eccentric structures, and perforated counterweights, and mass position control can be achieved through dimensional control and subsequent dynamic balancing inspection. Therefore, tungsten alloy is currently widely used in high-speed rotors, automobile balancing systems, aviation counterweights, and precision machinery.

(6) The Softness of Lead Is Sometimes an Advantage

It cannot simply be considered that the lower mechanical performance of lead is a disadvantage. Lead is very soft and easy to cut, press, and form. Therefore, for some counterweights with simple structures, low cost, and no need to withstand obvious



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mechanical loads, lead still has the characteristic of being easy to process. For example, some traditional counterweights can be completed by stamping, casting, or simple mechanical forming of lead blocks. However, if the product requires strict dimensional control, long-term shape retention, resistance to high-speed rotation, or mechanical vibration, then the softness of lead may become a limiting factor.

(7) Tungsten Alloy Has More Advantages in Environmental Protection and Occupational Safety

The biggest special problem with lead is its toxicity. Lead and its compounds have clear health hazards, so corresponding occupational hygiene and environmental management measures are required during manufacturing, processing, use, and disposal. Tungsten alloy cannot simply be summarized as absolutely risk-free in all environments, but tungsten heavy alloys represented by W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) usually do not have the same type of lead toxicity issues associated with lead materials, so they have material substitution value in many scenarios where the use of lead is restricted. Some public information also regards tungsten alloy as a replacement for traditional lead counterweights. Whether the actual product meets the environmental regulations of a certain region still needs to be confirmed according to the specific alloy composition, surface treatment, production process, and target market regulations.

(8) Differences Exist in Corrosion Resistance and Long-Term Dimensional Stability

Lead itself has a certain degree of corrosion resistance, but under different media, humidity, salt spray, and long-term service environments, surface corrosion or corrosion products may still occur. The corrosion resistance of tungsten alloy is closely related to the specific system. W-Ni-Fe and W-Ni-Cu cannot be completely equated and still need to be evaluated in combination with the binder phase, surface condition, and service medium. If used in automobiles, ships, outdoor equipment, or marine environments, nickel plating, zinc plating, coatings, or other protective solutions usually also need to be considered, and the final corrosion resistance cannot be judged solely by the material name.

(9) The Magnetic Properties of Tungsten Alloy and Lead Are Also Different

Lead is basically a non-magnetic material, so it has certain advantages in equipment sensitive to magnetic fields. Tungsten alloy, however, needs to be further distinguished by material system. W-Ni-Fe (Tungsten-Nickel-Iron) may have a certain magnetic response, and its specific magnetic properties are affected by the iron and nickel ratios and microstructure; W-Ni-Cu (Tungsten-Nickel-Copper) usually exhibits non-magnetic or very low magnetic response, so it is more suitable for certain magnetically sensitive equipment. Therefore, if the counterweight is installed near magnetic sensors, electronic compasses, magnetic encoders, or other magnetically sensitive components, density alone should not be compared; magnetic permeability or magnetic response indicators should also be clearly



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specified.

(10) There Are Obvious Differences in Processing Methods

Lead is very soft, and processing and forming are relatively easy, but this does not mean it is suitable for all precision machining scenarios. Because the material is prone to deformation, the dimensional stability and surface quality control after machining need to be combined with the specific process. Tungsten alloy is usually manufactured by powder metallurgy (Powder Metallurgy) and then processed by turning, milling, drilling, tapping, grinding, etc. according to final requirements. Because of its high tungsten content, processing parameters, tool selection, and cooling methods need to be optimized for the material grade. Some tungsten alloy counterweight suppliers also provide post-sintering mechanical machining and thread machining. Therefore, the manufacturing logic of the two materials is not simply the same processing method with a different material.

(11) In Terms of Cost, Lead Usually Has an Advantage

If only comparing material prices and the manufacturing cost of ordinary counterweights, lead is usually more economical than high-density tungsten alloy. Tungsten alloy contains a relatively high proportion of tungsten, and tungsten is a high-value metal; at the same time, tungsten alloy usually needs to go through powder metallurgy, sintering, and necessary precision machining. Therefore, its material and manufacturing costs are usually significantly higher than those of ordinary lead counterweights. However, actual projects cannot compare only the price per kilogram of material. If the use of lead requires increased counterweight installation space, structural modification, or an additional protective shell, or if it cannot meet weight concentration and dynamic balancing requirements, then the higher material cost of tungsten alloy may be partially offset through structural optimization. Therefore, a more reasonable comparison is to compare the comprehensive cost of the entire counterweight system, not just the unit price of the material.

(12) The Typical Application Focus of the Two Materials Is Different

Because lead has relatively high density, relatively low price, and is easy to form, it was widely used in the past in vehicle balance weights, ship ballast, industrial counterweights, and radiation protection, among other scenarios. With the increase in environmental regulations, occupational health requirements, and equipment miniaturization needs, some applications have begun to look for substitute materials for lead. With higher density, higher mechanical strength, and better dimensional stability, tungsten alloy has strong application value in aviation, automobiles, industrial balancing, electronic products, medical equipment, and other fields. For example, information in the automotive field shows that high-density tungsten alloy can be used for dynamic balancing of crankshafts, drive shafts, and wheels, providing a specified mass with a smaller volume when space is limited.



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(13) Comprehensive Comparison of Tungsten Alloy and Lead Counterweights

Comparison Item Tungsten Alloy Counterweight Lead Counterweight

Typical density About 17–18.5 g/cm³ About 11.34 g/cm³. Volume for the same mass Small
Relatively large: Mechanical strength High Low. Hardness Relatively high Very low

Deformation resistance Relatively good Relatively poor

Adaptability to high-speed rotation Relatively good Limited by mechanical properties

Precision dynamic balancing Suitable Depends on the structure

Processing difficulty Relatively high Relatively low

Material cost Relatively high Usually relatively low

Magnetic properties Depends on systems such as W-Ni-Fe and W-Ni-Cu Basically non-magnetic

Environment and occupational health Usually does not have the same type of toxicity issues as lead Lead exposure and waste management need to be seriously considered

Miniaturization capability Very strong General

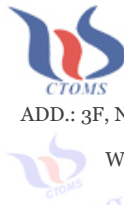
Long-term dimensional stability Relatively good Prone to plastic deformation

Typical advantages High density, small volume, high strength, precision counterweight Low cost, easy to form, relatively high density

(14) Should Tungsten Alloy or Lead Be Chosen?

If the main goals are low cost, sufficient structural space, low mechanical load, and the market and application environment permit the use of lead, then lead can still meet some traditional counterweight needs. If a relatively large mass is required in a very limited space, and the counterweight needs to withstand vibration, impact, high-speed rotation, or long-term mechanical load, the advantages of tungsten alloy will be more obvious. For fields such as aviation, racing, high-speed rotors, precision instruments, and micro electronic devices, this combination of high density and high strength is especially valuable. If environmental restrictions, occupational health requirements, or markets where the use of lead materials is restricted are also involved, tungsten alloy can also be evaluated as an important substitute material.

The difference between tungsten alloy and lead counterweights can be summarized as follows: the main advantages of lead are low cost, relatively high density, and easy forming; tungsten alloy further increases density, significantly reducing the volume of a counterweight of the same mass, while also having higher mechanical strength and better dimensional stability. For scenarios with limited space and high-precision dynamic balancing, the engineering value of tungsten alloy is more prominent; for ordinary, low-cost, large-space counterweights, lead may still have a cost advantage.



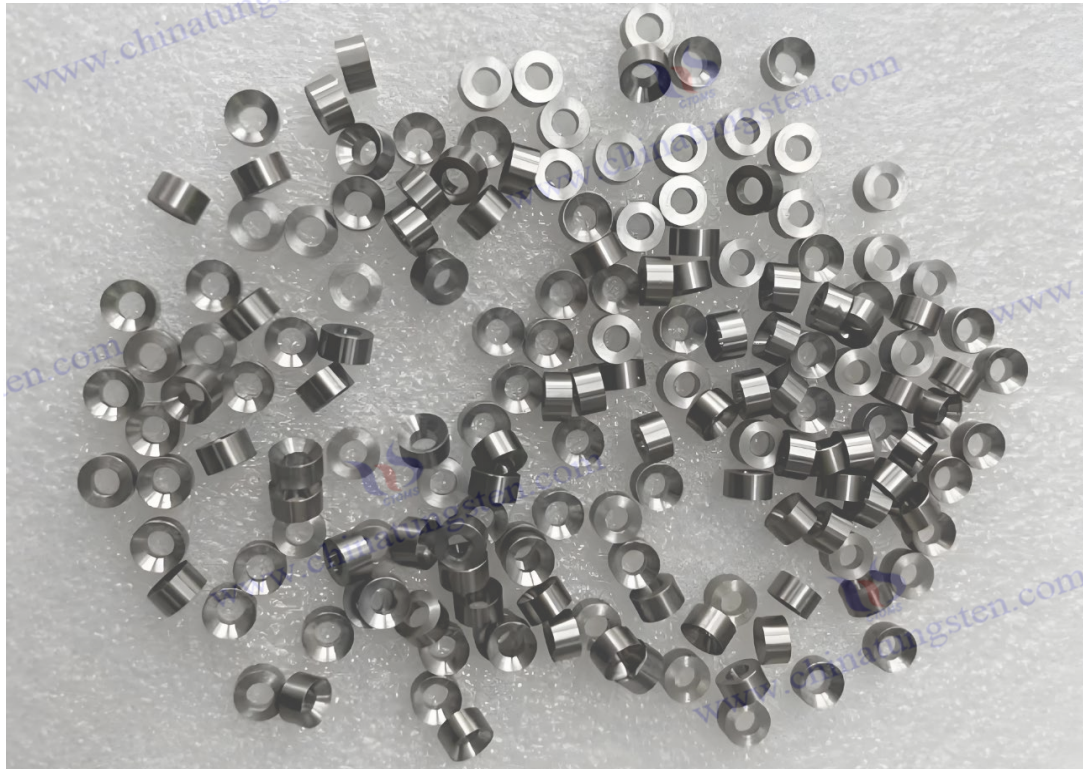
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Q8 What Advantages Does a Tungsten Alloy Counterweight Have Compared with Pure Tungsten?

Tungsten alloy counterweights and tungsten both have very high density, but when used for actual counterweight parts, their design orientations are not completely the same. The main advantages of pure tungsten are high tungsten content, density close to the theoretical maximum, an extremely high melting point, and excellent high-temperature performance; tungsten alloy counterweights, on the basis of maintaining relatively high density, improve ductility, toughness, machinability, and overall manufacturing economy by adding binder phases such as nickel, iron, and copper. Therefore, for most precision counterweight parts that require drilling, tapping, turning, milling, special-shaped machining, and long-term vibration resistance, tungsten alloys usually have better engineering adaptability. Public material data show that the density of pure tungsten is about 19.3 g/cm^3 , while the density of common tungsten heavy alloys is about $17\text{--}18.5 \text{ g/cm}^3$, and some grades can reach about $18.5\text{--}18.8 \text{ g/cm}^3$.

(1) Tungsten Alloy Achieves Better Overall Performance While Maintaining High Density

The biggest characteristic of pure tungsten is high density. The theoretical density of tungsten (W, Tungsten) is about 19.25 g/cm^3 , and actual high-purity tungsten products are usually about 19.3 g/cm^3 . Tungsten heavy alloy (Tungsten Heavy Alloy) is usually composed of about 90%–97% by mass of tungsten, plus a nickel-iron or nickel-copper binder phase.



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Because a binder phase with lower density than tungsten is added, its density is usually lower than that of pure tungsten, but it can still maintain a high density level of about 17–18.5 g/cm³. For example, among some heavy alloy grades publicly disclosed by Nippon Tungsten Co., Ltd., 97W-2Ni-1Cu has a density of 18.5 g/cm³, and 97W-2Ni-1Fe has a density of 18.4 g/cm³, which are already very close to the density of pure tungsten. Therefore, from the perspective of counterweights, tungsten alloy does not sacrifice a large amount of density in exchange for machinability, but rather obtains more balanced overall performance at a slightly lower density.

(2) The Ductility of Tungsten Alloy Is Usually Better Than That of Pure Tungsten

This is one of the most important differences between the two. Although pure tungsten has high strength and an extremely high melting point, its ductility at room temperature is relatively low, and it is more prone to brittle fracture when subjected to notches, impact, local stress concentration, or unreasonable machining. Tungsten heavy alloys such as W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) combine tungsten particles through a metal binder phase, causing the material to form a composite structure composed of tungsten particles and a tough metal matrix, thereby improving overall ductility and fracture resistance. Relevant material research and engineering data both indicate that tungsten heavy alloys have better ductility and toughness than pure tungsten. This is especially important for counterweights because actual counterweights not only need to withstand service loads, but may also experience transportation, assembly, clamping, threaded connections, vibration, and impact.

(3) Tungsten Alloy Is More Suitable for Manufacturing Counterweights with Holes, Threads, and Complex Structures

The brittleness of pure tungsten makes complex mechanical machining more difficult. For simple block-shaped or cylindrical pure tungsten parts, this problem may still be controllable, but if deep holes, thin walls, grooves, internal threads, external threads, steps, eccentric structures, etc. need to be machined, the process design must be more cautious. Because tungsten heavy alloy has a metal binder phase, it usually has better mechanical machining adaptability and can be used to complete complex structures by methods such as turning, milling, drilling, tapping, grinding, and electrical discharge machining (Electrical Discharge Machining). For counterweight products, this is very important because actual products are rarely just a solid block without any mounting structure. For example, an automobile rotor counterweight may require positioning holes, mounting holes, and fixing threads; a drone counterweight may require steps and mounting grooves; a precision instrument counterweight may require eccentric holes or precision positioning surfaces. The manufacturing adaptability of tungsten alloy for these structures is usually better than that of pure tungsten.



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(4) Tungsten Alloy Is More Suitable for Batch Precision Machining

The processing difficulty of pure tungsten affects not only single-piece manufacturing but also the processing cycle, tool life, processing cost, and dimensional consistency of batch production. Tungsten alloy is usually manufactured by powder metallurgy (Powder Metallurgy), first obtaining a high-density blank close to the final shape through pressing, sintering, and other processes, and then performing necessary finishing. This process route is particularly suitable for counterweight products because counterweights often have a large number of repeated standard structures. Through mold forming and a small amount of subsequent mechanical machining, the need to remove a large amount of material from a whole block entirely by cutting can be reduced. Therefore, for large batches of cylindrical, disc-shaped, ring-shaped, block-shaped, and special-shaped tungsten alloy counterweights, material utilization and production efficiency are usually more favorable than directly machining pure tungsten.

(5) The Manufacturing Cost of Tungsten Alloy Is Usually Lower Than That of Pure Tungsten

The high-purity requirements, high melting point, and relatively complex processing and manufacturing process of pure tungsten make it a relatively costly engineering material. Although tungsten heavy alloy still contains a large amount of tungsten, the proportion of pure tungsten is reduced by adding nickel, iron, or copper binder phases, while sintering and subsequent mechanical machining conditions are improved. Relevant material suppliers also clearly list lower cost and better machinability as important advantages of tungsten heavy alloy over pure tungsten. Therefore, if the goal is merely to obtain a high-density counterweight and there is no extreme high-temperature performance requirement such as that of pure tungsten, then using pure tungsten may be performance oversufficiency. For large-batch counterweights, tungsten alloy can usually achieve a more reasonable balance between material performance and manufacturing cost.

(6) Although the Density of Tungsten Alloy Is Slightly Lower, the Impact on Ordinary Counterweights Is Limited

From a purely density perspective, pure tungsten is indeed superior to tungsten alloy. Assuming the density of pure tungsten is 19.3 g/cm³ and the density of tungsten alloy is 18.0 g/cm³, then when manufacturing a 1 kg counterweight:

$$V_{\text{"pure tungsten"}} = 1000 / 19.3 \approx 51.8 \text{ [" cm"] }^3.$$

$$V_{\text{"tungsten alloy"}} = 1000 / 18.0 \approx 55.6 \text{ [" cm"] }^3.$$

The difference between the two is only about 3.8 cm³. Although pure tungsten has higher density, in many actual counterweight designs, a tungsten alloy of about 18.0 g/cm³ can already provide mass concentration capability very close to that of pure tungsten. If the design space itself allows an extra few cubic centimeters, then bearing higher processing difficulty in order to obtain the additional density advantage of about 7% from pure tungsten may not necessarily have practical value.



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(7) The Mechanical Reliability of Tungsten Alloy Is More Suitable for Vibration Environments

Counterweights often work in vibration environments, such as automobile engines, racing cars, high-speed rotors, drones, industrial motors, and precision motion mechanisms. If the material itself has obvious brittleness, holes, grooves, thread roots, and sharp corners in the counterweight may become stress concentration areas. The binder phase of tungsten heavy alloy can provide a certain degree of plastic deformation capacity and fracture buffering capacity, so it usually has a more tolerant structural design window under mechanical vibration and impact conditions. In the two-phase structure of W-Ni-Fe heavy alloy, tungsten particles are embedded in a nickel-iron matrix with a certain degree of plasticity, which is also an important source of its comprehensive mechanical properties. This does not mean that tungsten alloy will not fracture, but its material system is usually more suitable than pure tungsten at room temperature for bearing complex loads in actual mechanical structures.

(8) Tungsten Alloy Can Achieve Performance Adjustment Through Different Binder Phases

Pure tungsten is basically centered on the material characteristics of tungsten itself, while tungsten alloy can adjust material performance by changing the binder phase system and tungsten content. For example: W-Ni-Fe (Tungsten-Nickel-Iron) usually focuses on strength, ductility, and comprehensive mechanical properties; W-Ni-Cu (Tungsten-Nickel-Copper) can be used in occasions with special requirements such as magnetic properties. Therefore, counterweight design does not have to be limited to one fixed density and fixed performance, but can select the corresponding grade according to mass, dimensions, strength, magnetic properties, and processing requirements. This is especially important for precision instruments, aviation counterweights, automotive balancing parts, and electronic equipment.

(9) Tungsten Alloy Is More Suitable for Subsequent Processing of Precision Counterweights

Many counterweights are not used directly after sintering but require dimensional correction. For example: the outer diameter needs to reach ± 0.02 mm; mounting holes need hole diameter control; the two ends of the counterweight need parallelism assurance; rotating parts need coaxiality and circular runout control; threads need to meet the specified fit grade. Tungsten heavy alloy can usually achieve these subsequent dimensional controls through mechanical machining. For pure tungsten, more cautious process solutions need to be adopted according to its brittleness and processing characteristics. Relevant engineering data show that tungsten heavy alloy can be subjected to CNC (Computer Numerical Control) turning, milling, drilling, and thread machining, and is used for precision counterweights and dynamic balancing parts.



(10) Tungsten Alloy Is More Suitable for Most Actual Counterweight Applications

The most prominent advantages of pure tungsten are high purity, high melting point, high density, and high-temperature stability, so it is more suitable for scenarios with special requirements for high-temperature performance, such as high-temperature furnace components, heating elements, vacuum components, and certain X-ray (X-ray) targets. Tungsten alloy is more oriented toward high-density structural parts, including counterweights, balance weights, damping components, radiation shielding parts, and other products that require both high density and mechanical machining performance. For ordinary counterweights, the pure tungsten melting point of about 3422 °C is usually not required, nor is the extreme high-temperature performance of pure tungsten. Therefore, replacing part of the pure tungsten with a binder phase in exchange for better mechanical machining performance and toughness is often more in line with actual needs.

(11) Core Performance Comparison Between Tungsten Alloy and Pure Tungsten

Comparison Item	Tungsten Alloy Counterweight	Pure Tungsten Counterweight
Typical density	About 17–18.5 g/cm ³	About 19.3 g/cm ³
Tungsten content	Usually about 90%–97%	Usually ≥99.95% high-purity grade
Volume miniaturization	Very strong	Strongest
Room-temperature ductility	Usually relatively good	Relatively low
Toughness	Usually better than pure tungsten	Relatively low
Mechanical machining	Relatively easy	Relatively difficult
Drilling and tapping	Relatively suitable	High process requirements
Complex special-shaped structures	Relatively suitable	Relatively difficult
Batch manufacturing	Good powder metallurgy adaptability	Relatively high manufacturing difficulty
Material cost	Usually lower than pure tungsten	Usually relatively high
High-temperature performance	Relatively good, but limited by binder phase	Extremely high
Counterweight applications	Very suitable	Possible, but may be performance oversufficiency
Extreme high-temperature applications	Limited	Obvious advantages

(12) Why Do Counterweights Usually Tend to Use Tungsten Alloy Rather Than Pure Tungsten?

What a counterweight truly needs is usually not the highest-purity tungsten, but a comprehensive balance among high density, mechanical properties, processing performance, and cost. For example, for a 1 kg aviation counterweight, if pure tungsten requires about 51.8 cm³ and an 18.0 g/cm³ tungsten alloy requires about 55.6 cm³, then the difference between the two is only about 3.8 cm³. If the use of tungsten alloy can significantly reduce processing difficulty, improve structural toughness, and lower manufacturing cost, then this volume difference of a few cubic centimeters is usually acceptable. This is also an important reason why tungsten heavy alloys are widely used in counterweights and balancing parts. Relevant industry information clearly regards their



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high density, relatively good ductility, and machinability as the main engineering advantages over pure tungsten.

(13) Under What Circumstances Should Pure Tungsten Be Chosen Instead?

If the counterweight simultaneously performs a structural or functional role in an extreme high-temperature environment, for example, in applications that are close to the high-temperature performance advantages of pure tungsten for a long time, then pure tungsten still has irreplaceable value. In addition, if the structural space is extremely limited, the largest possible mass must be obtained in every cubic centimeter, and the product can accept the higher processing cost of pure tungsten, then the density advantage of pure tungsten at about 19.3 g/cm^3 may also become a basis for selection. Therefore, it cannot simply be considered that tungsten alloy is comprehensively superior to pure tungsten. The reasonable choice between the two depends on the specific working conditions.

The greatest advantage of tungsten alloy counterweights relative to pure tungsten can be summarized as follows: at the cost of a slight decrease in density, they obtain better ductility, toughness, machinability, structural adaptability, and manufacturing economy. The advantages of pure tungsten are mainly the highest density, high purity, and extremely high-temperature performance; tungsten alloy places more emphasis on the balance between high density and actual manufacturing capability. For counterweight parts that require drilling, tapping, turning, milling, complex special-shaped machining, and long-term vibration resistance, W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) usually have higher engineering practicality. Simply put, pure tungsten pursues density and high-temperature performance closer to the limits of the material itself, while tungsten alloy pursues a comprehensive balance among high density, machinability, toughness, and cost. For the vast majority of conventional high-density counterweights, this comprehensive balance is often more practically meaningful than simply pursuing the highest density.



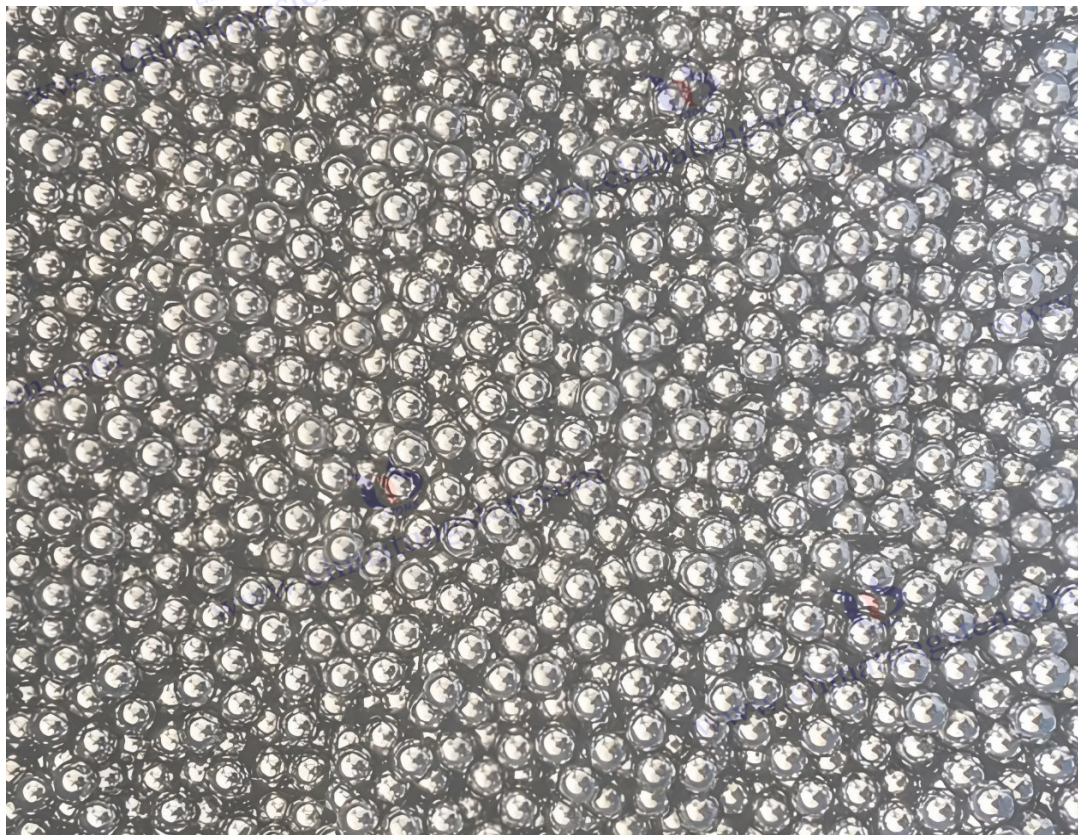
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PART II. Density, Weight, and Calculation Issues Concerning

Tungsten Alloy Counterweights

There is a direct mathematical relationship among the density, weight, and volume of a tungsten alloy counterweight, and this is also the most basic set of parameters when performing counterweight selection, dimensional design, weight verification, and supplier technical confirmation. For common high-density tungsten alloy counterweights, the actual density is usually about 17.0–18.5 g/cm³, with the specific value depending on the tungsten (W, Tungsten) content, the composition of binder phases such as nickel (Ni, Nickel) and iron (Fe, Iron) or copper (Cu, Copper), and the specific material grade.

Basic Relationship Among Density, Mass, and Volume

The basic formula for density is $\rho = m/V$, where ρ is density, m is mass, and V is volume. From this, $m = \rho V$ and $V = m/\rho$ can be obtained. When actually calculating a tungsten alloy counterweight, as long as two of these parameters are known, the third parameter can be determined.

For example, for a tungsten alloy counterweight with a density of 18.0 g/cm³ and a volume of 10 cm³, its mass is $m = 18.0 \times 10 = 180$ g; if it has already been determined that a 500 g tungsten alloy counterweight with a density of 18.0 g/cm³ needs to be made, then the



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required volume is $V=500/18.0 \approx 27.78 \text{ cm}^3$.

Weight and Volume Corresponding to Common Densities

Taking a 1 kg tungsten alloy counterweight as an example, the theoretical volumes corresponding to different densities are approximately:

Density Volume Required for 1 kg

17.0 g/cm³ 58.82 cm³

17.5 g/cm³ 57.14 cm³

18.0 g/cm³ 55.56 cm³

18.5 g/cm³ 54.05 cm³

From this it can be seen that, when the weight is the same, the higher the density, the smaller the required volume. For example, the volume of 1 kg of 18.0 g/cm³ tungsten alloy is about 55.56 cm³, while for steel (Steel) of the same mass, calculated at about 7.85 g/cm³, the volume is about 127.39 cm³, and the former volume is reduced by about 56.4%.

How to Calculate the Weight of a Tungsten Alloy Counterweight When Dimensions Are Known

If the counterweight is a regular shape, the geometric volume can be calculated first, and then the weight can be calculated by $m=pV$. The volume of a rectangular counterweight is $V=LWH$, where L is length, W is width, and H is height; the volume of a cylindrical counterweight is $V=\pi d^2 h/4$, where d is diameter and h is height; the volume of an annular counterweight is $V=\pi h(D^2-d^2)/4$, where D is outer diameter, d is inner diameter, and h is height. For example, for a tungsten alloy counterweight with dimensions of 20 mm×20 mm×10 mm, its volume is 4 cm³. If the actual density of the material is 18.0 g/cm³, then its weight is about 72 g.

Influence of Different Densities on Counterweight Dimensions

Assume that the product requires a fixed weight of 100 g. Then, when a 17.5 g/cm³ material is used, the volume is about 5.71 cm³; when 18.0 g/cm³ is used, it is about 5.56 cm³; when 18.5 g/cm³ is used, it is about 5.41 cm³. Therefore, one of the main values of high-density materials is not simply to make the counterweight heavier, but to make the counterweight more compact while the target weight remains unchanged. This is especially important for space-constrained components such as automobile crankshafts, aircraft control surfaces, industrial rotors, drones, mobile phone vibration structures, and golf clubs.

Why Actual Products Cannot Be Calculated Only According to Theoretical Density

In engineering calculations, it is necessary to distinguish among theoretical density, actual sintered density, and finished product weight. Tungsten alloy is a multiphase material, and its actual density is affected by factors such as material composition, powder condition, forming conditions, sintering process, and internal porosity. Therefore, if the drawing requires 18.0 g/cm³, it cannot simply be understood that all batches are naturally equal to



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18.000 g/cm³. For precision counterweights, what is more important is the actual mass, dimensions, center of gravity (CG, Center of Gravity), and, when necessary, dynamic balancing performance of the final finished product. Especially for rotating parts, even if the overall weight is accurate, if there is a deviation in the position of mass distribution, an obvious unbalanced force may still be generated. In actual tungsten alloy counterweight production, suppliers such as CTIA GROUP, which have powder metallurgy, sintering, and precision mechanical machining capabilities, usually need to carry out comprehensive control in combination with material density, target weight, dimensional tolerances, and final service conditions, rather than controlling only a single density value.

Several Common Conversions in Counterweight Calculations

If the designer has already determined the target weight, $V=m/\rho$ can be used directly. For example, the volume of 10 g of 18.0 g/cm³ tungsten alloy is about 0.556 cm³; 100 g is about 5.56 cm³; 500 g is about 27.78 cm³; and 1 kg is about 55.56 cm³. If the volume has already been determined, then $m=\rho V$ is used. For example, the weight of 20 cm³ of 18.0 g/cm³ tungsten alloy is about 360 g; 50 cm³ is about 900 g. If mass distribution design is also required, then calculating weight alone is not enough. For example, the mass moment generated by a counterweight can be expressed as $M=mr$, where m is mass and r is the distance from the mass to the reference axis; the centrifugal force in a rotating component can be expressed as $F=m\omega^2r$, where ω is angular velocity. It can thus be seen that for the same 100 g tungsten alloy counterweight, different installation positions may have significantly different effects on the overall balance and inertia characteristics. From the perspective of engineering application, the density calculation of a tungsten alloy counterweight is actually the starting point of the entire design chain, and subsequent comprehensive calculations still need to be carried out in combination with weight tolerances, dimensional tolerances, center-of-gravity position, installation method, dynamic balancing requirements, and material grade.



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Q9 How Is the Density of a Tungsten Alloy Counterweight Calculated?

The method for calculating the density of a tungsten alloy counterweight is not complicated. The most basic calculation formula is: $\rho = m/V$, where ρ is material density, m is counterweight mass, and V is the actual volume of the counterweight. For a finished tungsten alloy counterweight, the mass is usually obtained by precision weighing, the volume is then determined by dimensional measurement or other methods, and finally the actual density is calculated. The commonly used engineering unit is g/cm^3 , and kg/m^3 can also be used. The conversion relationship between the two is $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$.

(1) The Most Basic Density Calculation Formula

If a tungsten alloy counterweight has a mass of 180 g and an actual volume of 10 cm^3 , then: $\rho = 180/10 = 18.0 \text{ g/cm}^3$. Therefore, the measured density of this counterweight is 18.0 g/cm^3 . For tungsten alloy counterweights, this calculation result usually needs to be compared with the theoretical density specified by the material grade or the density range provided by the supplier, in order to judge the degree of densification of the material and production consistency. The density of common high-density tungsten alloy counterweights is approximately in the range of $17\text{--}18.5 \text{ g/cm}^3$, and different W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) grades will differ.

(2) How to Calculate the Density of a Regular Cylindrical Tungsten Alloy Counterweight

If the counterweight is a cylinder, the volume can first be calculated from the diameter and height. The formula for the volume of a cylinder is: $V = (\pi d^2 h)/4$, where d is the cylinder



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diameter and h is the cylinder height. For example, a tungsten alloy cylindrical counterweight has a diameter of 20 mm, a height of 35 mm, and a mass of 197.9 g. First, unify the units: $d=2.0$ "cm", $h=3.5$ "cm".

Therefore: $V=(\pi \times [2.0]^2 \times 3.5)/4 \approx 10.996$ ["cm"]³.

Then calculate the density: $\rho=197.9/10.996 \approx 18.0$ ["g/cm"]³.

From this, it can be judged that the actual density of the sample is about 18.0 g/cm³.

(3) How to Calculate the Density of a Square or Rectangular Counterweight

If the tungsten alloy counterweight is a regular rectangular prism, the calculation is even simpler: $V=LWH$, where L is length, W is width, and H is height. For example, a counterweight has dimensions of 30 mm × 20 mm × 10 mm and a mass of 108 g. Convert the dimensions to centimeters: 3.0 "cm" × 2.0 "cm" × 1.0 "cm".

The volume is: $V=3.0 \times 2.0 \times 1.0=6.0$ ["cm"]³.

Therefore: $\rho=108/6.0=18.0$ ["g/cm"]³.

This method is particularly suitable for regular block-shaped, plate-shaped, and rectangular tungsten alloy counterweights.

(4) How to Calculate a Ring-Shaped Tungsten Alloy Counterweight

If the counterweight is a ring, the volume formula for a complete cylinder cannot be used directly. Instead, the volume of the outer cylinder minus the volume of the inner hole should be calculated: $V=\pi h/4 (D^2-d^2)$, where D is the outer diameter, d is the inner diameter, and h is the height. For example, a ring-shaped counterweight has an outer diameter of 30 mm, an inner diameter of 20 mm, and a height of 10 mm, then: $V=(\pi \times 1.0)/4 ([3.0]^2 - [2.0]^2)$

$V \approx 3.927$ ["cm"]³.

If the actual weighed mass is 70.7 g, then: $\rho=70.7/3.927 \approx 18.0$ ["g/cm"]³.

This calculation method is suitable for sleeve-type counterweights, balance rings, rotor counterweight rings, and disc-shaped counterweights with center holes.

(5) Counterweights with Holes, Grooves, and Steps Require Deduction of Invalid Volume

Actual tungsten alloy counterweights are often not simple solid geometric bodies. For example, a counterweight may simultaneously have: a center hole, positioning holes, lightening grooves, mounting grooves, steps, threaded holes, countersunk holes, and other structures. At this time, the entire envelope volume cannot be calculated directly according to the external dimensions. Instead, it is necessary to calculate: $V_{\text{"actual"}} = V_{\text{"main body"}} - V_{\text{"holes"}} - V_{\text{"grooves"}} - V_{\text{"other removed parts"}}$.

Then substitute into: $\rho=m/V_{\text{"actual"}}$.

If the volume of holes or grooves is ignored, a density result that is obviously too low will be obtained. For high-precision counterweights, dimensional measurement should also consider factors such as chamfers, fillets, threads, and complex curved surfaces, because



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these structures all affect the final volume.

(6) Complex Special-Shaped Tungsten Alloy Counterweights Cannot Be Calculated Simply by Formulas

If the counterweight has complex three-dimensional curved surfaces, irregular eccentric structures, or multiple spatial cavities, estimating the volume only by length, width, and height will produce relatively large errors. For such products, volume can usually be determined by three-dimensional coordinate measurement, three-dimensional scanning, computer-aided design model volume, liquid displacement method, or other density measurement methods. If the product has a complete three-dimensional CAD (Computer-Aided Design) model, and the actual machined dimensions are highly consistent with the model, the theoretical volume can be obtained directly from the model, and then combined with the measured mass to calculate: $\rho = m_{\text{measured}} / V_{\text{CAD}}$. However, for precision counterweights, the CAD theoretical volume is not necessarily equal to the final physical volume, so final acceptance usually still requires combination with actual dimensions or physical density testing.

(7) Why May the Actual Density Be Lower Than the Theoretical Density?

This is a very important point in tungsten alloy density testing. Tungsten alloy is a multiphase material, and its final density depends not only on chemical composition but also on sintering densification, porosity, tungsten content, binder phase ratio, and manufacturing process. For example, if the theoretical density of a certain material is 18.2 g/cm³, but a small amount of residual porosity exists after sintering, the actually measured density may be lower than the theoretical value.

It can be simply understood as: $\rho_{\text{actual}} < \rho_{\text{theoretical}}$.

This does not necessarily mean that the material composition is wrong; it may also indicate that the theoretical dense state was not fully achieved during sintering. Of course, if the measured density clearly deviates from the range specified by the material grade, then the raw material ratio, powder mixing, pressing, debinding, sintering, and subsequent processing processes need to be further checked.

(8) How to Estimate Theoretical Density Based on the Ratio of Tungsten and Binder Phase?

For tungsten alloy material design, the theoretical density can be estimated based on the mass fraction and density of each component. A commonly used approximate relationship is: $1/\rho_{\text{theoretical}} = \sum w_i / \rho_i$, where w_i is the mass fraction of the i-th component and ρ_i is the density of that component. For example, if the material is mainly composed of tungsten, nickel, and iron, theoretical estimation can be carried out based on the mass fractions of tungsten, nickel, and iron and their respective densities. However, actual tungsten heavy alloys are not simple ideal mixtures. Their sintered structure, porosity, and microstructure all affect the final measured density. Therefore, this formula is mainly used for material design and theoretical estimation and cannot replace the measured density of



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the final product.

(9) Units in Density Calculation Must Be Unified

One of the most common problems in actual testing is that mass and volume units are not unified. For example:

1 ["g/cm"] ^3=1000 ["kg/m"] ^3.

Therefore: 18.0 ["g/cm"] ^3=18000 ["kg/m"] ^3.

If mass is in g and volume is in cm³, the calculation result is in g/cm³; if mass is in kg and volume is in m³, the calculation result is in kg/m³. For example, 1 kg of tungsten alloy with a volume of 55.56 cm³:

$\rho = 1000 / 55.56 \approx 18.0$ ["g/cm"] ^3.

When converted to the International System of Units: $\rho \approx 18000$ ["kg/m"] ^3.

The two represent the same density.

(10) In Actual Measurement, Mass Accuracy Is Very Important

For ordinary counterweights, an electronic scale with appropriate accuracy can be used; for high-precision counterweights, a precision balance should be selected according to the target mass tolerance. For example, if the counterweight mass is 100.00 g, and the balance can only be accurate to 0.1 g, then the mass measurement itself may produce relatively obvious uncertainty. If the product needs to be controlled to the 100.000 g level, precision weighing equipment with corresponding accuracy is required. The relative error of density calculation is roughly affected by both mass and volume measurement errors: $\Delta\rho/\rho \approx \Delta m/m + \Delta V/V$.

Therefore, for high-precision tungsten alloy counterweights, it is not enough to improve only weighing accuracy while ignoring dimensional measurement accuracy.

(11) Dimensional Measurement Also Affects Density Results

Taking a cylindrical counterweight as an example: $V = (\pi d^2 h) / 4$.

It can be seen that the diameter d is a squared term, so the influence of diameter measurement error on volume calculation is more obvious than that of height measurement.

For example, if the actual cylinder diameter is 20.00 mm, and the measurement error reaches 0.10 mm, then the volume error will obviously affect the final density calculation. Therefore, for precision tungsten alloy counterweights, suitable measuring equipment such as micrometers, calipers, and coordinate measuring machines usually need to be used, and the corresponding inspection accuracy should be selected according to dimensional tolerances.

(12) Density and the Actual Weight of the Counterweight Can Be Converted into Each Other

After knowing the density, the volume required for the counterweight can be calculated in



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reverse: $V=m/\rho$. The mass that can be obtained from a given volume can also be calculated: $m=\rho V$. For example, if the material density is 18.0 g/cm^3 and the design volume is 20 cm^3 : $m=18.0 \times 20=360 \text{ g}$. If the designer has already determined the installation space, the maximum counterweight mass that can be accommodated can first be calculated, and then the appropriate material density and structural dimensions can be determined. This is also a very commonly used calculation method in the structural design of tungsten alloy counterweights.

(13) How to Judge Whether the Measured Density Is Qualified?

A unified qualified value cannot simply be specified. For example, if a tungsten alloy grade specifies a density of $17.5\text{--}18.0 \text{ g/cm}^3$, then a measured value of 17.8 g/cm^3 may be completely normal; if another grade specifies $18.3\text{--}18.8 \text{ g/cm}^3$, then 17.8 g/cm^3 may not meet the requirements. Therefore, density acceptance should be based on the specific material grade, procurement technical conditions, or product drawings, rather than simply using 18.0 g/cm^3 as the standard for all tungsten alloy counterweights. During actual procurement, suppliers can be required to provide material grade, nominal density, allowable density deviation, and batch inspection data.

(14) What Is the Relationship Between Density Calculation and Actual Counterweight Acceptance?

Density is an important material indicator of a tungsten alloy counterweight, but it is not equal to the final performance of the counterweight. For precision counterweights, it is also necessary to simultaneously inspect: mass and mass tolerance, external dimensions, hole diameter and hole position, coaxiality, circular runout, flatness, surface roughness, center-of-gravity position, and dynamic balancing grade. Especially for high-speed rotating parts, even if the densities of two products are exactly the same, if the positions of their centers of mass are different, the actual dynamic balancing results may still differ. Therefore, density calculation mainly solves the relationship between material, mass, and volume, while dynamic balancing testing solves the actual distribution of mass in space. The two cannot replace each other.

(15) A Complete Example: How to Calculate the Density of a Tungsten Alloy Counterweight

Suppose there is a cylindrical tungsten alloy counterweight: diameter 20.00 mm , height 35.00 mm , measured mass 197.9 g .

First calculate the volume: $V=(\pi d^2 h)/4$.

After converting units: $V=(\pi \times [2.00]^2 \times 3.50)/4 \approx 10.996 \text{ [\" cm\"]}^3$.

Then: $\rho=197.9/10.996 \approx 18.0 \text{ [\" g/cm\"]}^3$.

Therefore, the measured density of this counterweight is about 18.0 g/cm^3 . If the design grade of this product requires a density of $17.8\text{--}18.2 \text{ g/cm}^3$, then this result is within the specified range; if the design requirement is $18.3\text{--}18.8 \text{ g/cm}^3$, then the material grade and



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manufacturing state need to be further checked.

(16) Recommended Calculation Process in Actual Engineering

For regular tungsten alloy counterweights, the process can be carried out as follows: mass measurement → dimensional measurement → calculation of geometric volume → density calculation → comparison with grade requirements. For complex counterweights, the method can be: mass measurement → determination of three-dimensional volume → density calculation → verification of material grade → independent density testing when necessary. For batch production, multiple samples can also be statistically analyzed to calculate average density and density dispersion, thereby judging the consistency of the powder mixing, pressing, and sintering processes. Overall, the density calculation of a tungsten alloy counterweight is essentially mass divided by actual volume: $\rho=m/V$.

However, in actual engineering inspection, the key is not the formula itself, but whether the mass and volume are measured accurately, and whether the calculation result matches the density requirements of the specific W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) grades. For regular counterweights, geometric formulas can be used directly for calculation, while for complex special-shaped counterweights, three-dimensional measurement or other reliable volume determination methods should be used.





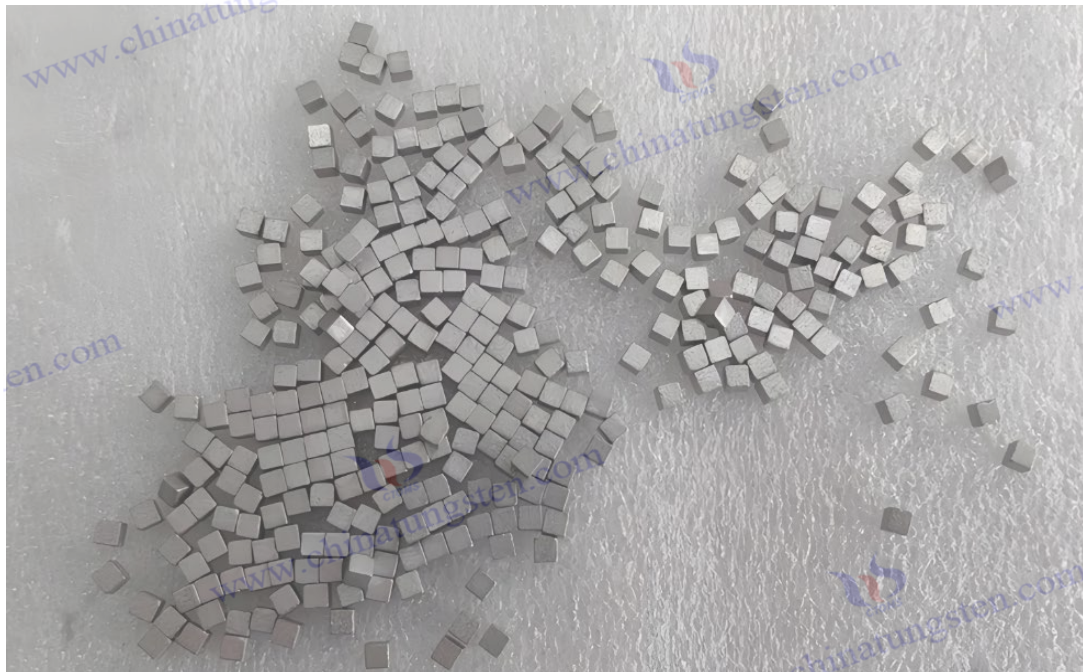
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Q10 How Is the Weight of a Tungsten Alloy Counterweight Calculated?

The weight calculation of a tungsten alloy counterweight is essentially the use of material density and counterweight volume to determine mass. The most basic relationship is: $m = \rho V$, where m is the counterweight mass, ρ is the tungsten alloy density, and V is the counterweight volume. In engineering, the theoretical volume of the counterweight is usually first calculated according to the drawing, and then multiplied by the actual material density to obtain the theoretical weight; if the product has already been manufactured, the actual weight can be directly measured using a precision balance. For common W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) tungsten alloy counterweights, the density is usually about 17–18.5 g/cm³. Therefore, at the same size, their weight will be significantly higher than that of ordinary structural materials such as steel and aluminum.

(1) The Most Basic Weight Calculation Formula

The mass formula for a tungsten alloy counterweight is: $m = \rho V$. If the gravity corresponding to the weight needs to be calculated, then the following must be further used: $G = mg$, where G is gravity, m is mass, and g is the local gravitational acceleration, usually taken as about 9.81 m/s² on the Earth's surface. In engineering counterweight design, what users call weight usually actually refers to mass, such as 100 g, 500 g, or 1 kg. Therefore, most tungsten alloy counterweight calculations directly use: $m = \rho V$. For example, if a certain tungsten alloy has a density of 18.0 g/cm³ and the counterweight volume is 20 cm³, then: $m = 18.0 \times 20 = 360$ g.



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Therefore, the theoretical mass of this counterweight is 360 g.

(2) How to Calculate the Weight of a Tungsten Alloy Counterweight After Knowing the Volume

This is the most common calculation situation. Suppose the dimensions of a tungsten alloy counterweight are 30 mm × 20 mm × 10 mm, and the material density is 18.0 g/cm³. First convert the dimensions into centimeters: 3 cm, 2 cm, 1 cm. Volume: $V = 3.0 \times 2.0 \times 1.0 = 6.0$ [cm³].

Weight: $m = 18.0 \times 6.0 = 108$ g. Therefore, the theoretical mass of this counterweight is about 108 g.

(3) How to Calculate the Weight of a Cylindrical Tungsten Alloy Counterweight

If the counterweight is a solid cylinder, the cylinder volume can first be calculated: $V = (\pi d^2 h) / 4$, and then directly substituted: $m = \rho (\pi d^2 h) / 4$, where d is the diameter and h is the height. For example, a tungsten alloy cylindrical counterweight has a diameter of 20 mm, a height of 30 mm, and a material density of 18.0 g/cm³. Converted: $d = 2.0$ cm, $h = 3.0$ cm, so:

$V = (\pi \times [2.0]^2 \times 3.0) / 4 \approx 9.425$ [cm³].

Weight: $m = 18.0 \times 9.425 \approx 169.65$ g. Therefore, the theoretical mass of this cylindrical tungsten alloy counterweight is about 169.7 g.

(4) How to Calculate the Weight of a Ring-Shaped Counterweight

If the counterweight is a ring, the volume of the central hole must first be deducted. The volume of the ring is: $V = \pi h / 4 (D^2 - d^2)$.

Therefore, the mass is: $m = \rho \pi h / 4 (D^2 - d^2)$,

where D is the outer diameter, d is the inner diameter, and h is the height. For example: outer diameter 30 mm, inner diameter 20 mm, height 10 mm, density 18.0 g/cm³. Converted: $D = 3.0$ cm, $d = 2.0$ cm, $h = 1.0$ cm. Volume: $V = (\pi \times 1.0) / 4 ([3.0]^2 - [2.0]^2) \approx 3.927$ [cm³]. Mass: $m = 18.0 \times 3.927 \approx 70.69$ g.

Therefore, the theoretical mass of this ring-shaped counterweight is about 70.7 g.

(5) How to Calculate a Tungsten Alloy Counterweight with Holes

If the counterweight has structures such as mounting holes, threaded holes, or countersunk holes, the weight cannot be calculated directly according to the external envelope dimensions.

The basic calculation method is: $V_{\text{actual}} = V_{\text{main body}} - V_{\text{holes}}$.

Then: $m = \rho V_{\text{actual}}$. If there are multiple holes, grooves, and steps, it can be expanded to: $V_{\text{actual}} = V_{\text{main body}} - \sum V_{\text{holes}} - \sum V_{\text{grooves}} - \sum V_{\text{removed parts}}$.

For example, for an external solid structure of 100 cm³, if holes and grooves of 5 cm³ are machined internally, the actual material volume is 95 cm³. If a tungsten alloy with a density of 18.0 g/cm³ is used: $m = 18.0 \times 95 = 1710$ g, that is, about 1.71 kg.



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(6) How to Calculate the Weight of Special-Shaped Counterweights

Modern tungsten alloy counterweights often use complex structures such as eccentric blocks, curved blocks, balance rings, grooved blocks, and embedded counterweights. Such products are not suitable for simple estimation using length $\times$ width $\times$ height, because the external envelope volume will be significantly larger than the actual material volume. If a CAD (Computer-Aided Design) three-dimensional model is already available, the theoretical volume in the model can be read directly: $m_{\text{theoretical}} = \rho V_{\text{CAD}}$. For example, if the CAD model shows an actual material volume of 32.5 cm^3 and the design material density is 18.0 g/cm^3 : $m = 32.5 \times 18.0 = 585 \text{ g}$. Therefore, the theoretical mass is about 585 g. For complex parts, the final actual weight should also be confirmed by precision weighing, because the actual sintering density, dimensional deviations, and subsequent processing will all affect the final mass.

(7) Tungsten Alloys of Different Densities Have Different Weights at the Same Volume

This is a very important point when selecting materials. Suppose the counterweight volume is all 10 cm^3 :

Material Density Theoretical Mass

16.0 g/cm^3 160 g

17.0 g/cm^3 170 g

17.5 g/cm^3 175 g

18.0 g/cm^3 180 g

18.5 g/cm^3 185 g

19.0 g/cm^3 190 g

Therefore, the weight of a counterweight cannot be judged only by its dimensions; the actual density of the material must also be known. For example, for two counterweights with exactly the same dimensions, one using a 17.5 g/cm^3 material and the other using an 18.5 g/cm^3 material, their masses will differ by about 5.7%.

(8) Conversely, Calculate How Large a Counterweight Is Needed According to the Target Weight

In actual product design, this calculation is often more common than directly calculating weight. The formula can be transformed into: $V = m/\rho$. For example, if the design requires a tungsten alloy counterweight with a mass of 500 g and the material density is 18.0 g/cm^3 : $V = 500/18.0 \approx 27.78 \text{ cm}^3$. Therefore, the designer needs to provide an actual material volume of about 27.78 cm^3 . If the target mass is 1 kg: $V = 1000/18.0 \approx 55.56 \text{ cm}^3$. This is also the basic reason why tungsten alloy can achieve small-volume counterweights.

(9) Why May There Be a Difference Between Theoretical Weight and Actual Weighed Weight?

The theoretical calculation gives the design mass, while the actual product weighing gives the actual mass after manufacturing. The two are not necessarily completely consistent.



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The main factors causing the difference include actual material density deviation, sintering shrinkage, porosity, dimensional machining errors, hole position dimensional errors, surface treatment, and material batch differences. For example, if the design uses 18.0 g/cm^3 as the calculation density, but the actual material test result is 17.95 g/cm^3 , then at the same volume, the actual mass will be slightly lower than the theoretical value. Therefore, in mass production, it is usually necessary to simultaneously control material density, dimensional tolerances, and individual piece weight tolerances.

(10) Sintered Tungsten Alloy Counterweights Especially Need to Consider Actual Density

Tungsten alloys are usually produced by the powder metallurgy (Powder Metallurgy) route. After sintering, the pressed and formed blank undergoes dimensional changes and forms the final multi-phase dense structure. Therefore, the theoretical volume on the drawing, the sintered blank volume, and the volume after final mechanical machining may not be exactly the same. For precision counterweights, a relatively reasonable calculation process is:

design volume $\rightarrow$ material theoretical density $\rightarrow$ calculate theoretical mass $\rightarrow$ determine sintering shrinkage $\rightarrow$ mechanical machining $\rightarrow$ actual weighing $\rightarrow$ adjust dimensions or group matching. Only in this way can the final product meet the specified weight tolerance.

(11) High-Precision Counterweights Also Need to Consider Weight Tolerance

For example, the drawing requires: $m=100.00\pm0.05 \text{ g}$, which means that the actual mass of each product needs to be controlled within: $99.95 \text{ g} \leq m \leq 100.05 \text{ g}$. If the material density is 18.0 g/cm^3 , then the corresponding theoretical volume is about: $V=100/18.0=5.556 \text{ cm}^3$,

and the volume change corresponding to the allowable mass range of $\pm 0.05 \text{ g}$ is about: $\Delta V=0.05/18.0 \approx 0.00278 \text{ cm}^3$. This shows that high-precision weight tolerances actually translate into very strict dimensional control requirements. For high-speed rotors, precision instruments, and inertial systems, it is not enough to control only the weight of individual pieces; the center-of-gravity position and dynamic balance also need to be controlled.

(12) Static Weight and Dynamic Counterweight Cannot Be Confused

The same weight of tungsten alloy counterweights does not mean that they produce exactly the same effect on a rotating system. The centrifugal force in a rotating system is approximately: $F=m\omega^2 r$, where m is the counterweight mass, ω is the angular velocity, and r is the distance from the counterweight center of mass to the rotating shaft. Therefore, a 100 g counterweight installed at a distance of 100 mm from the rotating shaft and another 100 g counterweight installed at a distance of 50 mm from the rotating shaft have different effects on the rotating system. Similarly, the moment of inertia: $I=\sum m_i r_i^2$, is also affected by the position of mass distribution. Therefore, for dynamic balancing counterweights, weight calculation is only the first step, and parameters such as



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installation position, eccentricity, angle, coaxiality, and circular runout also need to be further controlled.

(13) What Method Should Be Used for Actual Weighing?

Ordinary tungsten alloy counterweights can be tested for mass using a calibrated electronic balance; high-precision counterweights should use a precision balance of an appropriate grade according to the target mass tolerance. For example, if the product requires $1 \text{ kg} \pm 0.1 \text{ g}$, it is necessary to ensure that the resolution and measurement uncertainty of the weighing equipment itself can meet the requirements. In mass production, individual pieces can also be weighed one by one and grouped and matched according to mass intervals. For example, products can be divided into intervals such as: 999.90–999.95 g, 999.95–1000.00 g, 1000.00–1000.05 g, etc. For products requiring dynamic balancing, precision weighing can be combined with dynamic balancing testing.

(14) Common Quick Weight Calculation Table

If a tungsten alloy with a density of 18.0 g/cm^3 is used, the following can be quickly obtained:

Counterweight Volume 1 cm^3 5 cm^3 20 cm^3 50 cm^3 55.56 cm^3 100 cm^3

Theoretical Mass 18 g 90 g 360 g 900 g 1000 g 1800 g

Therefore, for the common 18.0 g/cm^3 tungsten alloy, a very practical relationship can be directly remembered: the theoretical mass per 1 cm^3 of material is about 18 g.

(15) Recommended Calculation Process When Designing Tungsten Alloy Counterweights

If the counterweight drawing dimensions are already known, the actual material volume can first be calculated, and then the theoretical mass can be calculated according to the selected material density: $V \rightarrow \rho \rightarrow m$. If the target weight has already been determined, then calculate the required material volume in reverse: $m \rightarrow \rho \rightarrow V$.

After that, design the external shape, hole positions, fixing structure, and machining allowance according to the installation space. For complex precision counterweights, CAD volume, actual material density, sintering shrinkage rate, mechanical machining allowance, and final weight tolerance should also be combined, and calculation cannot be carried out using only a nominal density.

(16) A Complete Calculation Example

Suppose a tungsten alloy cylindrical counterweight with a mass of about 1 kg needs to be designed, using a W-Ni-Fe (Tungsten-Nickel-Iron) material with a density of 18.0 g/cm^3 . First calculate the required material volume: $V = 1000 / 18.0 = 55.56 \text{ [" cm"] }^3$.

If the cylinder diameter is determined to be 40 mm, that is, 4.0 cm, then: $V = (\pi d^2 h) / 4$. Substituting: $55.56 = (\pi \times [4.0]^2 \times h) / 4$.

Therefore: $h \approx 4.42 \text{ " cm"}$.

That is, in theory, it can be designed as a solid cylinder with a diameter of about 40 mm and



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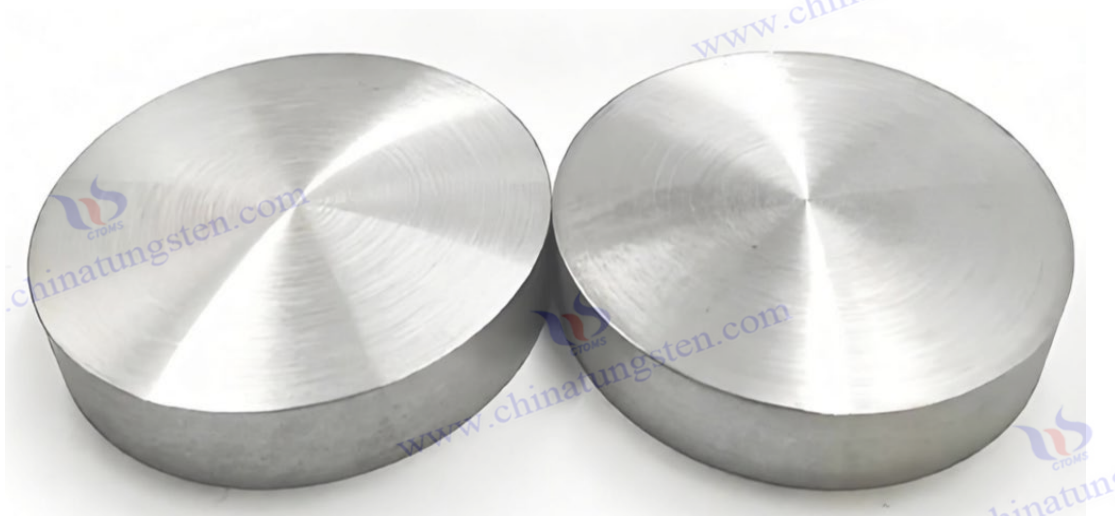
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a height of about 44.2 mm, and then adjusted in combination with actual machining tolerances, actual material density, and final weighing results. This example reflects the basic relationship in tungsten alloy counterweight design: first determine the target mass, then obtain the required volume according to density, and finally distribute the volume into the specific structure through geometric dimensions.

In general, the weight calculation of a tungsten alloy counterweight is very clear: mass equals density multiplied by actual material volume, that is, $m = \rho V$. Regular cylinders, rings, rectangular prisms, etc. can be directly calculated by geometric formulas; structures with holes, grooves, and special shapes should first deduct the non-material volume or directly read the actual material volume from the three-dimensional model. For final products, the theoretical weight also needs to be verified by actual weighing. In particular, for W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) counterweights manufactured by powder metallurgy, the actual material density, sintering shrinkage, machining tolerances, and weight tolerances should be included in the calculation together.



Q11 Given Density and Volume, How Is the Weight of a Tungsten Alloy Counterweight Calculated?

Once the density and volume of a tungsten alloy counterweight are known, calculating the weight is very straightforward. The core relationship is that mass equals density multiplied by volume: $m = \rho V$, where m is the mass of the tungsten alloy counterweight, ρ is the material density, and V is the actual material volume of the counterweight. In engineering calculations, g is usually used as the unit of mass, g/cm^3 as the unit of density, and cm^3 as the unit of volume, so that the calculated m is directly in grams (g). If it needs to be expressed in kilograms (kg), simply divide by 1000.



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(1) The Most Basic Calculation Method

For example, if a tungsten alloy counterweight has a density of 18.0 g/cm^3 and a volume of 10 cm^3 , then: $m=18.0 \times 10=180 \text{ g}$.

Converted into kilograms: $180 \div 1000=0.18 \text{ kg}$. Therefore, the theoretical mass of this tungsten alloy counterweight is 180 g , that is, 0.18 kg . If the weight mentioned here refers strictly in the physical sense to gravity, then the following must also be used: $G=mg$, where G is gravity, m is mass, and g is gravitational acceleration, usually taken as about 9.81 m/s^2 on the Earth's surface. However, in counterweight manufacturing, procurement, and drawing annotation, the so-called weight usually actually refers to mass, such as 500 g or 1 kg , so generally $m=\rho V$ can be used directly for calculation.

(2) Units Must Remain Consistent

The most common problem in calculation is not the formula, but that the units of density, dimensions, and volume are not unified. If density is in g/cm^3 , then volume should be in cm^3 ; if density is in kg/m^3 , then volume must be in m^3 . The relationship between the two commonly used unit systems is: $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$.

For example, 18.0 g/cm^3 is equal to: $18.0 \times 1000=18000 \text{ kg/m}^3$.

Therefore: $18.0 \text{ g/cm}^3 = 18000 \text{ kg/m}^3$.

If a counterweight has a volume of 50 cm^3 , using the first set of units: $m=18.0 \times 50=900 \text{ g}=0.9 \text{ kg}$.

(3) At Different Densities, Counterweights of the Same Volume Have Different Weights

Suppose the volume of a tungsten alloy counterweight is fixed at 10 cm^3 . Then, when the volume is the same, for every increase of 1 g/cm^3 in density, the mass of every 10 cm^3 of material increases by 10 g . In actual products, it cannot simply be assumed that all tungsten alloys are 18.0 g/cm^3 . Different W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) grades, tungsten contents, binder phases, and manufacturing processes have different actual densities. Common high-density counterweight materials can fall within the range of about $17\text{--}18.5 \text{ g/cm}^3$, while the broader tungsten heavy alloy range may reach about $16.5\text{--}19.0 \text{ g/cm}^3$.

(4) What If the Volume Unit Is mm^3 ?

Tungsten alloy counterweight drawings usually use mm as the dimension unit, so mm^3 is often encountered. The conversion relationship is: $1 \text{ cm}^3 = 1000 \text{ mm}^3$. Therefore: $V(\text{cm}^3) = V(\text{mm}^3) / 1000$.

For example, if the volume calculated by a CAD (Computer-Aided Design) model of a certain counterweight is $25,000 \text{ mm}^3$: $V=25000/1000=25 \text{ cm}^3$.

If the material density is 18.0 g/cm^3 : $m=18.0 \times 25=450 \text{ g}$.

Therefore, the theoretical mass is 450 g . It is also possible to directly use unified units such as kg/mm^3 for calculation, but in actual engineering communication, it is usually more intuitive to first convert the volume to cm^3 and then use g/cm^3 for calculation.



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(5) If the Volume Is Calculated from Dimensions

If the length, width, and height of the counterweight are already known, first calculate the volume, and then calculate the mass. For example, a rectangular tungsten alloy counterweight has dimensions of 40 mm × 25 mm × 10 mm: $V = 40 \times 25 \times 10 = 10000$ ["mm"]³.

Converted to: $V = 10$ ["cm"]³.

If the material density is 18.0 g/cm³: $m = 18.0 \times 10 = 180$ "g".

Therefore, the theoretical mass of this counterweight is 180 g. For a cylindrical counterweight, first calculate: $V = (\pi d^2 h) / 4$, and then use: $m = \rho V$.

In other words, the complete calculation chain is actually: "dimensions" → "volume" → "mass".

(6) Counterweights with Holes Cannot Directly Use the External Volume

If a tungsten alloy counterweight has a central hole, mounting holes, threaded holes, weight-reduction grooves, or countersunk holes, the actual remaining material volume should be calculated. The basic relationship is: $V_{\text{"actual"}} = V_{\text{"external shape"}} - V_{\text{"holes"}} - V_{\text{"grooves"}}$.

Then: $m = \rho V_{\text{"actual"}}$.

For example, if the external volume of a counterweight is 30 cm³ and a total of 2 cm³ of material is removed by machining holes and grooves, then: $V_{\text{"actual"}} = 30 - 2 = 28$ ["cm"]³. If the material density is 18.0 g/cm³: $m = 18.0 \times 28 = 504$ "g".

Therefore, the actual theoretical mass is 504 g, not 540 g.

(7) Special-Shaped Tungsten Alloy Counterweights Can Directly Use CAD Volume for Calculation

For eccentric counterweights, balance rings, curved counterweights, stepped structures, and complex embedded counterweights, manual volume calculation is often cumbersome. If a three-dimensional CAD model has already been established, the actual material volume can be read directly. For example: $V_{\text{"CAD"}} = 42.8$ ["cm"]³.

Material density: $\rho = 18.2$ ["g/cm"]³.

Then: $m = 18.2 \times 42.8 = 778.96$ "g". The theoretical mass is about 779.0 g. This method is particularly suitable for customized tungsten alloy counterweights, because holes, grooves, chamfers, steps, and complex curved surfaces can all be directly included in the volume calculation.

(8) When the Target Weight Is Known, the Volume Can Also Be Calculated in Reverse

If the volume is not known, but the target mass has already been determined, the formula can be transformed: $V = m / \rho$.

For example, if a 1 kg tungsten alloy counterweight is required and the material density is 18.0 g/cm³: $V = 1000 / 18.0 \approx 55.56$ ["cm"]³.



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In other words, an actual material volume of about 55.56 cm^3 is needed. If the target weight is 500 g: $V=500/18.0 \approx 27.78 \text{ cm}^3$.

This is very practical in counterweight structure design. The target mass can first be determined, then the required material volume can be determined according to the material density, and finally the volume can be distributed among structural dimensions such as length, width, height, diameter, and thickness.

(9) Why May the Theoretically Calculated Weight Differ from the Actual Weighed Weight?

The formula $m=\rho V$ gives the theoretical mass based on a given density and geometric volume. The weighed mass of an actually produced tungsten alloy counterweight may differ to some extent from the theoretical value. The main reasons include deviation between the actual material density and the nominal density, trace porosity after powder metallurgy sintering, dimensional changes caused by sintering shrinkage, mechanical machining dimensional tolerances, hole diameter and groove dimension errors, and surface treatment layers. For example, if the design is calculated according to 18.0 g/cm^3 , but the actual measured material density is 17.95 g/cm^3 , and the volume remains 10 cm^3 , then the actual mass is: $m=17.95 \times 10 = 179.5 \text{ g}$.

Compared with the 180 g calculated according to 18.0 g/cm^3 , the difference is 0.5 g. For ordinary counterweights, this difference may not be important; for high-precision counterweights, it must be included in the mass tolerance design.

(10) High-Precision Counterweights Also Need to Control Weight Tolerance

Suppose the drawing requires the counterweight mass: $m=500.00 \pm 0.10 \text{ g}$.

Then the actual mass must be within: $499.90 \text{ g} \leq m \leq 500.10 \text{ g}$.

If the material density is 18.0 g/cm^3 , the corresponding theoretical volume is: $V=500/18.0 \approx 27.78 \text{ cm}^3$. The volume corresponding to a mass change of 0.10 g is about: $\Delta V=0.10/18.0 \approx 0.00556 \text{ cm}^3$. Therefore, the stricter the weight tolerance, the higher the requirements for material density consistency and final dimensional accuracy. For high-speed rotating parts, mass alone cannot be checked. The counterweight installation position, eccentricity, angular position, coaxiality, circular runout, etc. will all affect dynamic balance.

(11) A Complete Engineering Calculation Example

Suppose a tungsten alloy cylindrical counterweight has a diameter of 30 mm, a height of 40 mm, and a material density of 18.0 g/cm^3 . First convert the dimensions: $d=3.0 \text{ cm}$, $h=4.0 \text{ cm}$.

Calculate the volume: $V=(\pi \times [3.0]^2 \times 4.0)/4 \approx 28.27 \text{ cm}^3$.

Calculate the mass: $m=18.0 \times 28.27 \approx 508.9 \text{ g}$. Therefore, the theoretical mass of this cylindrical tungsten alloy counterweight is about 509 g.

If the part also has a central hole, then the central hole volume should first be subtracted from 28.27 cm^3 , and then the mass should be recalculated.



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(12) How Should the Calculation Results Be Used in Actual Counterweight Design?

For tungsten alloy counterweights, calculating the weight after knowing the density and volume is only the first step. Actual design usually works backward from the target mass to the material volume, then determines the structural dimensions according to the installation space, then checks the actual volume according to the CAD model, and finally calculates the theoretical mass in combination with the actual material density and verifies it through finished product weighing. For ordinary counterweights, the main focus can be on mass and dimensions; for dynamic counterweights such as automobile crankshafts, industrial rotors, aviation control surfaces, and inertial systems, mass distribution and rotation radius also need to be further considered, because the centrifugal force of a rotating system satisfies $F = m\omega^2 r$. If the mass is the same but the installation radius is different, its dynamic effect will also change significantly. In short, when density and volume are known, the core calculation of the weight of a tungsten alloy counterweight is: $(m = \rho V)$

For example, if the density is 18.0 g/cm^3 and the volume is 20 cm^3 , then the mass is 360 g; if the volume unit is mm^3 , first divide by 1000 to convert it to cm^3 . For actual customized parts, the final actual material density and actual material volume should also be used for verification, and precision weighing should be used to confirm whether the final product meets the specified weight tolerance.





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Q12 What Volume Is Needed for a 10-Gram Tungsten Alloy Counterweight?

The volume needed for a 10-gram tungsten alloy counterweight depends on the actual density of the tungsten alloy used. The basic calculation formula is: $V=m/\rho$, where V is the counterweight volume, m is the counterweight mass, and ρ is the tungsten alloy density. For common high-density tungsten alloy counterweights, it can be estimated at 17–18.5 g/cm³, so the volume required for 10 g of tungsten alloy is only about 0.54–0.59 cm³.

(1) Calculation Based on 18.0 g/cm³

If a tungsten alloy with a density of 18.0 g/cm³ is used: $V=10/18.0=0.5556$ [" cm"] ^3. Therefore, a 10-gram tungsten alloy counterweight requires about: $\square(0.556$ [" cm"] ^3), which converted into mm³ is: $0.5556 \times 1000 = 555.6$ [" mm"] ^3. In other words, the actual material volume of 10 g of 18.0 g/cm³ tungsten alloy is about 556 mm³.

(2) Volume of 10 Grams of Tungsten Alloy at Different Densities

Tungsten Alloy Density Volume Required for 10 g Approximate Volume

16.5 g/cm³ 0.606 cm³ 606 mm³

17.0 g/cm³ 0.588 cm³ 588 mm³

17.5 g/cm³ 0.571 cm³ 571 mm³

18.0 g/cm³ 0.556 cm³ 556 mm³

18.5 g/cm³ 0.541 cm³ 541 mm³

19.0 g/cm³ 0.526 cm³ 526 mm³

It can be seen that the higher the density, the smaller the volume occupied by the same 10-gram mass. If common high-density tungsten alloy counterweights use materials of 17–18.5 g/cm³, the volume required for a 10-gram counterweight is about 541–588 mm³.

(3) Approximately How Big Is 10 Grams of Tungsten Alloy?

Taking 18.0 g/cm³ as an example, the volume of 10 grams of tungsten alloy is about 0.556 cm³. If designed as a solid cube, its side length satisfies: $a=\sqrt[3]{V}$, so: $a=\sqrt[3]{0.556} \approx 0.822$ " cm, " that is, about: $\square(8.2 \times 8.2 \times 8.2$ " mm"). Therefore, if a 10-gram, 18.0 g/cm³ tungsten alloy counterweight is designed as a solid cube, its dimensions are only about 8.2 mm square. This also reflects the high-density advantage of tungsten alloy counterweights: although the mass is only 10 grams, the required mass can be achieved in a very small space.

(4) What If It Is Designed as a Cylinder?

Assume that an 18.0 g/cm³ tungsten alloy is still used, the target mass is 10 g, and the cylinder diameter is designed as 10 mm, that is, 1 cm.

The required volume is: $V=0.5556$ [" cm"] ^3. The cylinder volume formula is: $V=(\pi d^2 h)/4$, so: $h=4V/(\pi d^2)$.

Substituting: $h=(4 \times 0.5556)/(\pi \times 1^2) \approx 0.707$ " cm", that is: $\square(h \approx 7.1$ " mm").

Therefore, an 18.0 g/cm³ tungsten alloy cylinder with a diameter of 10 mm and a height of



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about 7.1 mm has a theoretical mass of about 10 grams.

If the diameter is reduced to 8 mm, then while maintaining the same 10-gram mass, the height needs to be increased accordingly.

(5) How Big Is the Difference Compared with Steel and Lead?

To intuitively see the difference, assume that three materials all need to be made into 10-gram counterweights. The density of steel is about 7.85 g/cm³: $V_{\text{steel}} = 10/7.85 \approx 1.274$ ["cm"]³. The density of lead (Pb, Lead) is about 11.34 g/cm³: $V_{\text{lead}} = 10/11.34 \approx 0.882$ ["cm"]³. For 18.0 g/cm³ tungsten alloy: $V_{\text{tungsten alloy}} = 10/18.0 \approx 0.556$ ["cm"]³. Therefore, for the same 10 grams: Material Typical Density Volume Required for 10 g

Steel 7.85 g/cm³ 1.274 cm³

Lead 11.34 g/cm³ 0.882 cm³

Tungsten alloy 18.0 g/cm³ 0.556 cm³. The volume of 18.0 g/cm³ tungsten alloy is about 43.6% of that of a steel counterweight of the same mass, a reduction of about 56.4% compared with steel; relative to a lead counterweight, its volume is about 63.0%, a reduction of about 37.0%.

(6) Actual Products Cannot Be Calculated Only by Nominal Density

The above results are theoretical volumes. For example, if the drawing requires 10.00 g and the nominal density of the material grade is 18.0 g/cm³, the theoretical material volume can be obtained as about 0.5556 cm³. In actual production, factors such as the actual material density, porosity after sintering, dimensional tolerances, machining allowance, and surface treatment also need to be considered. For W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) counterweights manufactured by powder metallurgy (Powder Metallurgy), the final calculation should be based on the actual material density and actual dimensions of the finished product, and the final mass should be confirmed by precision weighing. If the 10-gram counterweight also requires mounting holes, threads, grooves, or chamfers, then what is calculated during design is the net material volume, not the external envelope volume of the product.

(7) How Should Dimensions Be Determined When Designing a 10-Gram Precision Counterweight?

A relatively reasonable design process is to first determine the target mass of 10 g, then determine the material grade and actual density, then obtain the required net material volume through $V=m/\rho$, and finally select a cylindrical, disc-shaped, ring-shaped, block-shaped, or special-shaped structure according to the installation space. For example, if an 18.0 g/cm³ material is used: $10 \text{ g} \rightarrow 0.556$ ["cm"]³ $\rightarrow 556$ ["mm"]³. That is, no matter what shape it is subsequently designed into, as long as the final actual material volume is close to 556 mm³, the theoretical mass will be close to 10 grams. For precision dynamic counterweights, the center-of-gravity position, eccentricity, installation angle, coaxiality, and circular runout also need to be further controlled. This is because in a



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rotating system, mass itself cannot completely determine the counterweight effect; the position of mass distribution is equally important. In summary, there is no single fixed volume for a 10-gram tungsten alloy counterweight. If common 17–18.5 g/cm³ high-density tungsten alloy is used, the required volume is about 0.541–0.588 cm³; if calculated at 18.0 g/cm³, it is about 0.556 cm³, that is, about 556 mm³. For actual customized products, the actual density of the specific material grade should be used as the final calculation basis.



Q13 What Volume Is Needed for a 100-Gram Tungsten Alloy Counterweight?

The volume needed for a 100-gram tungsten alloy counterweight depends on the actual density of the material. The basic calculation formula is: $V = m / \rho$. Here, V is the counterweight volume, m is the mass, and ρ is the tungsten alloy density. For common high-density tungsten alloy counterweights, if calculated at 17–18.5 g/cm³, the material volume required for 100 grams of tungsten alloy is about 5.41–5.88 cm³.

(1) Calculation Based on 18.0 g/cm³

If a tungsten alloy with a density of 18.0 g/cm³ is used: $V = 100 / 18.0 = 5.556$ cm³. Therefore: $V \approx 5.56$ cm³, which converted into mm³ is: $5.556 \times 1000 = 5556$ mm³. In other words, the actual material volume of a 100-gram, 18.0 g/cm³ tungsten alloy counterweight is about 5556 mm³.



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(2) Volume of 100 Grams of Tungsten Alloy at Different Densities

Tungsten Alloy Density Volume Required for 100 g Approximate Volume

16.5 g/cm³ 6.061 cm³ 6061 mm³

17.0 g/cm³ 5.882 cm³ 5882 mm³

17.5 g/cm³ 5.714 cm³ 5714 mm³

18.0 g/cm³ 5.556 cm³ 5556 mm³

18.5 g/cm³ 5.405 cm³ 5405 mm³

19.0 g/cm³ 5.263 cm³ 5263 mm³

Therefore, if common 17–18.5 g/cm³ high-density tungsten alloy is used, the volume required for a 100-gram counterweight is about 5.41–5.88 cm³. If 18.0 g/cm³ is used as the design density, preliminary structural design can be carried out directly at about 5.56 cm³.

(3) Approximately How Big Is 100 Grams of Tungsten Alloy?

Taking 18.0 g/cm³ as an example, the volume of 100 grams of tungsten alloy is 5.556 cm³. If designed as a solid cube, its side length is: $a = \sqrt[3]{5.556} \approx 1.771$ cm, that is, about 17.7 × 17.7 × 17.7 mm. Therefore, a 100-gram, 18.0 g/cm³ tungsten alloy solid cube has theoretical dimensions of about 17.7 mm square.

(4) If Designed as a Cylinder

Assume that a 100-gram counterweight uses 18.0 g/cm³ tungsten alloy and is designed as a solid cylinder with a diameter of 20 mm. It is known that $V = 5.556$ cm³, and the cylinder volume formula is $V = \pi d^2 h / 4$, where $d = 2.0$ cm. Therefore, $h = 4V / (\pi d^2)$. Substituting: $h = 4 \times 5.556 / (\pi \times 2.0^2) \approx 1.768$ cm, that is, $d = 20$ mm, $h \approx 17.7$ mm. The theoretical mass of this cylinder is about 100 grams.

(5) How Large Is the Volume Difference Compared with Steel and Lead?

When making 100-gram counterweights in the same way, an intuitive comparison can be made. The typical density of steel is about 7.85 g/cm³: $V_{\text{steel}} = 100 / 7.85 \approx 12.74$ cm³. The density of lead (Pb, Lead) is about 11.34 g/cm³: $V_{\text{lead}} = 100 / 11.34 \approx 8.82$ cm³. For 18.0 g/cm³ tungsten alloy: $V_{\text{tungsten alloy}} = 100 / 18.0 \approx 5.56$ cm³.

Material Typical Density Volume Required for 100 g

Steel 7.85 g/cm³ 12.74 cm³

Lead 11.34 g/cm³ 8.82 cm³

Tungsten alloy 18.0 g/cm³ 5.56 cm³

Therefore, at the same 100-gram mass, the volume of 18.0 g/cm³ tungsten alloy is about 43.6% of that of steel, equivalent to a reduction of about 56.4% in volume; relative to lead, the volume is reduced by about 37.0%. This is also an important reason why tungsten alloy is used for miniaturized counterweights, precision balancing parts, and space-constrained structures.



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(6) If the Counterweight Has Holes, 5.56 cm³ Is Not the External Dimension Volume

5.56 cm³ refers to the net volume of actual tungsten alloy material, not the external envelope volume of the product. For example, if a 100-gram counterweight uses 18.0 g/cm³ material, it needs: $V_{\text{material}} = 5.556 \text{ cm}^3$. If mounting holes, threaded holes, grooves, or other material-removal structures are designed into the product, then the external geometric volume of the product must be greater than 5.556 cm³, because part of the space does not contain tungsten alloy material. The actual design can be expressed as: $V_{\text{material}} = V_{\text{outer shape}} - V_{\text{holes}} - V_{\text{grooves}} - V_{\text{other removed material}}$. In the end, as long as the actual net material volume meets about 5.556 cm³, the theoretical mass will be close to 100 grams.

(7) Why May It Not Be Exactly 100 Grams During Actual Manufacturing?

The above calculation belongs to theoretical mass. When actual tungsten alloy counterweights are manufactured by powder metallurgy (Powder Metallurgy), the actual material density, sintering shrinkage, residual porosity, and mechanical machining dimensions will all affect the final mass. For example, if the design is calculated at 18.0 g/cm³, but the actual density of a certain batch of material is 17.95 g/cm³, then the actual mass of 5.556 cm³ of material is: $m = 17.95 \times 5.556 \approx 99.72 \text{ g}$, a difference of about 0.28 grams from the theoretical value of 100 grams. For ordinary counterweights, this difference can be controlled through final weighing and dimensional correction; if it is a high-precision counterweight, the material density range and weight tolerance should be clearly specified at the design stage.

(8) How Are the Final Dimensions of a 100-Gram Precision Tungsten Alloy Counterweight Determined?

If 100.00 g is required, rather than approximately 100 g, it is recommended to carry out reverse design according to the density of the actual material grade. First determine the target mass of 100 g, then calculate the net material volume: $V = 100 / \rho$. For example, if the actual design density is 18.0 g/cm³: $V = 100 / 18.0 = 5.556 \text{ cm}^3$. Then determine the specific structure according to the installation space; it can be designed as a cylinder, disc, ring, rectangular block, eccentric block, or special-shaped structure. After completing CAD (Computer-Aided Design) modeling, read the actual material volume and calculate the theoretical mass, and finally verify it by precision weighing. In actual tungsten alloy counterweight projects, CTIA GROUP can serve as a professional designer and manufacturer of tungsten alloy counterweights, carrying out material selection, structural design, manufacturing processing, and quality control according to target weight, installation space, structural dimensions, and precision requirements. If used in a high-speed rotating system, the counterweight's center-of-gravity position, eccentricity, installation angle, coaxiality, and circular runout also need to be considered at the same time. A 100-gram counterweight placed at different rotating radii has different dynamic effects on the system.



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(9) Quick Conversion

For a tungsten alloy with a density of 18.0 g/cm^3 , a very convenient conversion relationship can be used directly: $1 \text{ cm}^3 \approx 18 \text{ g}$. Therefore: $100 \text{ g} \approx 5.56 \text{ cm}^3$, $200 \text{ g} \approx 11.11 \text{ cm}^3$, $500 \text{ g} \approx 27.78 \text{ cm}^3$, $1000 \text{ g} \approx 55.56 \text{ cm}^3$. Therefore, a 100-gram tungsten alloy counterweight can be simply understood as: when using 18.0 g/cm^3 material, about 5.56 cm^3 of actual material volume is required.

In summary, there is no fixed volume for a 100-gram tungsten alloy counterweight that is independent of the material. Calculated according to common $17\text{--}18.5 \text{ g/cm}^3$ high-density tungsten alloy, its net material volume is about $5.41\text{--}5.88 \text{ cm}^3$; if 18.0 g/cm^3 tungsten alloy is used, it is about 5.56 cm^3 , that is, 5556 mm^3 . For actual customization, the actual density and final weight tolerance of the specific W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) grade should be used as the basis for dimensional design.



Q14 What Volume Is Required for a 1 kg (1 Kilogram) Tungsten Alloy Counterweight?

The volume required for a 1 kg (1 kilogram) tungsten alloy counterweight mainly depends on the actual density of the tungsten alloy. The calculation formula is $V = m / \rho$, where V is volume, m is mass, and ρ is density. For common high-density tungsten alloy counterweights, if the density is in the range of $17\text{--}18.5 \text{ g/cm}^3$, the volume required for 1 kilogram of tungsten alloy is about $54.05\text{--}58.82 \text{ cm}^3$; if calculated at 18.0 g/cm^3 , the volume is about 55.56 cm^3 , that is, about $55,556 \text{ mm}^3$.



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(1) Calculated at 18.0 g/cm³, What Volume Is 1 Kilogram of Tungsten Alloy?

If a tungsten alloy with a density of 18.0 g/cm³ is used, 1 kilogram = 1000 g, so $V = 1000 / 18.0 = 55.56 \text{ cm}^3$. Converted into cubic millimeters, $55.56 \times 1000 = 55,560 \text{ mm}^3$. Therefore, for a 1 kg tungsten alloy counterweight with a density of 18.0 g/cm³, the material volume is about 55.56 cm³, that is, about 55,560 mm³. This is also a commonly used estimated value in engineering design. For example, if a 1 kg tungsten alloy counterweight can be allowed by the structural design to occupy about 56 cm³ of material space, preliminary dimensional planning can be carried out according to the 18.0 g/cm³ grade.

(2) For Tungsten Alloys of Different Densities, What Volume Is Required for 1 Kilogram?

The density of tungsten alloy is not a fixed value. Different tungsten contents, binder phase compositions, sintering processes, and specific grades will produce differences. Calculated according to different densities, the results are as follows:

Tungsten Alloy Density Volume Required for 1 Kilogram

16.5 g/cm³ 60.61 cm³

17.0 g/cm³ 58.82 cm³

17.5 g/cm³ 57.14 cm³

18.0 g/cm³ 55.56 cm³

18.5 g/cm³ 54.05 cm³

19.0 g/cm³ 52.63 cm³

From the common range of 17–18.5 g/cm³, the volume of a 1 kg tungsten alloy counterweight is about 54.05–58.82 cm³. The higher the density, the smaller the material volume required under the same mass.

(3) About How Large Is 1 Kilogram of 18.0 g/cm³ Tungsten Alloy?

If the 55.56 cm³ of material is simplified into a cube, its side length is about $\sqrt[3]{55.56} \approx 3.81 \text{ cm}$, that is, about 38.1 mm. Therefore, in theory, a solid cube of about 38.1 mm × 38.1 mm × 38.1 mm can be used to contain 1 kilogram of 18.0 g/cm³ tungsten alloy material. An actual tungsten alloy counterweight is usually not directly designed as a standard cube, but is machined into a cylinder, disc, ring, block, sector, special-shaped part, perforated part, or threaded structure, etc., according to the installation position.

(4) If Made into a Cylindrical Shape, How Long Does 1 Kilogram of Tungsten Alloy Need to Be?

Assume that a tungsten alloy with a density of 18.0 g/cm³ is used, and the designed cylinder diameter is 40 mm, that is, 4 cm. The cylinder volume formula is $V = \pi d^2 h / 4$, where d is the diameter and h is the height. Substituting $V = 55.56 \text{ cm}^3$ and $d = 4 \text{ cm}$, we obtain $h = 4V / \pi d^2 = 4 \times 55.56 / (\pi \times 4^2) \approx 4.42 \text{ cm}$, that is, about 44.2 mm. Therefore, a solid cylinder with a diameter of 40 mm and a length of about 44.2 mm, under the theoretical density of 18.0 g/cm³, has a mass of about 1 kilogram. If the product requires a central hole, mounting holes, positioning grooves, threaded holes, or lightening grooves, the volume of these



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removed parts must be deducted, and the final external dimensions usually need to be larger than the above theoretical dimensions.

(5) How Much Volume Does 1 Kilogram of Tungsten Alloy Have Compared with 1 Kilogram of Steel and Lead?

Using tungsten alloy at 18.0 g/cm³, steel at 7.85 g/cm³, and lead at 11.34 g/cm³ for comparison, the volumes required for 1 kilogram of material are respectively: tungsten alloy $V = 1000 / 18.0 \approx 55.56 \text{ cm}^3$, steel $V = 1000 / 7.85 \approx 127.39 \text{ cm}^3$, lead $V = 1000 / 11.34 \approx 88.18 \text{ cm}^3$.

Material Typical Density Volume of 1 Kilogram Relative to Tungsten Alloy Volume

Tungsten alloy 18.0 g/cm³ 55.56 cm³ 100%

Lead 11.34 g/cm³ 88.18 cm³ About 159%

Steel 7.85 g/cm³ 127.39 cm³ About 229%

According to this density example, the volume of 1 kilogram of tungsten alloy is about 63.0% of the same mass of lead, a reduction of about 37.0% compared with lead; it is about 43.6% of the same mass of steel, a reduction of about 56.4% compared with steel. This is an important advantage of high-density tungsten alloy when making counterweights in limited installation space.

(6) Why Can the Volume of an Actual Tungsten Alloy Counterweight Not Be Considered as Only 55.56 cm³?

55.56 cm³ is the pure material volume obtained by theoretical calculation at 18.0 g/cm³, and is not equal to the final product's external envelope volume. If the counterweight has structures such as central holes, threaded holes, countersunk holes, notches, chamfers, and mounting cutouts, the material volume needs to be calculated according to the actual geometric shape, which can be expressed as $V_{\text{material}} = V_{\text{external shape}} - V_{\text{holes}} - V_{\text{grooves}} - V_{\text{other removed material}}$. For example, if a counterweight with a designed external volume of 60 cm³ has a total of 4.44 cm³ of material removed by internal holes and grooves, then the actual tungsten alloy volume is 55.56 cm³, and the theoretical mass at 18.0 g/cm³ density is about 1000 g. For complex special-shaped counterweights, the theoretical volume is usually obtained directly through a CAD (Computer-Aided Design) model, and then the mass is calculated in combination with the actual material density, which is more accurate than simply estimating according to length, width, and height.

(7) What Should Be Done When There Is a Difference Between Actual Density and Theoretical Density?

After pressing, sintering, and subsequent processing, the actual density of powder metallurgy tungsten alloy may differ to some extent from the theoretical value of the designed grade. Residual porosity, tungsten content, nickel-iron or nickel-copper binder phase ratio, sintering state, and processing material removal will all affect the final mass. For example, if the design volume is 55.56 cm³ and the actual density is 17.95 g/cm³, then the actual mass is about $55.56 \times 17.95 \approx 997.8 \text{ g}$, which differs from the 1 kilogram target



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value by about 2.2 g. For ordinary counterweights, the impact may be limited, but if used in high-speed rotating components, aviation structures, precision instruments, or inertial systems, the actual mass and mass distribution need to be further controlled.

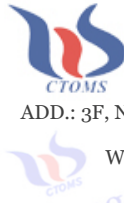
(8) How Should Precision Dimensional Design Be Carried Out for a 1 kg Tungsten Alloy Counterweight?

If the goal is not simply to obtain 1 kilogram of material, but to manufacture an actually installable 1 kg precision counterweight, it is necessary to simultaneously consider parameters such as target mass, material grade and density, external dimensions, hole and groove structures, installation method, dimensional tolerances, mass tolerances, center-of-gravity position, coaxiality, circular runout, flatness, and surface roughness. For rotating counterweights, mass distribution rather than only total weight also needs to be considered. The centrifugal force in a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft; the moment of inertia can be expressed as $I = \sum m_i r_i^2$. That is to say, even if two counterweights are both 1 kilogram, as long as the mass distribution positions are different, their dynamic characteristics may also be different. CTIA GROUP can serve as a professional designer and manufacturer of tungsten alloy counterweights, carrying out material selection, structural design, manufacturing and processing, and quality control according to target weight, installation space, structural dimensions, and precision requirements.

(9) Quick Volume Conversion for a 1 kg Tungsten Alloy Counterweight

If quick estimation is carried out at 18.0 g/cm^3 , the following can be directly remembered: 1 cm^3 of tungsten alloy is about 18 g, 10 cm^3 is about 180 g, 50 cm^3 is about 900 g, 55.56 cm^3 is about 1000 g, and 100 cm^3 is about 1800 g. When calculating in reverse, volume $V = \text{mass } m / 18.0$, so 500 g requires about 27.78 cm^3 , 1 kilogram requires about 55.56 cm^3 , and 2 kilograms require about 111.11 cm^3 .

A 1 kg (1 kilogram) tungsten alloy counterweight does not have a completely fixed volume; it needs to be calculated according to the actual density. According to the common range of $17\text{--}18.5 \text{ g/cm}^3$, 1 kilogram of tungsten alloy requires about $54.05\text{--}58.82 \text{ cm}^3$; calculated at 18.0 g/cm^3 , then $V = 1000 / 18.0 \approx 55.56 \text{ cm}^3$, that is, about $55,560 \text{ mm}^3$. If used for actual customization, the final external dimensions should be determined based on the actual density of the specific W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) grade, combined with holes and grooves, machining allowance, dimensional tolerances, and mass tolerances.



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Q15 What Is the Difference Between 17.5 g/cm³ and 18.0 g/cm³ Tungsten Alloys?

17.5 g/cm³ and 18.0 g/cm³ both belong to common density grades of high-density tungsten alloy counterweights. The most intuitive difference between the two is that their densities differ by 0.5 g/cm³, meaning that 18.0 g/cm³ is about 2.86% higher than 17.5 g/cm³. At the same mass, the volume required by 18.0 g/cm³ tungsten alloy is smaller; at the same volume, the mass of 18.0 g/cm³ tungsten alloy is greater. However, actual material performance cannot be judged based on density alone; it is also related to W (Tungsten) content, Ni (Nickel), Fe (Iron), or Cu (Copper) binder phase, microstructure, sintering state, and the specific material grade.

(1) The Most Direct Difference: Different Densities

The basic relationship of density is $\rho = m / V$, where ρ is density, m is mass, and V is volume. 17.5 g/cm³ means that every 1 cm³ of material theoretically has about 17.5 g, while 18.0 g/cm³ means that every 1 cm³ of material has about 18.0 g. The density difference between the two is $18.0 - 17.5 = 0.5$ g/cm³; relative to 17.5 g/cm³, the density increase ratio is $0.5 / 17.5 \times 100\% \approx 2.86\%$. From the perspective of counterweight design, this is a density difference that has practical significance but is not particularly large.

(2) At the Same Weight, 18.0 g/cm³ Has a Smaller Volume

Suppose both are made into 1 kilogram (1000 g) tungsten alloy counterweights. Calculated according to $V = m / \rho$, 17.5 g/cm³ material requires $V = 1000 / 17.5 \approx 57.14$ cm³, while 18.0



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g/cm³ material requires $V = 1000 / 18.0 \approx 55.56 \text{ cm}^3$. In other words, for the same 1 kilogram, 18.0 g/cm³ tungsten alloy occupies about $57.14 - 55.56 = 1.58 \text{ cm}^3$ less material volume than 17.5 g/cm³ tungsten alloy, a volume reduction of about 2.78%.

Item 17.5 g/cm³ 18.0 g/cm³

Mass per 1 cm³ 17.5 g 18.0 g

Volume for 100 g 5.71 cm³ 5.56 cm³

Volume for 500 g 28.57 cm³ 27.78 cm³

Volume for 1 kg 57.14 cm³ 55.56 cm³

Volume difference for the same mass — About 2.78% smaller

For counterweight structures with very compact space, this 2.78% volume difference may be translated into a shorter length, a smaller diameter, or more internal installation space.

(3) At the Same Volume, 18.0 g/cm³ Has a Greater Weight

Conversely, if both tungsten alloys are machined into 10 cm³, the theoretical mass of 17.5 g/cm³ material is $m = 17.5 \times 10 = 175 \text{ g}$, while the theoretical mass of 18.0 g/cm³ material is $m = 18.0 \times 10 = 180 \text{ g}$. Therefore, at the same volume, 18.0 g/cm³ tungsten alloy is about 5 g heavier per 10 cm³. For counterweights that need to achieve a specific mass within a fixed space, 18.0 g/cm³ can provide a higher mass per unit volume.

(4) The Two Densities Do Not Necessarily Represent Completely Different Material Systems

17.5 g/cm³ and 18.0 g/cm³ are first of all density grades, not two fixed material names. Actual products may use the W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) system, and different densities can be obtained by adjusting W content, binder phase ratio, and process parameters. Generally speaking, increasing W content helps to increase material density, because the theoretical density of W (Tungsten) is about 19.25 g/cm³, while the densities of Ni (Nickel), Fe (Iron), and Cu (Copper) are significantly lower than that of W. However, the final actual density is also affected by factors such as porosity, sintering density, and compositional uniformity, so it cannot be simply understood that a density of 18.0 g/cm³ necessarily means that the W content is higher than that of 17.5 g/cm³ by some fixed percentage.

(5) Mechanical Properties Cannot Be Judged Only by 17.5 and 18.0

In many cases, users directly associate density with strength, hardness, toughness, or processing performance, but this judgment is not accurate. The density difference between 17.5 g/cm³ and 18.0 g/cm³ itself cannot directly determine tensile strength, yield strength, elongation, hardness, or fracture toughness. Specific properties need to be checked against the corresponding material grade and test data. For example, for two tungsten alloys with similar densities, if one uses the W-Ni-Fe system and the other uses the W-Ni-Cu system, their magnetic properties, ductility, processing characteristics, and mechanical properties may all differ significantly. For counterweight products, material selection



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should usually consider density, mechanical properties, processing method, service temperature, magnetic requirements, corrosion resistance requirements, and cost at the same time, rather than only looking at the number 17.5 or 18.0.

(6) What Does 0.5 g/cm³ Mean for Precision Counterweights?

For ordinary fixed counterweights, the difference between 17.5 and 18.0 g/cm³ usually does not become a decisive factor, because both can provide relatively high mass per unit volume. However, for aerospace, precision rotating mechanisms, robot joints, gyroscope systems, engine components, and counterweight structures with highly limited space, the density difference may directly affect structural dimensions. For example, when the target mass is fixed at 1 kg, 17.5 g/cm³ requires about 57.14 cm³, while 18.0 g/cm³ requires only about 55.56 cm³. If the installation space is only about 56 cm³, then 18.0 g/cm³ has basically met the material volume requirement, while 17.5 g/cm³ may require readjusting the structural dimensions. If the counterweight is installed on a rotating component, mass distribution must also be considered. Centrifugal force can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft; the moment of inertia is related to the mass and its distance to the rotating shaft. Therefore, counterweight design cannot compare only total mass and density; parameters such as center of gravity, eccentricity, coaxiality, and circular runout must also be controlled.

(7) Which Is More Suitable for Counterweights, 17.5 g/cm³ or 18.0 g/cm³?

Which one is more suitable cannot be judged simply by higher or lower density, but should be selected according to the design constraints of the product. If the installation space is limited and the target mass must be obtained in the smallest possible volume, then 18.0 g/cm³ can provide a higher mass-to-volume ratio. If the structural space is relatively sufficient, and 17.5 g/cm³ material better meets specific requirements in terms of mechanical properties, processing technology, supply stability, or cost, then 17.5 g/cm³ can also serve as a suitable material grade. For products requiring precise mass control, actual density tolerance and final mass tolerance should also be compared, rather than only comparing nominal density.

(8) How Should 17.5 and 18.0 Be Distinguished During Actual Procurement?

When purchasing tungsten alloy counterweights, it is recommended not to specify only 17.5 g/cm³ or 18.0 g/cm³, but to also provide information such as target weight, density requirements, material system, dimensions, tolerances, hole positions, surface treatment, and service environment. For example, if the same 1 kg counterweight is required and 18.0 g/cm³ is specified, the material volume design can first be carried out according to 55.56 cm³; if 17.5 g/cm³ is specified, then the design is carried out according to 57.14 cm³. Then, combined with the hole and groove structure, machining allowance, and actual density, the final external dimensions are determined. CTIA GROUP can carry out tungsten alloy



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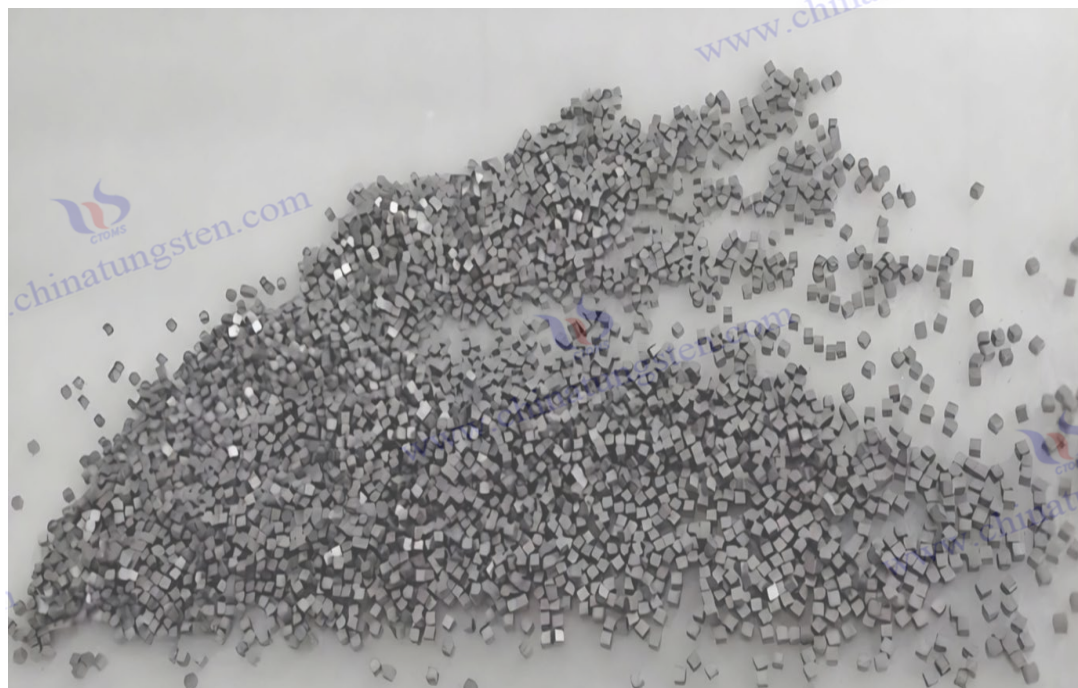
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material selection, structural design, processing, and quality control according to the target mass, installation space, and precision requirements of the counterweight, and is suitable for customized counterweights with clear requirements for volume and mass distribution.

(9) Summary of the Core Differences Between 17.5 g/cm³ and 18.0 g/cm³

From a purely density perspective, 18.0 g/cm³ is 0.5 g/cm³ higher than 17.5 g/cm³, or about 2.86% higher; when making counterweights of the same mass, the volume required by 18.0 g/cm³ is about 2.78% smaller. For example, for a 1 kilogram counterweight, 17.5 g/cm³ requires about 57.14 cm³, while 18.0 g/cm³ requires about 55.56 cm³, a difference of only about 1.58 cm³. If the product does not have particularly strict volume restrictions, the difference between the two density grades is usually not very large; if it belongs to miniaturization, high mass-to-volume ratio, space-limited, or precision dynamic counterweight applications, then the 0.5 g/cm³ difference may have practical design value. Ultimately, the specific W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper) material grade and actual measured density should be used as the basis for material selection.



Q16 What Is the Difference Between 18.0 g/cm³ and 18.5 g/cm³ Tungsten Alloys?

Both 18.0 g/cm³ and 18.5 g/cm³ are common density grades among high-density tungsten alloy counterweights, with a difference of 0.5 g/cm³ between them. The density of 18.5 g/cm³ is approximately 2.78% higher than that of 18.0 g/cm³, which is mainly manifested as a smaller volume for the same mass and a greater mass for the same volume. However, density does not represent all the properties of a material; the actual differences also



depend on the W (Tungsten) content, the Ni (Nickel), Fe (Iron), or Cu (Copper) binder phase, sintered densification, microstructure, and specific grade designation.

(1) The Most Fundamental Difference: 18.5 g/cm³ Has a Higher Density

The density calculation relationship is $\rho = m / V$, where ρ is density, m is mass, and V is volume. 18.0 g/cm³ means that the theoretical mass of the material per 1 cm³ is approximately 18.0 g, while 18.5 g/cm³ means that the theoretical mass of the material per 1 cm³ is approximately 18.5 g. The density difference between the two is $18.5 - 18.0 = 0.5$ g/cm³; relative to 18.0 g/cm³, 18.5 g/cm³ represents an increase of $0.5 / 18.0 \times 100\% \approx 2.78\%$. This difference does not imply that the two materials exhibit a corresponding 2.78% change in all properties; rather, it primarily affects the mass that can be provided per unit volume.

(2) At the Same Weight, 18.5 g/cm³ Occupies a Smaller Volume

Assuming that 1 kg (1000 g) counterweights are produced from 18.0 g/cm³ and 18.5 g/cm³ tungsten alloys respectively, the required volume is calculated according to $V = m / \rho$. The 18.0 g/cm³ material requires $V = 1000 / 18.0 \approx 55.56$ cm³, while the 18.5 g/cm³ material requires $V = 1000 / 18.5 \approx 54.05$ cm³. In other words, for the same mass, the 18.5 g/cm³ tungsten alloy occupies approximately 1.50 cm³ less than the 18.0 g/cm³ tungsten alloy, representing a volume reduction of approximately 2.70%.

Item	18.0 g/cm ³	18.5 g/cm ³
Mass per 1 cm ³	18.0 g	18.5 g
Volume for 100 g	5.56 cm ³	5.41 cm ³
Volume for 500 g	27.78 cm ³	27.03 cm ³
Volume for 1 kg	55.56 cm ³	54.05 cm ³
Volume difference at same mass	—	Approx. 2.70% reduction

For counterweights with very limited installation space, 18.5 g/cm³ can further reduce the material volume under the same mass requirement.

(3) At the Same Volume, 18.5 g/cm³ Has a Greater Mass

If both materials are processed into 10 cm³, the theoretical mass of the 18.0 g/cm³ tungsten alloy is $m = 18.0 \times 10 = 180$ g, while the theoretical mass of the 18.5 g/cm³ tungsten alloy is $m = 18.5 \times 10 = 185$ g. In other words, for the same external dimensions, there is a difference of approximately 5 g per 10 cm³ of material. For structures that require increasing counterweight mass within a fixed installation space, this difference possesses certain design value. For example, for a fixed-volume counterweight block of 50 cm³, the theoretical mass when using the 18.0 g/cm³ material is approximately 900 g, while when using the 18.5 g/cm³ material it is approximately 925 g, a difference of approximately 25 g.

(4) 18.5 g/cm³ Usually Implies a Higher Tungsten Content or Higher Densification

High-density tungsten alloys typically use W (Tungsten) as the primary heavy element and



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are formed into sintered heavy alloys through Ni-Fe (Nickel-Iron) or Ni-Cu (Nickel-Copper) binder phases. Generally, increasing the W content is conducive to increasing the material density, because the theoretical density of tungsten is approximately 19.25 g/cm^3 , while the densities of Ni (Nickel), Fe (Iron), and Cu (Copper) are lower than that of tungsten. However, 18.0 g/cm^3 and 18.5 g/cm^3 cannot be simply correlated with two fixed W contents, because the actual density is also affected by the binder phase ratio, porosity, sintering process, and material microstructure. Therefore, one cannot judge that a certain tungsten alloy must have a specific fixed W content based solely on the figure of 18.5 g/cm^3 ; actual procurement should still be based on the specific material grade and the supplier's technical data.

(5) The Mechanical Properties of the Two Cannot Be Judged by Density Alone

The fact that 18.5 g/cm^3 has a higher density than 18.0 g/cm^3 does not mean that its tensile strength, hardness, elongation, toughness, or wear resistance will necessarily increase in the same proportion. For example, tungsten alloys with different binder systems may exhibit different mechanical properties and processing characteristics even if their densities are similar. W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) may differ in magnetic properties, ductility, and processing behavior. For counterweight products, density primarily addresses the mass-per-unit-volume issue, while mechanical properties relate to the reliability of the product under impact, vibration, assembly, and long-term use; the two should be evaluated separately.

(6) What Is the Practical Value of 18.5 g/cm^3 for Precision Counterweights?

If it is just an ordinary fixed counterweight, the difference between 18.0 and 18.5 g/cm^3 is usually not particularly significant. However, for space-constrained applications such as aerospace, motorsports, precision rotating equipment, robotic joints, gyroscopic systems, inertial systems, and miniature electronic devices, a higher density can provide greater design freedom. For example, when the target mass is 1 kg , 18.0 g/cm^3 requires approximately 55.56 cm^3 of material, while 18.5 g/cm^3 requires only approximately 54.05 cm^3 . For a counterweight structure that is already approaching its spatial limit, this difference of approximately 1.50 cm^3 may be used to reduce the axial length, decrease the outer diameter, or provide space for mounting holes, locating structures, and other components. If the counterweight is used in a high-speed rotating system, attention must also be paid to the mass distribution. The centrifugal force of a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the axis of rotation; the moment of inertia is related to the mass and its distance from the axis of rotation. Therefore, 18.5 g/cm^3 does not automatically result in better dynamic balance; ultimately, this still depends on the actual mass distribution, eccentricity, mounting position, coaxiality, and runout of the counterweight.



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(7) How to Choose Between 18.0 g/cm³ and 18.5 g/cm³?

If the structural space is relatively ample, the volume difference between the two densities is only a few percentage points, and 18.0 g/cm³ is already sufficient to meet a large number of counterweight applications. If the product emphasizes miniaturization, mass-per-unit-volume, or if the installation space is very tight, 18.5 g/cm³ can further reduce the required material volume. If the product is more sensitive to cost, processing performance, or specific mechanical properties, one should not simply choose 18.5 g/cm³ just because it has a higher density. The material grade, processing difficulty, dimensional tolerance, mass tolerance, supply stability, and batch cost also need to be taken into account. In other words, the main advantage of 18.5 g/cm³ is its higher mass-to-volume ratio, not that it is superior to 18.0 g/cm³ in all engineering indicators.

(8) What Needs Special Attention in Actual Customization?

For tungsten alloy counterweights, 18.0 g/cm³ or 18.5 g/cm³ usually refers to the material density index, while the final product also requires the determination of target weight, external dimensions, hole and groove structures, mounting methods, dimensional tolerances, mass tolerances, surface treatment, and operating environment. For example, if the requirement is to produce a 1 kg counterweight, the design can be initially estimated based on a material volume of 55.56 cm³ for 18.0 g/cm³ and 54.05 cm³ for 18.5 g/cm³. If the product has center holes, threaded holes, countersunk holes, or slots, the calculation must be redone based on the actual material volume; one cannot directly treat 55.56 cm³ or 54.05 cm³ as the final external envelope volume. For counterweight requirements of both the 18.0 g/cm³ and 18.5 g/cm³ density grades, CTIA (China Tungsten Intelligent Manufacturing) can perform a design evaluation of the volume occupied by different density materials in combination with the target weight and installation space, and further complete the matching of counterweight structural dimensions, hole and groove positions, mass tolerances, and processing schemes, so that the material density selection is coordinated with the actual product structural requirements.

(9) The Core Difference Between 18.0 and 18.5 g/cm³

From the perspective of density itself, 18.5 g/cm³ is 0.5 g/cm³ higher than 18.0 g/cm³, approximately 2.78% higher. Taking a 1 kg counterweight as an example, 18.0 g/cm³ requires approximately 55.56 cm³, while 18.5 g/cm³ requires approximately 54.05 cm³; 18.5 g/cm³ can reduce the material volume by approximately 1.50 cm³, or approximately 2.70%. Therefore, the core difference between the two can be summarized as follows: 18.0 g/cm³ possesses a relatively high high-density counterweight capability, while 18.5 g/cm³ further increases the mass per unit volume on this basis and is more suitable for scenarios with stricter restrictions on counterweight volume. However, the actual material properties, processing performance, and use effects cannot be judged by density alone; they should be comprehensively determined in combination with the composition, properties, and actual test data of the specific W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper)



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grade.



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PART III. Material Selection for Tungsten Alloy Counterweights in Different Applications

Tungsten alloy counterweights are not universally better simply because the density is higher. In practice, material selection typically requires simultaneous consideration of density, target weight, volume constraints, strength and toughness, magnetic properties, machinability, corrosion resistance, operating temperature, and cost. The common material systems primarily include W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper), in which tungsten (W) provides the main high-density characteristic, while nickel (Ni) and iron (Fe) or copper (Cu) constitute the binding phase.

Material Selection for Different Applications

Application Field	Common Material System	Primary Selection Considerations
Automotive crankshaft, rotor counterweight	W-Ni-Fe	High density, strength, vibration resistance, machinability
Automotive wheel and localized counterweight	W-Ni-Fe, W-Ni-Cu	Volume constraints, quality control, environmental performance
Racing counterweight	High-density W-Ni-Fe	Achieving large mass in small volume, reliable fixation
Aircraft control surface counterweight	W-Ni-Fe, W-Ni-Cu	Density, mass tolerance, center-of-gravity position, reliability
UAV counterweight	W-Ni-Fe, W-Ni-Cu	Miniaturization, center-of-gravity adjustment, magnetic environment requirements
Industrial motor, generator rotor	W-Ni-Fe	Density, mechanical strength, dynamic balance
High-speed rotor	High-density W-Ni-Fe	Structural integrity & balance stability under high-speed rotation
Mobile phone vibration counterweight	W-Ni-Fe, W-Ni-Cu	Small size, high mass, mass consistency
Golf club counterweight	W-Ni-Fe, W-Ni-Cu	Density, center-of-gravity adjustment, machining and assembly
Precision instrument counterweight	Selected to magnetic/space needs	Weight accuracy, magnetic properties, dimensional stability
Underwater and outdoor counterweight	W-Ni-Fe, W-Ni-Cu	Density, corrosion resistance, environmental adaptability

How to Choose Between W-Ni-Fe and W-Ni-Cu

W-Ni-Fe typically exhibits better comprehensive mechanical properties and higher strength, making it suitable for counterweights in automotive, aerospace, and industrial rotors where structural reliability is critical. Because it contains iron (Fe), its magnetic response is usually more pronounced than that of W-Ni-Cu; therefore, when positioned near magnetic sensors, electronic compasses, or similar devices, magnetic properties must be confirmed as a design parameter. W-Ni-Cu employs copper (Cu) as one of the primary binding phases and generally features lower magnetic response characteristics, giving it application value in certain electronic devices, precision instruments, and structures sensitive to magnetic environments. However, whether it is suitable for a specific product still requires verification against actual magnetic permeability, operating temperature, mechanical load,



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and machining requirements; one cannot simply define either material as absolutely non-magnetic.

Selecting Material Based on Density

If the primary goal is to reduce counterweight volume, higher density grades can be prioritized. For example, for a design requirement of 500 g, the theoretical volume of a tungsten alloy at 18.0 g/cm³ is approximately 27.78 cm³; if 17.0 g/cm³ is used, it is approximately 29.41 cm³. For counterweight mounting positions where space is extremely limited, increasing material density can further compress dimensions. However, higher density does not mean all properties improve simultaneously. Higher tungsten content generally favors increased density, but may also alter hardness, toughness, machining difficulty, and material cost. Therefore, the target density should be determined based on actual functional requirements, rather than simply pursuing the highest density.

Selecting Material Based on Rotational Speed

For crankshafts, rotors, flywheels, and other high-speed rotating components, material selection cannot rely on density alone; resistance to centrifugal load and dynamic balance performance must also be considered. The centrifugal force generated by a rotating counterweight can be expressed as $F = m\omega^2r$, where m is the counterweight mass, ω is the angular velocity, and r is the distance from the counterweight's center of mass to the rotation axis. The higher the rotational speed and the larger the mass or mounting radius, the higher the demands on the fixing structure and material performance. Such applications typically focus more on high-density tungsten alloys such as W-Ni-Fe with better comprehensive mechanical properties, while also requiring control of finished product mass, dimensions, center of gravity, coaxiality, runout, and mounting reliability. Whether it can ultimately be used for high-speed rotation still requires verification in combination with specific rotational speed, structural design, and safety factors.

Selecting Material Based on Magnetic Properties

When a tungsten alloy counterweight is located near magnetic sensors, motor magnetic circuits, electronic compasses, or other magnetically sensitive components, the material's magnetic response becomes an important factor. The iron in W-Ni-Fe introduces a certain magnetic response, while W-Ni-Cu is generally more suitable for scenarios requiring reduced magnetic interference. However, the actual magnetic properties of a product depend not only on the material system, but also on tungsten content, binding phase ratio, processing state, and specific grade. If the product has explicit requirements for magnetic properties, it is best to directly specify magnetic permeability, magnetization intensity, or actual test indicators in the technical requirements, rather than simply writing W-Ni-Fe or W-Ni-Cu.



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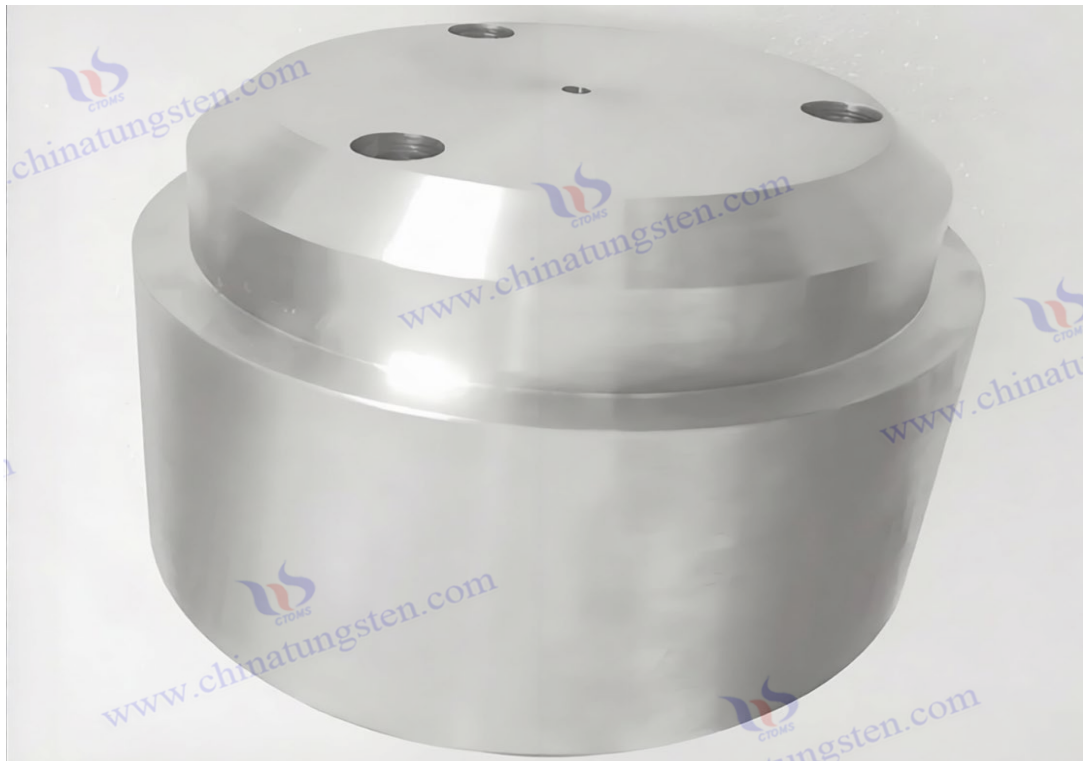
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Selecting Material Based on Machining Method

Tungsten alloys are typically produced via the powder metallurgy (PM) route, followed by precision machining such as turning, milling, drilling, tapping, and grinding according to drawing requirements. Material hardness, microstructure, and tungsten content all affect tool wear and machining efficiency. For counterweights with simple structures and large quantities, blanks close to the final shape can be obtained through die pressing and sintering to reduce subsequent machining; for small-batch or structurally complex products, sintered blanks combined with CNC machining can be used to achieve more flexible dimensional and structural control. Overall, automotive and high-speed rotating machinery typically prioritize the comprehensive mechanical properties, density, and dynamic balance of W-Ni-Fe; electronic devices and magnetically sensitive structures require focused comparison of the magnetic properties of W-Ni-Fe versus W-Ni-Cu; aerospace and UAV counterweights require simultaneous attention to density, weight tolerance, center of gravity, and reliability; and sports equipment such as golf clubs focus more on local mass distribution, center of gravity, and moment of inertia (MOI) for material selection. The final material selection can be summarized as: first determine the target mass and installation space, then determine the required density, and subsequently screen the material system based on magnetic properties, mechanical load, working environment, machining method, and cost—rather than simply selecting based on tungsten content or density level alone.





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Q17 What Elements Are Typically Used in Tungsten Alloy Counterweights?

Tungsten alloy counterweights are a class of high-density alloy materials in which W (Tungsten) serves as the primary heavy element, combined with one or more binder-phase elements. The most common industrial systems are W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper), where tungsten provides the main high-density characteristic, while Ni (Nickel), Fe (Iron), and Cu (Copper) primarily serve to form the metallic binder phase, improving the material's sintering performance, toughness, ductility, and machinability. For different applications, the proportions of these elements may be adjusted, and small quantities of other elements may be added to optimize density, mechanical properties, magnetic properties, corrosion resistance, and processing performance.

(1) Tungsten (W) Is the Primary Element in Tungsten Alloy Counterweights

W (Tungsten) is the most critical element in tungsten alloy counterweights and the fundamental reason these products can achieve high density in a small volume. Pure tungsten has a theoretical density of approximately 19.25 g/cm³; therefore, increasing the mass fraction of tungsten in the alloy generally contributes to a higher overall material density. Common high-density tungsten alloys typically contain a high level of tungsten, and engineering products can employ different formulations based on target density and performance requirements. For example, some high-density grades can achieve tungsten contents exceeding 90%. For counterweight applications, higher tungsten content usually means higher density, but this does not necessarily mean it is the best choice for all applications. As tungsten content, binder-phase proportions, and microstructure vary, the material's strength, ductility, toughness, machinability, and manufacturing cost also change.

(2) Nickel (Ni) Is Primarily Used to Form the Binder Phase

Ni (Nickel) is one of the most common binder-phase elements in tungsten heavy alloys. Tungsten itself has an extremely high melting point, making it difficult to manufacture dense complex counterweight components with good comprehensive mechanical properties directly. Therefore, powder metallurgy processes such as liquid-phase sintering are typically employed, allowing nickel and other elements to form a metallic binder phase that bonds the tungsten particles together. The addition of nickel can improve the microstructural bonding and comprehensive mechanical properties of tungsten alloys, while also helping to achieve a more uniform and denser sintered microstructure. In the W-Ni-Fe system, nickel and iron together constitute the binder phase; in the W-Ni-Cu system, the binder phase is primarily formed by nickel and copper. Although both systems use tungsten as the main component, their final material properties and processing characteristics are not identical.



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(3) Iron (Fe) Is Commonly Used in W-Ni-Fe Tungsten Alloys

Fe (Iron) is an important binder-phase element in W-Ni-Fe tungsten alloys. W-Ni-Fe is a very common material system for high-density tungsten alloy counterweights, offering high density and good comprehensive mechanical properties. It is therefore widely used in counterweight products requiring a high mass-to-volume ratio, high strength, and precision machining. In the W-Ni-Fe system, tungsten particles constitute the primary high-density phase, while the Ni-Fe combination forms the binder phase. By adjusting the proportions among W, Ni, and Fe, different density and performance grades can be obtained. This type of material is particularly suitable for structural counterweights with high strength requirements, such as mechanical balance weights, automotive and racing counterweights, aerospace counterweights, rotating component counterweights, and precision instrument counterweights.

(4) Copper (Cu) Is Primarily Used in W-Ni-Cu Tungsten Alloys

Cu (Copper) is another common binder-phase element for tungsten alloy counterweights. The W-Ni-Cu (Tungsten-Nickel-Copper) system uses tungsten as the primary heavy element, with the Ni-Cu binder phase improving the material's sintering and processing characteristics. Although both W-Ni-Cu and W-Ni-Fe can be used to manufacture high-density counterweights, they may differ in magnetic properties, mechanical properties, ductility, processing behavior, and specific operating environments. For example, when a product has strict requirements regarding magnetic response, W-Ni-Cu is typically worth serious evaluation; whereas for structural counterweights requiring higher strength and comprehensive mechanical properties, W-Ni-Fe is the common choice. Actual performance still depends on the specific composition ratios, manufacturing processes, and material grades, and cannot be judged solely by the system name.

(5) Why Not Use 100% Tungsten for Counterweights?

From a density perspective, pure tungsten at approximately 19.25 g/cm³ is indeed denser than most tungsten heavy alloys. However, counterweight materials are not solely about maximizing density; factors such as processability, toughness, manufacturing complexity, cost, and batch production stability must also be considered. Pure tungsten has characteristics such as a high melting point and high hardness, making it difficult to machine and manufacture into complex structures. By adding binder-phase elements such as Ni (Nickel), Fe (Iron), or Cu (Copper), it is possible to maintain high density while improving the material's comprehensive engineering properties, making it more suitable for manufacturing precision counterweights with holes, slots, threads, steps, and irregular shapes. For example, the theoretical volume of 1 kg of pure tungsten is approximately 1000 / 19.25 $\approx$ 51.95 cm³, while an 18.0 g/cm³ tungsten alloy is approximately 55.56 cm³—a difference of only about 3.61 cm³. For many counterweight applications, sacrificing a small amount of volume in exchange for significantly better manufacturing performance and structural adaptability is of considerable engineering value.



(6) What Role Does Each Element Play in Tungsten Alloys?

The role of each element in common tungsten alloy counterweights can be simply understood as follows: W (Tungsten) is primarily responsible for high density and mass-to-volume ratio; Ni (Nickel) primarily participates in forming the binder phase and improving microstructural bonding; Fe (Iron) is mainly used for binder-phase modulation in the W-Ni-Fe system; and Cu (Copper) is primarily used in the W-Ni-Cu system, influencing the material's ductility, processing characteristics, and magnetic properties.

Element	Name	Primary Role in Tungsten Alloys
W	Tungsten	Provides high density and high mass-to-volume ratio
Ni	Nickel	Forms the binder phase; improves microstructural bonding and comprehensive properties
Fe	Iron	Modulates the W-Ni-Fe binder phase and mechanical properties
Cu	Copper	Constitutes W-Ni-Cu binder phase; influences processing, ductility, & magnetic properties

These roles are general engineering summaries; no single element carries only one function. The final material properties result from the combined effects of the overall composition, phase constitution, tungsten particle size, sintering process, and microstructure.

(7) Why Do Different Element Ratios Affect the Density of Tungsten Alloy Counterweights?

The density of tungsten is much higher than that of Ni, Fe, and Cu; therefore, changing the ratio between W and the binder phase affects the theoretical density of the final material. For example, under otherwise similar conditions, increasing the tungsten proportion generally raises the overall density. However, the actual density of a sintered tungsten alloy is not simply calculated by linearly combining the densities of its constituent elements. Powder particle size, compaction density, liquid-phase sintering conditions, residual porosity, and compositional uniformity all influence the final measured density. For engineering counterweights, what truly matters is the measured density and mass tolerance of the final product. For example, for a material with a nominal density of 18.0 g/cm³, the final product still requires density testing and weighing to confirm whether it meets the design requirements.

(8) Elemental Composition Also Affects the Magnetic Properties of Tungsten Alloy Counterweights

The elemental composition of a material affects not only its density but also its magnetic properties. W (Tungsten) itself is not a typical ferromagnetic material, but the W-Ni-Fe system may exhibit significant magnetic response due to the presence of Fe (Iron) and other elements. The W-Ni-Cu system typically has a lower magnetic response, making it more suitable for some applications sensitive to magnetic environments. Therefore, if a tungsten alloy counterweight is to be installed near gyroscopes, precision sensors, electronic equipment, magnetic field environments, or inertial systems, simply specifying a density requirement of 18.0 g/cm³ or 18.5 g/cm³ may not be sufficient. It is also necessary to



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clarify requirements for magnetic permeability, magnetic response, and other related properties, and to verify these against the specific material grade.

(9) Are Other Elements Added to Tungsten Alloy Counterweights?

Conventional tungsten alloy counterweights are primarily designed around the W-Ni-Fe and W-Ni-Cu systems; this does not mean that all products contain only these three elements. In specific material systems and manufacturing processes, trace elements or process controls may be introduced to improve sintering behavior, microstructural stability, mechanical properties, or other special characteristics. However, for ordinary high-density tungsten alloy counterweights, there is no need to add large quantities of elements in pursuit of compositional complexity. The core of counterweight materials remains establishing a rational compositional system based on the target density, mechanical properties, processing requirements, magnetic properties, corrosion resistance requirements, and operating environment. CTIA (China Tungsten Intelligent Manufacturing) can match W-Ni-Fe, W-Ni-Cu, and other material systems for custom tungsten alloy counterweights based on target density, mass requirements, structural dimensions, and specific application environments, and can design material compositions and manufacturing processes in accordance with the intended counterweight use.

(10) W-Ni-Fe and W-Ni-Cu Are the Two Most Common Systems

From a practical engineering perspective, common tungsten alloy counterweight materials can be broadly divided into two routes: W-Ni-Fe primarily emphasizes high density, strength, and comprehensive mechanical properties, making it suitable for structural and high-reliability counterweights; W-Ni-Cu has different binder-phase characteristics and offers application value in counterweights with specific requirements for magnetic properties, processing performance, or particular environments. Both can be manufactured via powder metallurgy into cylindrical, disc-shaped, ring-shaped, block-shaped, plate-shaped, and various irregular counterweight forms, and can be further processed by turning, milling, drilling, grinding, and other operations to achieve the required dimensional accuracy.

Tungsten alloy counterweights are typically not single-element materials. Instead, they use W (Tungsten) as the primary high-density element, with Ni (Nickel), Fe (Iron), or Cu (Copper) added to form the binder phase. The most common material systems are W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). Among these, W primarily determines the high-density and small-volume counterweight capability, while Ni, Fe, and Cu influence the material's sintered densification, mechanical properties, processing performance, and magnetic properties through the binder phase and compositional proportions. When selecting a material, one should not look only at tungsten content or nominal density; the specific grade's composition, measured density, mechanical properties, magnetic properties, and processing requirements must also be considered.



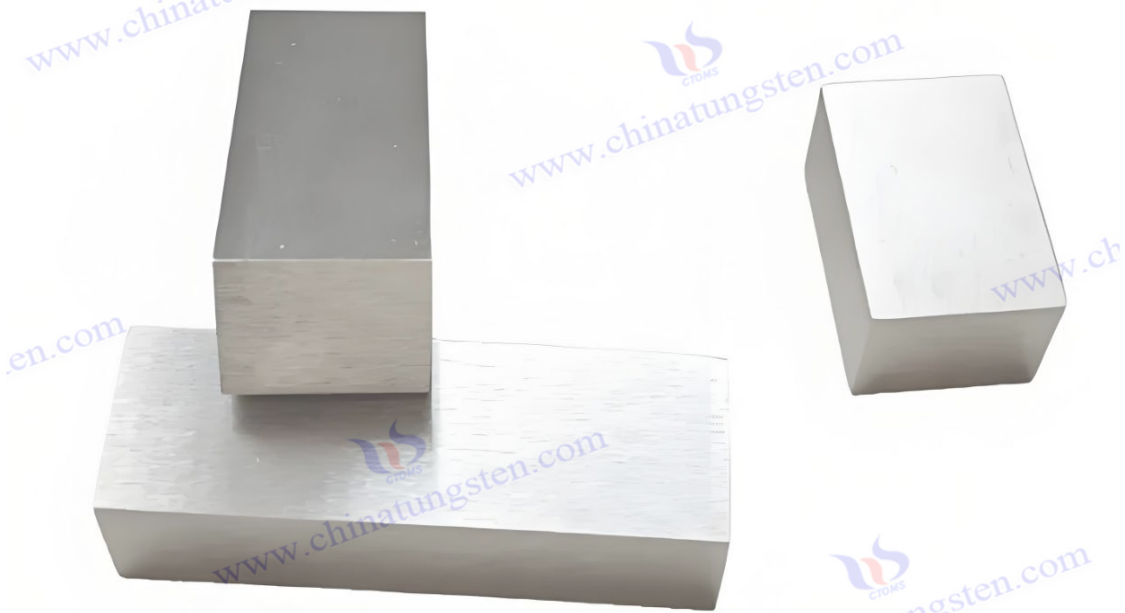
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Q18 What Kind of Material Is W-Ni-Fe (Tungsten-Nickel-Iron)?

W-Ni-Fe (Tungsten-Nickel-Iron) is a high-density tungsten heavy alloy (Tungsten Heavy Alloy) with W (Tungsten) as the main constituent phase and Ni (Nickel) and Fe (Iron) as the binder phase. It is usually manufactured by powder metallurgy processes, forming a metal material with relatively high density, good strength, and toughness through pressing, sintering, and other processes. Because it combines high density with relatively good comprehensive mechanical properties, W-Ni-Fe is widely used in tungsten alloy counterweights, balance weights, inertial components, radiation shielding parts, and fields such as aerospace, automobiles, and precision machinery.

(1) What Kind of Material Is W-Ni-Fe Specifically?

W-Ni-Fe is essentially a tungsten-based heavy alloy, in which W constitutes the main high-density phase, and Ni and Fe form a continuous or semi-continuous metal binder phase that binds a large number of tungsten particles together. Unlike pure tungsten, W-Ni-Fe is not usually manufactured by completely melting tungsten and then directly casting it; instead, it is usually manufactured by the powder metallurgy route. Tungsten powder, nickel powder, and iron powder are mixed in designed proportions, pressed and formed, and then liquid-phase sintered, so that the material obtains relatively high density and a stable microstructure. The core idea of this material system can be summarized as: using W to provide high density, and using the Ni-Fe binder phase to improve the bonding between tungsten particles and the comprehensive mechanical properties of the material.



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(2) How Much Tungsten Does W-Ni-Fe Usually Contain?

W-Ni-Fe belongs to the category of high-tungsten-content materials. The actual W content is adjusted according to target density, mechanical properties, processing performance, and specific grades. In engineering, the commonly used high-density tungsten alloy systems are about 90%–97% W. As the W content increases, the overall density of the material usually increases, because the theoretical density of W (Tungsten) is about 19.25 g/cm³, while the densities of Ni and Fe are significantly lower than that of W. For example, some high-density W-Ni-Fe materials can reach more than 18 g/cm³, or even close to 18.5 g/cm³. The specific composition, density, and mechanical properties of different suppliers and different grades may differ, so a fixed density cannot be determined simply by the name W-Ni-Fe.

(3) What Roles Do W, Ni, and Fe Play in the Material Respectively?

W (Tungsten) mainly provides characteristics such as high density, high mass-to-volume ratio, and high-temperature resistance, and is the basis for W-Ni-Fe to achieve high density; Ni (Nickel) mainly participates in forming the binder phase, helping to improve the bonding between tungsten particles and the comprehensive properties of the material; Fe (Iron) and Ni together constitute the binder phase and are used to adjust the material's microstructure, strength, ductility, and sintering behavior. Therefore, W-Ni-Fe is not simply a mixture of three metals, but a composite metal material with a specific microstructure formed after sintering. The ratio, distribution state, and interface bonding quality between tungsten particles and the Ni-Fe binder phase all affect the final performance.

(4) Why Is W-Ni-Fe Suitable for Making Tungsten Alloy Counterweights?

One of the greatest advantages of W-Ni-Fe is high density. The density of ordinary steel is about 7.85 g/cm³, while high-density W-Ni-Fe can reach about 17–18.5 g/cm³ or even higher for specific grades. Therefore, under the same mass requirement, the volume required by W-Ni-Fe is significantly smaller than that of steel. For example, for a 1 kg counterweight, if 18.0 g/cm³ W-Ni-Fe is used, the theoretical material volume is about $V = 1000 / 18.0 \approx 55.56$ cm³; if 7.85 g/cm³ steel is used, about $1000 / 7.85 \approx 127.39$ cm³ is required. The difference between the two is about 71.83 cm³. For aerospace, automobiles, racing cars, robots, precision rotating equipment, and electronic devices with limited space, this high mass-to-volume ratio can help designers obtain the required counterweight mass within a limited space.

(5) What Is the Difference Between W-Ni-Fe and Pure Tungsten?

The theoretical density of pure tungsten is about 19.25 g/cm³, while W-Ni-Fe is usually lower than pure tungsten. Therefore, from the perspective of density alone, pure tungsten has a higher mass-to-volume ratio. However, the engineering advantage of W-Ni-Fe is not only density. Through the Ni-Fe binder phase, the material's toughness, ductility, and comprehensive mechanical properties can be improved, and it is more suitable for



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manufacturing complex shapes through powder metallurgy and subsequent mechanical machining. For example, the theoretical volume of 1 kg of pure tungsten is about $1000 / 19.25 \approx 51.95 \text{ cm}^3$, while that of 18.0 g/cm^3 W-Ni-Fe is about 55.56 cm^3 , with a difference of only about 3.61 cm^3 . For many counterweight applications, exchanging a small volume difference for better comprehensive processing and structural adaptability has practical value.

(6) What Are the Main Performance Characteristics of W-Ni-Fe?

W-Ni-Fe usually has high density, relatively high strength, relatively good toughness, relatively good impact resistance, and good dimensional stability. Its material properties are affected by many factors, such as W content, Ni/Fe ratio, tungsten powder particle size, sintering temperature, sintering time, and final microstructure. Compared with pure tungsten, W-Ni-Fe usually has better plasticity and toughness; compared with ordinary steel, its density is significantly higher and it can provide greater mass in a smaller volume. However, W-Ni-Fe cannot simply be understood as a material that is superior to steel or pure tungsten in all performance indicators. Its value mainly lies in the balance between high density and comprehensive performance.

(7) What Are the Magnetic Properties of W-Ni-Fe?

W-Ni-Fe contains Fe (Iron) and Ni (Nickel), so it usually has a certain magnetic response, and its specific magnetic properties depend on material composition, microstructure, and processing state. This point is especially important for certain precision counterweights. For example, if the counterweight is installed near magnetic sensors, gyroscopes, inertial measurement devices, or other systems sensitive to magnetic fields, density alone cannot be considered; magnetic permeability and magnetic response should also be evaluated according to specific application requirements. If the product has high requirements for low-magnetic or non-magnetic performance, material systems such as W-Ni-Cu (Tungsten-Nickel-Copper) can be further considered and selected according to actual material data.

(8) How Is W-Ni-Fe Manufactured?

W-Ni-Fe is usually manufactured by powder metallurgy processes. The basic process includes batching and mixing of tungsten powder, nickel powder, and iron powder, press forming, pretreatment or debinding, liquid-phase sintering, necessary heat treatment, and subsequent mechanical machining, and finally dimensional, density, mass, and appearance inspection. Among these, liquid-phase sintering is an important step in forming a high-density W-Ni-Fe structure. During sintering, the binder phase becomes liquid and promotes the rearrangement, wetting, and densification of tungsten particles, ultimately forming a structure with tungsten particles as the main hard phase and Ni-Fe as the binder phase. For precision counterweights, turning, milling, drilling, grinding, thread machining, etc. may also be carried out after sintering to achieve the dimensions and tolerances



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specified in the drawing.

(9) What Kinds of Tungsten Alloy Counterweights Can W-Ni-Fe Be Machined Into?

W-Ni-Fe has relatively good engineering processing adaptability and can be manufactured according to product structure into cylindrical counterweights, disc counterweights, ring counterweights, block counterweights, plate counterweights, eccentric counterweights, and special-shaped counterweights with holes, grooves, and threads. For rotating components, the mass distribution, installation position, and geometric accuracy of the counterweight can also be controlled through precision machining. For example, the centrifugal force in a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft; when there is a slight deviation in the installation position of the counterweight, it may also produce an obvious dynamic effect under high-speed rotation. Therefore, the final mass, dimensions, hole positions, coaxiality, circular runout, and center-of-gravity position of W-Ni-Fe counterweights may all become important quality control indicators.

(10) In Which Fields Is W-Ni-Fe Mainly Used?

Typical applications of W-Ni-Fe include aerospace counterweights, aircraft control surface counterweights, automotive and racing balance parts, engine and rotating component counterweights, industrial rotor balance parts, robot joint counterweights, precision instrument inertial components, medical equipment counterweights, and some radiation shielding structures. In counterweight applications, its core value mainly comes from high density and good comprehensive mechanical properties. It can achieve relatively large mass in a limited space and can be manufactured into different structures through powder metallurgy and precision mechanical machining.

(11) What Is the Difference Between W-Ni-Fe and W-Ni-Cu?

W-Ni-Cu (Tungsten-Nickel-Copper) and W-Ni-Fe both belong to common tungsten heavy alloy systems, and the main difference lies in the binder phase. W-Ni-Fe uses a Ni-Fe binder phase, while W-Ni-Cu uses a Ni-Cu binder phase. Both can achieve high density, but they may differ in magnetic properties, ductility, mechanical properties, processing behavior, and specific service environments. Because W-Ni-Fe contains Fe, it usually has a more obvious magnetic response; W-Ni-Cu usually has a lower magnetic response. Therefore, when selecting a tungsten alloy counterweight, if the main requirement is high strength and comprehensive mechanical properties, W-Ni-Fe can be evaluated with priority; if the application has special requirements for magnetic response, W-Ni-Cu can be further evaluated. Ultimately, the specific material grade and test data should still be used as the basis.

(12) What Types of Counterweight Designs Is W-Ni-Fe Suitable For?

W-Ni-Fe is especially suitable for counterweight designs requiring high density, small



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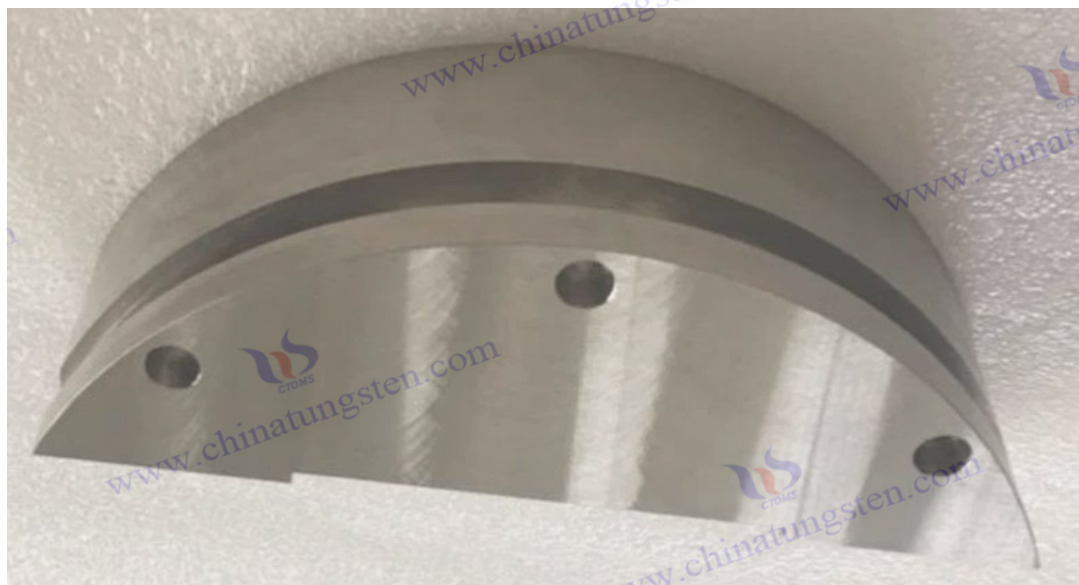
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volume, and relatively high mechanical reliability. For example, when mass needs to be added, the center of gravity adjusted, or the moment of inertia changed within a limited space, the relatively high density of W-Ni-Fe can be used to achieve a compact structure. For a counterweight with a fixed mass, the volume can be preliminarily calculated according to $V = m / \rho$; for example, if the target mass is 500 g and the material density is 18.0 g/cm³, the material volume is about $500 / 18.0 = 27.78 \text{ cm}^3$. Actual design also needs to deduct the volume of holes and grooves and consider machining allowance, density tolerance, and final mass tolerance. For small and medium-sized precision counterweights, the center of gravity or moment of inertia can be precisely adjusted by changing external dimensions, installation position, and mass distribution.

W-Ni-Fe (Tungsten-Nickel-Iron) is a tungsten heavy alloy with W (Tungsten) as the main high-density phase and Ni (Nickel) and Fe (Iron) as the binder phase. It is usually manufactured by powder metallurgy and liquid-phase sintering processes. Its typical characteristics are high density, relatively good strength and toughness, relatively balanced comprehensive mechanical properties, and the ability to manufacture various precision structures through subsequent mechanical machining. For tungsten alloy counterweights, W-Ni-Fe can provide relatively large mass within a limited space while also taking into account structural strength, processing, and long-term service reliability. Therefore, it is widely used in aerospace, automotive racing, industrial rotating equipment, precision instruments, and other high-density counterweight scenarios. When selecting materials specifically, the appropriate W-Ni-Fe grade should be selected according to target density, mass tolerance, mechanical properties, magnetic properties, structural dimensions, and processing requirements, and the final performance cannot be judged only by the material name W-Ni-Fe.





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19 What Material Is W-Ni-Cu (Tungsten-Nickel-Copper) ?

W-Ni-Cu (Tungsten-Nickel-Copper) is a tungsten heavy alloy (Tungsten Heavy Alloy) composed primarily of W (Tungsten) as the high-density phase, with Ni (Nickel) and Cu (Copper) serving as the binder phase. It is typically manufactured through powder metallurgy, including batching, mixing, compaction, and liquid-phase sintering to form a high-density material. W-Ni-Cu combines the high density of tungsten with the toughness, ductility, and machinability provided by the metallic binder phase. As a result, it is commonly used for tungsten alloy counterweights, balancing weights, inertial components, vibration-damping components, and certain precision structures with specific magnetic-performance requirements.

1. What exactly is W-Ni-Cu?

W-Ni-Cu is a tungsten-based heavy alloy whose main component is a high proportion of W (tungsten) particles, while Ni (nickel) and Cu (copper) form the binder phase. Unlike pure tungsten, W-Ni-Cu does not rely solely on tungsten as the structural material. Instead, tungsten particles provide high density, while the Ni-Cu binder phase improves bonding between the tungsten particles and provides better overall mechanical and manufacturing characteristics.

Its typical manufacturing route consists of batching and mixing tungsten powder, nickel powder, and copper powder according to a designed ratio, followed by compaction and liquid-phase sintering to produce a high-density tungsten heavy alloy. After sintering, precision counterweights can also be manufactured through turning, milling, drilling, grinding, and other machining processes.

2. How much tungsten does W-Ni-Cu typically contain?

W-Ni-Cu is a high-tungsten-content material. The specific W content depends on the target density, mechanical properties, magnetic properties, and intended application. In engineering applications, common tungsten heavy alloy systems typically have a high W mass fraction, such as approximately 90%–97% W.

Increasing the W content generally helps increase overall density because the theoretical density of W is approximately 19.25 g/cm³, while Ni and Cu have lower densities than W. However, the actual density of the finished product is also affected by powder particle size, compaction conditions, sintering densification, and residual porosity.

Therefore, the name W-Ni-Cu alone cannot determine whether the material has a density of exactly 18.0 g/cm³, 18.5 g/cm³, or another fixed value. The actual density should be determined according to the specific material grade and test results.



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3. What roles do W, Ni, and Cu play in the material?

W (Tungsten) is primarily responsible for providing high density, high mass-to-volume ratio, and relatively high-temperature resistance. It is the key element responsible for the high density of W-Ni-Cu. Ni (Nickel) primarily participates in forming the binder phase and helps improve bonding between tungsten particles and the stability of the sintered microstructure. Cu (Copper) forms the binder phase together with Ni and affects the material's ductility, machinability, thermal conductivity, and magnetic response. The three elements do not perform completely independent functions. The final material properties depend on the elemental proportions, tungsten particle size, binder-phase distribution, and sintering process.

4. Why is W-Ni-Cu suitable for tungsten alloy counterweights?

One of the most important advantages of W-Ni-Cu is its high density, which allows a relatively large counterweight mass to be achieved within a limited volume. For example, if 18.0 g/cm^3 W-Ni-Cu is used to manufacture a 1 kg counterweight, the theoretical material volume is $V = 1000 / 18.0 \approx 55.56 \text{ cm}^3$. If steel with a density of 7.85 g/cm^3 is used, the required volume is approximately $1000 / 7.85 \approx 127.39 \text{ cm}^3$. At the same mass, the tungsten alloy requires only about 43.6% of the volume required by steel, representing a volume reduction of approximately 56.4%. This high mass-to-volume ratio provides significant design value for space-constrained counterweight structures in automotive, aerospace, robotics, precision machinery, and electronic equipment.

5. What is the difference between W-Ni-Cu and pure tungsten?

The theoretical density of pure tungsten is approximately 19.25 g/cm^3 , which is higher than that of most W-Ni-Cu tungsten heavy alloys. Therefore, when density alone is compared, pure tungsten provides a higher mass-to-volume ratio. However, pure tungsten is relatively difficult to machine, particularly when manufacturing complex holes, grooves, threads, irregular geometries, and precision components in volume production. W-Ni-Cu uses a Ni-Cu binder phase to improve overall manufacturing characteristics while maintaining relatively high density, making it more suitable for complex-shaped counterweights. For example, the theoretical volume of 1 kg of pure tungsten is approximately $1000 / 19.25 \approx 51.95 \text{ cm}^3$, while 18.0 g/cm^3 W-Ni-Cu requires approximately 55.56 cm^3 . The difference is only about 3.61 cm^3 . For many counterweight products, this limited difference in volume can be exchanged for better machinability and structural adaptability.

6. What are the main properties of W-Ni-Cu?

W-Ni-Cu generally offers high density, good ductility, a certain degree of toughness, and good machinability. Its specific properties are closely related to W content, the Ni/Cu ratio, tungsten particle size, sintering temperature, and microstructure. Compared with pure tungsten, W-Ni-Cu is generally more suitable for machining and complex structural manufacturing. Compared with ordinary steel, it has significantly higher density and can



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achieve the same mass within a smaller space. In addition, the Ni-Cu binder phase also affects the material's thermal conductivity, electrical conductivity, and magnetic response. Therefore, W-Ni-Cu is not simply a counterweight material designed only to maximize density.

7. What are the magnetic properties of W-Ni-Cu?

One reason W-Ni-Cu attracts attention in certain applications is its generally low magnetic response. Compared with W-Ni-Fe (Tungsten-Nickel-Iron), which contains Fe (Iron), W-Ni-Cu does not contain Fe and is therefore generally more suitable for certain precision structures where magnetic response needs to be controlled. However, low magnetic response does not mean that every W-Ni-Cu product has exactly the same non-magnetic characteristics. Specific magnetic permeability and magnetic response can still be affected by material composition, impurities, microstructure, and manufacturing processes. If the counterweight is used near magnetic sensors, precision electronic equipment, gyroscopes, inertial measurement units, or other magnetically sensitive environments, specific magnetic-performance requirements should be stated directly, and the supplier should provide corresponding test data for the material.

8. How is W-Ni-Cu manufactured?

W-Ni-Cu is typically manufactured using powder metallurgy. First, the W, Ni, and Cu ratios are determined according to the target density and material properties. The powders are then mixed and compacted into the required shape, followed by liquid-phase sintering to achieve high densification. During sintering, the Ni-Cu binder phase forms a liquid phase and wets the tungsten particles, promoting particle rearrangement and densification. The resulting material consists of a composite microstructure of tungsten particles and a metallic binder phase.

For precision counterweights, the sintered product is typically subjected to further machining, including turning, milling, drilling, grinding, and thread machining. Density testing, dimensional inspection, weighing, and visual inspection are then performed to verify whether the product meets the design requirements.

9. What types of counterweights can be manufactured from W-Ni-Cu?

W-Ni-Cu can be manufactured into cylindrical counterweights, disc counterweights, ring-shaped counterweights, block-shaped counterweights, plate-shaped counterweights, spherical or irregular counterweights, as well as components with center holes, mounting holes, counterbores, threaded holes, and locating grooves.

For rotating equipment, precision machining can also be used to control mass distribution and installation position. The centrifugal force in a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass



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to the rotational axis. Therefore, for high-speed rotating counterweights, simply achieving the specified total weight is not sufficient. Eccentricity, concentricity, radial runout, installation position, and mass distribution must also be controlled.

10. What is the difference between W-Ni-Cu and W-Ni-Fe?

W-Ni-Cu and W-Ni-Fe are both common tungsten heavy alloy systems. Their primary difference lies in the composition of the binder phase. W-Ni-Cu uses a Ni-Cu binder phase, while W-Ni-Fe uses a Ni-Fe binder phase.

Comparison Item	W-Ni-Cu	W-Ni-Fe
Main high-density element	W (Tungsten)	W (Tungsten)
Binder phase	Ni-Cu	Ni-Fe
High-density capability	High	High
Magnetic response	Generally lower	Generally more noticeable
Ductility and machinability	Good	Good, depending on grade
Typical applications	Counterweights, precision structures, selected low-magnetic applications	Counterweights, structural components, aerospace, automotive, etc.

Actual material properties cannot be determined solely from the alloy system designation. The specific grade's density, tensile strength, elongation, hardness, magnetic properties, and machinability should also be evaluated.

11. What counterweight applications are suitable for W-Ni-Cu?

W-Ni-Cu is suitable for certain counterweight applications requiring high density, small volume, and relatively low magnetic response, such as precision instrument counterweights, electronic equipment counterweights, inertial components, vibration counterweights, selected aerospace structures, and high-density mechanical balancing components. If the counterweight must fit within a fixed installation space, the high-density material can be used to increase mass per unit volume. If it is used in a rotating system, precision machining can be used to adjust mass distribution to meet dynamic balancing requirements. For example, if a 500 g counterweight is made from material with a density of 18.0 g/cm³, the theoretical material volume is approximately $500 / 18.0 \approx 27.78$ cm³. If the actual product contains mounting holes and grooves, the calculation should be based on the net material volume after subtracting these features.

12. Why can W-Ni-Cu be used for precision miniature counterweights?

High density is one of the most important reasons why W-Ni-Cu is suitable for miniature counterweights. For a fixed mass, volume is inversely proportional to density, expressed as $V = m / \rho$. When the target mass remains unchanged, increasing material density reduces the required material volume. For example, a 100 g counterweight made from 18.0 g/cm³ material has a theoretical volume of approximately $100 / 18.0 = 5.56$ cm³, while 18.5 g/cm³ material requires approximately $100 / 18.5 = 5.41$ cm³. This volume difference may not be



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particularly significant for large counterweights, but in miniature motors, vibration mechanisms, precision instruments, and electronic equipment with extremely limited installation space, it may directly determine whether the target mass can be achieved within the available space.

13. What parameters should be considered when selecting W-Ni-Cu?

When selecting W-Ni-Cu tungsten alloy counterweights, it is not sufficient to specify only W-Ni-Cu as the material. The target density, target mass, dimensions, tolerances, structural configuration, magnetic properties, mechanical properties, surface treatment, and operating environment should also be specified. For products used in high-speed rotating components, additional requirements should be defined for mass tolerance, eccentricity, concentricity, radial runout, and dynamic balancing. For magnetically sensitive equipment, magnetic permeability or magnetic-response requirements should be clearly stated. For customized counterweights, the final mass should be verified through actual weighing, and the actual density should be confirmed through appropriate testing. Nominal density can be used for preliminary structural design but cannot completely replace final product inspection.

W-Ni-Cu (Tungsten-Nickel-Copper) is a tungsten heavy alloy in which W (Tungsten) acts as the primary high-density phase while Ni (Nickel) and Cu (Copper) form the binder phase. It is typically manufactured through powder metallurgy and liquid-phase sintering. Its main characteristics include high density, good overall mechanical properties, good machinability, and generally low magnetic response. It is suitable for tungsten alloy counterweights, precision balancing components, inertial components, and certain space-constrained precision structures.

Compared with W-Ni-Fe (Tungsten-Nickel-Iron), W-Ni-Cu has a Ni-Cu binder phase and can provide advantages in certain low-magnetic-response applications. Compared with pure tungsten, it has somewhat lower density but generally offers better overall manufacturing adaptability. Actual material selection should still be based on the specific grade's density, mechanical properties, magnetic characteristics, machining requirements, and operating environment.



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Q20 What Is the Difference Between W-Ni-Fe and W-Ni-Cu?

W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) are both common tungsten heavy alloys (Tungsten Heavy Alloy). Both use W (Tungsten) as the primary high-density element, while their main difference lies in the composition of the binder phase: W-Ni-Fe uses a Ni (Nickel)-Fe (Iron) binder phase, whereas W-Ni-Cu uses a Ni (Nickel)-Cu (Copper) binder phase. Both can be used for high-density tungsten alloy counterweights, but they differ in magnetic properties, mechanical properties, ductility, machinability, thermal characteristics, and typical application areas. In practical material selection, neither alloy should simply be considered universally superior to the other. The choice should be matched to the counterweight's mass, volume constraints, magnetic environment, mechanical loads, and machining requirements.

1. What is the most fundamental difference: the binder phase

Both W-Ni-Fe and W-Ni-Cu use a high proportion of W particles as the primary high-density phase, but their binder phases are different. In W-Ni-Fe, the binder phase is primarily composed of Ni-Fe, with tungsten particles distributed within the Ni-Fe binder phase. In W-Ni-Cu, the binder phase is primarily composed of Ni-Cu, producing a microstructure different from that of W-Ni-Fe. This difference further affects magnetic properties, ductility, mechanical properties, machining behavior, and thermal properties.



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Item	W-Ni-Fe	W-Ni-Cu
Main elements	W, Ni, Fe	W, Ni, Cu
High-density phase	W (Tungsten)	W (Tungsten)
Main binder phase	Ni-Fe	Ni-Cu
Density	Generally available in high-density grades	Generally available in high-density grades
Magnetic response	Generally more noticeable	Generally lower
Overall mechanical properties	Good	Good
Ductility	Good, depending on grade	Good, depending on grade
Typical advantages	Strength and overall performance	Low magnetic response, specific machining and thermal requirements
Common applications	Structural counterweights, aerospace, automotive	Precision counterweights, low-magnetic environments, electronics, instruments, etc.

2. Why do both materials have high density?

The high density of both materials primarily comes from W (Tungsten). The theoretical density of tungsten is approximately 19.25 g/cm³. Therefore, when the material contains a high proportion of tungsten, it can achieve a density significantly higher than that of steel and lead.

Common high-density tungsten alloys can reach approximately 17–18.5 g/cm³, although specific grades may cover a broader density range. The actual density depends on W content, binder-phase proportion, powder particle size, sintering densification, and final microstructure. Therefore, although W-Ni-Fe and W-Ni-Cu have different binder phases, both can be used to manufacture compact, high-mass counterweights.

3. At the same mass, the volume difference between the two is usually not as large as the alloy names might suggest

If W-Ni-Fe and W-Ni-Cu have similar density grades, their volumes at the same mass will usually be very close. For example, if both are calculated at 18.0 g/cm³, the theoretical material volume of a 1 kg counterweight is $V = 1000 / 18.0 \approx 55.56 \text{ cm}^3$ for both materials. If a specific W-Ni-Fe grade has a density of 18.0 g/cm³ while a specific W-Ni-Cu grade has a density of 17.5 g/cm³, the required volumes for 1 kg are approximately 55.56 cm³ and 57.14 cm³, respectively. The difference therefore comes primarily from the actual material density rather than simply from the names Fe and Cu. For counterweight design, the actual density of the specific grade should be compared rather than assuming volume characteristics solely from whether the alloy is W-Ni-Fe or W-Ni-Cu.

4. Magnetic properties are one of the most important differences

W-Ni-Fe contains Fe (Iron) and therefore generally exhibits a more noticeable magnetic response than W-Ni-Cu. The exact magnetic behavior is also affected by Ni (Nickel) content,



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microstructure, and processing condition. W-Ni-Cu does not contain Fe and generally has lower magnetic response, making it potentially advantageous in certain magnetically sensitive environments. For example, when a counterweight is installed near magnetic sensors, gyroscopes, inertial measurement units, precision instruments, or other equipment sensitive to magnetic fields, W-Ni-Cu may deserve priority evaluation. However, low magnetic response does not mean that every W-Ni-Cu product has identical magnetic properties. For products with strict magnetic permeability requirements, specific magnetic-performance criteria should be defined and verified using actual material test data.

5. How do their mechanical properties differ?

W-Ni-Fe generally provides good strength, toughness, and overall mechanical performance, making it suitable for structural counterweights subjected to mechanical loads, impact, or vibration. W-Ni-Cu can also provide good ductility and toughness, but its specific mechanical properties are closely related to the Ni-Cu binder-phase ratio, W content, tungsten particle size, and sintering process. Therefore, it is not appropriate to state categorically that W-Ni-Fe is always stronger than W-Ni-Cu or that W-Ni-Cu is always softer than W-Ni-Fe. For an actual comparison, the specific grade's tensile strength, yield strength, elongation, hardness, and fracture toughness should be reviewed directly. For ordinary fixed counterweights, mechanical properties may not be the primary limiting factor. For high-speed rotating components, automotive parts, aerospace structures, and counterweights exposed to impact or vibration, mechanical properties become significantly more important.

6. How do their machining characteristics differ?

Both materials can be manufactured through powder metallurgy and subsequently processed by turning, milling, drilling, grinding, threading, and other machining methods. Because their binder phases are different, W-Ni-Fe and W-Ni-Cu may exhibit different tool wear behavior, cutting-parameter adaptability, surface finish, and machining efficiency. Specific differences are also affected by W content, tungsten particle size, sintered microstructure, and machining equipment. Therefore, when a product contains numerous precision holes, deep holes, threads, or complex geometries, the material should be evaluated together with the machining process rather than selected solely on the basis of density.

7. Thermal properties are also an important difference

W (Tungsten) itself has a very high melting point and good high-temperature characteristics, but the overall thermal properties of W-Ni-Fe and W-Ni-Cu are also affected by their respective binder phases. Cu (Copper) has relatively high thermal conductivity, so the Ni-Cu binder phase can give W-Ni-Cu thermal conduction characteristics different from those of W-Ni-Fe. If the tungsten alloy counterweight is installed in equipment with significant heat



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sources or temperature gradients, such as certain engines, electronic equipment, precision instruments, or thermal-management structures, thermal expansion coefficient, thermal conductivity, and operating temperature should be evaluated in addition to density.

8. How should the two materials be selected for counterweight applications?

If the primary requirements are high density, structural strength, and overall mechanical performance, W-Ni-Fe is generally a material system worth evaluating, particularly for automotive, racing, aerospace, mechanical rotating components, and structural counterweights. If the product is more sensitive to magnetic response, specific thermal properties, or precision-instrument requirements, W-Ni-Cu may deserve particular consideration. For example, if a 1 kg counterweight must fit into an installation space of approximately 55 cm³, an 18.0 g/cm³ material can essentially satisfy the volume requirement. If the same counterweight is also installed near magnetically sensitive equipment, material selection cannot be based on density alone. The magnetic properties of W-Ni-Fe and W-Ni-Cu must also be compared.

9. Can both materials be used for dynamic counterweights?

Both W-Ni-Fe and W-Ni-Cu can be manufactured into cylindrical, disc, ring-shaped, block-shaped, irregular, and drilled counterweights. Precision machining can be used to control dimensions and mass distribution. For rotating components, total mass is only one parameter. The centrifugal force in a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the rotational axis. The moment of inertia is also related to mass and its distance from the rotational axis. Therefore, regardless of whether W-Ni-Fe or W-Ni-Cu is used, the counterweight's mass tolerance, center of gravity, eccentricity, installation position, concentricity, and radial runout must be controlled. The alloy system does not change the fundamental design principles of dynamic balancing.

10. In actual procurement, it is not sufficient to specify only W-Ni-Fe or W-Ni-Cu

When ordering customized tungsten alloy counterweights, specifying only W-Ni-Fe or W-Ni-Cu is generally insufficient. The technical specification should preferably define the target density, W content or material grade, target mass, dimensions, tolerances, hole locations, surface treatment, mechanical properties, and magnetic-performance requirements. For example, a specific density-grade W-Ni-Fe alloy can be specified for high-speed rotating counterweights, together with mass tolerance, concentricity, and radial runout requirements. If W-Ni-Cu is selected, low magnetic response and the corresponding testing requirements can be specified.

CTIA GROUP can match the density, magnetic properties, structural dimensions, and machining requirements of W-Ni-Fe and W-Ni-Cu tungsten alloy counterweights according to specific applications, and develop corresponding counterweight structures and manufacturing solutions for different alloy systems.



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11. The difference between W-Ni-Fe and W-Ni-Cu can be understood in this way

If a tungsten alloy counterweight is viewed as a material consisting of a high-density framework and a metallic binder phase, both materials derive their high density primarily from W (Tungsten). Their main difference comes from the binder phase: W-Ni-Fe uses Ni-Fe, while W-Ni-Cu uses Ni-Cu. W-Ni-Fe is more commonly considered when structural strength, overall mechanical performance, and high density are important, particularly for structural counterweights. W-Ni-Cu may offer advantages in certain low-magnetic-response applications, as well as applications with specific thermal or machining requirements. Both materials can be manufactured into high-density counterweights through powder metallurgy followed by precision machining. W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) differ primarily in their binder phases: W-Ni-Fe uses a Ni-Fe binder phase, while W-Ni-Cu uses a Ni-Cu binder phase. Both use W (Tungsten) as the primary high-density element and can achieve high density for compact counterweight applications. From an application perspective, W-Ni-Fe is generally suitable for structural counterweights requiring strength, toughness, and overall mechanical performance, while W-Ni-Cu is often considered for precision counterweights requiring lower magnetic response or specific thermal and machining characteristics. However, these are general characteristics at the alloy-system level. Actual product selection should be based on the specific grade's density, composition, mechanical properties, magnetic characteristics, and machining data.





Q21 What Effect Does Tungsten Content Have on Tungsten Alloy Counterweights?

Tungsten content is one of the important material parameters affecting the performance and application of tungsten alloy counterweights. For tungsten alloys in which W (Tungsten, 钨) is the primary high-density phase, changes in W content directly affect material density and, in turn, counterweight volume, mass distribution, dimensional design, mechanical properties, machinability, and cost. However, a higher tungsten content does not necessarily mean that a counterweight will be better for every application. The actual material needs to be selected according to a balance among density, volume, strength, toughness, machinability, and cost.

(1) Higher tungsten content generally results in higher density

The theoretical density of W (Tungsten, 钨) is approximately 19.25 g/cm³, while the densities of binder-phase metals such as Ni (Nickel, 镍), Fe (Iron, 铁), and Cu (Copper, 铜) are lower than that of tungsten. Therefore, when other conditions are similar, increasing the mass fraction of tungsten in a tungsten alloy generally increases the final material density. Common high-density tungsten alloy counterweights typically have densities in the range of approximately 17–18.5 g/cm³, although specific material grades may cover a broader range. Actual density is affected not only by W content but also by the proportions of the Ni-Fe or Ni-Cu binder phase, powder particle size, porosity, and sintering conditions. Therefore, W content and density are strongly correlated, but the final product density cannot be calculated simply from W content alone.

(2) Increasing tungsten content can further reduce counterweight volume

The basic relationship for a counterweight is $V = m / \rho$, where V is volume, m is mass, and ρ is material density. At the same mass, the higher the density, the smaller the required material volume. For example, when manufacturing a 1000 g tungsten alloy counterweight, if the material density is 17.0 g/cm³, $V = 1000 / 17.0 \approx 58.82$ cm³; if the density increases to 18.5 g/cm³, $V = 1000 / 18.5 \approx 54.05$ cm³. The difference is approximately 4.77 cm³. For counterweight structures with very limited available space, this difference in volume can directly determine whether the product can be installed in the specified location.

(3) At the same volume, a higher-tungsten-content material can provide greater mass

If the external dimensions of a counterweight have already been determined, increasing material density allows greater mass to be obtained within the same volume. For example, for a counterweight with an effective material volume of 10 cm³, the mass is $m = 17.0 \times 10 = 170$ g at a density of 17.0 g/cm³, while $m = 18.5 \times 10 = 185$ g at a density of 18.5 g/cm³, representing a difference of 15 g. This is particularly important for products where available space is fixed and the required mass must be achieved through the material itself, such as small actuator counterweights, precision instrument weights, rotating-component balance weights, and certain aerospace counterweights.



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(4) Tungsten content affects mass-distribution design

A tungsten alloy counterweight is not simply designed to achieve a specified total mass; it often needs to control how that mass is distributed within a specific space. For a rotating system, centrifugal force can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the mass center of gravity to the rotational axis. At the same mass, a higher-density material can complete the required mass arrangement within a smaller structural volume, leaving more space for the rest of the structural design. The moment of inertia can be expressed as $I = \sum m_i r_i^2$, where m_i is each individual mass element and r_i is its distance from the rotational axis. For products that require adjustment of the moment of inertia, increasing tungsten content and material density can change how mass is distributed within the available space, providing greater flexibility for inertia design. This is one reason why high-density tungsten alloys are commonly used in high-speed rotating components, inertial elements, and precision balance weights.

(5) Higher tungsten content does not necessarily mean universally improved mechanical properties

As tungsten content increases, the proportion of tungsten particles in the material increases while the proportion of the binder phase decreases accordingly. Although higher tungsten content generally helps achieve higher density, strength, ductility, toughness, and fracture behavior do not simply increase in parallel with W content. Tungsten alloys are typical two-phase or multiphase materials, and their properties are closely related to tungsten particle size, particle morphology, binder-phase composition, interfacial bonding, porosity, and sintered microstructure. For example, even if two materials both have densities of approximately 18.0 g/cm^3 , one based on a W-Ni-Fe (Tungsten-Nickel-Iron, 钨-镍-铁) system and the other based on a W-Ni-Cu (Tungsten-Nickel-Copper, 钨-镍-铜) system may still have significant differences in mechanical and magnetic properties. Therefore, W content alone cannot be used to determine whether a tungsten alloy counterweight has higher strength or better reliability.

(6) Tungsten content affects ductility and toughness

Tungsten has high density, a high melting point, and relatively high hardness, but it is not used at room temperature as a highly ductile metal. Tungsten alloys use Ni-Fe or Ni-Cu binder phases to bond large amounts of tungsten particles together, allowing the material to combine high density with a certain degree of plasticity and toughness. As W content continues to increase, the proportion of the binder phase decreases, which can reduce the available capacity for plastic deformation. If the bonding between tungsten particles and the microstructure are not properly controlled, the risk of brittle failure may also increase. For counterweights subjected to impact, vibration, or cyclic loading, such as those used in automobiles, racing vehicles, aerospace systems, and high-speed rotating components, W content should not be increased indefinitely merely to pursue maximum density. Toughness and fatigue reliability must also be considered.



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(7) Tungsten content also affects machinability

A higher W content means that machining involves a greater proportion of the high-density tungsten phase, which can affect cutting resistance, tool wear, and machining efficiency. Tungsten alloy counterweights can generally be turned, milled, drilled, ground, and threaded, but the actual machining difficulty depends on W content, tungsten particle size, binder-phase composition, sintered microstructure, and material condition. For relatively simple cylindrical, disc-shaped, and block-shaped counterweights, the machining impact associated with higher W content may be relatively easy to control. For products featuring deep holes, fine threads, thin walls, complex curved surfaces, or tight dimensional tolerances, machining considerations should be incorporated into material selection from the beginning.

(8) Tungsten content affects material cost

W (Tungsten, 钨) is a high-value metal, so under otherwise similar conditions, increasing W content generally increases material cost. For example, when producing the same 1 kg counterweight, increasing material density from 17.5 g/cm³ to 18.5 g/cm³ can reduce the required volume, but the unit material cost, powder cost, sintering cost, and machining cost may also change. Therefore, for large counterweights where installation space is not restrictive, the volume advantage obtained by increasing W content may not offset the additional material cost. For small, high-value, precision counterweights where space is highly constrained, the spatial value of a high-density material may be considerably more important.

(9) Different tungsten contents are suitable for different counterweight designs

The effect of tungsten content on counterweights can be understood as a design trade-off. Higher W content generally helps increase density, reduce volume, and increase mass per unit volume, while materials with moderate or lower W content may provide a different balance among cost, machinability, and certain mechanical properties. For example, in miniature counterweights where available space is extremely limited, higher-density grades may be preferred; for larger industrial counterweights with sufficient installation space, it may not be necessary to pursue the highest possible W content. For high-speed rotating counterweights, density must be evaluated together with mechanical properties, dimensional accuracy, and dynamic balancing performance.

(10) Tungsten content and final density are not exactly equivalent

In actual production, even two products with the same W content may have differences in final density. This is because actual tungsten alloy density is also affected by binder-phase composition, powder-mixing uniformity, compaction density, liquid-phase sintering conditions, residual porosity, and final microstructure. In material design, theoretical density can be estimated from the mass fractions and theoretical densities of the individual constituents using $1 / \rho_{\text{theoretical}} = \sum (w_i / \rho_i)$, where w_i is the mass fraction of each



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constituent and ρ_i is its corresponding density. However, this calculation is primarily used during material design. The actual density of a finished tungsten alloy counterweight should still be determined through measurement of its mass and effective volume.

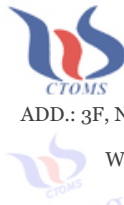
(11) For precision counterweights, tungsten content should not be considered alone

If a product is used for dynamic balancing, W content is only one material parameter. The actual counterweight must also meet requirements for mass tolerance, external dimensions, hole and groove locations, concentricity, radial runout, eccentricity, and center of gravity. For example, an 18.5 g/cm³ counterweight with significant eccentricity after machining may still provide poor dynamic balancing performance. Conversely, a counterweight with slightly lower density but well-controlled mass distribution and machining accuracy may fully satisfy the balancing requirements of a particular piece of equipment. For different tungsten-content requirements, CTIA GROUP can match material density and W content according to the target mass, available installation space, and structural accuracy, while also considering the counterweight's loading conditions, machining difficulty, and mass tolerance to determine an appropriate material and manufacturing solution.

(12) How should tungsten content be selected according to actual requirements?

If the design priority is minimum volume and maximum mass per unit volume, a higher-W-content, higher-density material can be considered. If sufficient installation space is available, material cost and machining performance can be evaluated together. If the counterweight is subjected to high-speed rotation, impact, or cyclic loading, toughness, strength, fatigue performance, and microstructural stability should also receive particular attention. For the two common systems, W-Ni-Fe and W-Ni-Cu, the binder-phase type, specific W content, target density, and mechanical and magnetic performance requirements should be clearly defined. Instead of simply specifying a high-tungsten alloy, the actual material grade or technical specifications should be identified.

The most direct effect of tungsten content on a tungsten alloy counterweight is its influence on density. Generally, when other conditions are similar, the higher the W (Tungsten, 钨) content, the higher the material density, the smaller the volume required for a counterweight of the same mass, and the greater the mass that can be achieved within the same volume. At the same time, increasing W content also affects the proportion of the binder phase, mechanical properties, ductility, toughness, machinability, and material cost. For precision counterweights, the highest possible W content is not necessarily the most suitable solution. A rational material selection should consider density, space limitations, mass requirements, mechanical loading, machining accuracy, magnetic properties, and cost as a whole.



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Q22 Is a High-Density Tungsten Alloy Counterweight Always Better?

Not necessarily. The greatest advantage of a high-density tungsten alloy counterweight is that it occupies less volume for the same mass. However, a higher density does not necessarily mean better overall performance. For an actual counterweight, the selected material should simultaneously satisfy requirements for mass, volume, mechanical properties, machining accuracy, dynamic balancing, magnetic properties, cost, and service environment. Common high-density tungsten alloy counterweights typically have densities of approximately 17–18.5 g/cm³, although different material systems and grades may cover a broader range. The key to determining whether a tungsten alloy counterweight is suitable is not simply pursuing the highest possible density, but determining whether its density matches the structural and functional requirements of the product.

(1) The most direct advantage of high density is a reduction in counterweight volume

The relationship among counterweight mass, density, and volume is $V = m / \rho$, where V is volume, m is mass, and ρ is density. At the same mass, the higher the density, the smaller the required material volume. For example, for a 1 kg counterweight, a material with a density of 17.5 g/cm³ requires $V = 1000 / 17.5 \approx 57.14$ cm³, while a material with a density of 18.5 g/cm³ requires $V = 1000 / 18.5 \approx 54.05$ cm³, a difference of approximately 3.09 cm³. If the



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available installation space inside the equipment is extremely limited, even a few cubic centimeters can have practical significance.

(2) The value of high-density materials is more apparent when space is limited

For aerospace equipment, unmanned aerial vehicles, precision instruments, electronic devices, and miniature machinery, counterweights are often constrained by available installation space. For example, a 100 g counterweight requires $V = 100 / 17.0 \approx 5.88 \text{ cm}^3$ at a density of 17.0 g/cm^3 , while only approximately 5.41 cm^3 is required at 18.5 g/cm^3 . If the counterweight is installed inside a narrow cavity, thin-walled structure, or complex mechanism, a high-density material can reduce the occupied space and leave more design clearance for other components, wiring, and moving mechanisms.

(3) However, if sufficient space is available, the benefit of further increasing density may decrease

If the equipment already has sufficient installation space, the volume reduction obtained by increasing density from 17.5 g/cm^3 to 18.5 g/cm^3 may not be the primary design consideration. For example, if a large mechanical counterweight requires less than 100 cm^3 of installation space while the structure can accommodate 120 cm^3 , pursuing the highest possible density may not provide a significant product benefit. In such cases, material cost, machinability, mechanical properties, supply stability, and manufacturing lead time can be compared instead of simply pursuing maximum density.

(4) High density does not necessarily mean better mechanical properties

The density of a tungsten alloy is mainly affected by W (Tungsten, 钨) content and binder-phase composition, but the strength, toughness, and ductility of the material are not determined by density alone. Tungsten alloys generally consist of a large proportion of W particles combined with Ni (Nickel, 镍)-Fe (Iron, 铁) or Ni-Cu (Copper, 铜) binder phases. Increasing W content generally helps increase density, but it also changes the binder-phase proportion and microstructure. For counterweights subjected to impact, vibration, or cyclic loading, blindly pursuing high W content and maximum density while neglecting material toughness and microstructural quality may actually be unfavorable to long-term reliability.

(5) Higher density may result in higher material costs

W (Tungsten, 钨) is a high-value metal, and increasing tungsten content generally increases the value of the raw material. For example, if both 17.5 g/cm^3 and 18.5 g/cm^3 materials meet the installation-space requirements of a particular product, the 18.5 g/cm^3 material can further reduce the volume, but if the product is not subject to strict space limitations, its additional material cost may need to be reconsidered. This difference is particularly important for large-volume industrial counterweights because even a small increase in the material cost per piece can become significant across a large procurement quantity.



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(6) Higher density may introduce additional machining considerations

The high proportion of W particles in tungsten alloys affects machining behavior, together with factors such as W content, particle size, binder-phase composition, and sintered microstructure. For simple cylindrical, disc-shaped, and block-shaped counterweights, machining can generally be controlled relatively easily. However, for structures involving deep holes, fine holes, threads, thin walls, or complex curved surfaces, the specific machining characteristics of the high-density material require careful evaluation. Particularly for products requiring extensive machining, material cost is not the only cost factor; tool consumption, machining time, equipment loading, dimensional control, and subsequent inspection must also be considered.

(7) Dynamic counterweights cannot be evaluated by density alone

For rotating counterweights, high density is only a material-level advantage. The actual dynamic balancing performance is determined by mass and its spatial distribution. The centrifugal force in a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of gravity of the mass to the rotational axis. The moment of inertia can be expressed as $I = \sum m_i r_i^2$, where m_i is each mass element and r_i is its distance from the rotational axis. Therefore, even if an 18.5 g/cm³ counterweight has a higher density, significant eccentricity, hole-position errors, installation-position errors, or excessive radial runout may still prevent it from achieving ideal dynamic balancing performance. For high-speed rotors, engine components, racing components, and precision rotating mechanisms, mass distribution and machining accuracy can be just as important as density.

(8) High density does not directly determine magnetic properties

Different tungsten alloy systems can have different magnetic properties even when their densities are similar. W-Ni-Fe (Tungsten-Nickel-Iron, 钨-镍-铁) contains Fe and generally exhibits a more noticeable magnetic response than W-Ni-Cu, while W-Ni-Cu (Tungsten-Nickel-Copper, 钨-镍-铜) generally has a lower magnetic response. Therefore, if a counterweight is installed near a magnetic sensor, gyroscope, inertial measurement unit, or other magnetically sensitive device, increasing density alone cannot solve magnetic-performance requirements. The magnetic properties of the specific material grade must also be tested and controlled.

(9) High-density materials are not necessarily suitable for every structure

Counterweight design is also constrained by dimensions, tolerances, connection methods, and installation locations. For example, if a counterweight must be secured with threads, a material may have very high density but still require consideration of machinability and structural strength if the design contains fine threads, thin walls, and complex holes or grooves. Conversely, for a simple embedded counterweight block with a relatively thick structure and few machining features, the volume-reduction advantage of a high-density



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material can be utilized more effectively.

(10) The real objective should be an appropriate density, not the highest density

Tungsten alloy counterweights can be understood as having an application-specific density range. When installation space is extremely limited, densities of approximately 18.0–18.5 g/cm³ or even higher may be considered. When space requirements are moderate, materials in the range of approximately 17–18 g/cm³ can be compared more comprehensively in terms of cost and performance. If the product is more sensitive to mass distribution, mechanical strength, or machining performance, the priority should be given to a material grade that satisfies the overall technical requirements. In other words, the design objective should be the most appropriate density that satisfies the product requirements, rather than simply the maximum possible density.

(11) Selection logic for high-density versus moderate-density counterweights

Several typical scenarios illustrate the selection logic. For miniature equipment with extremely limited space, high density generally provides a clear advantage because volume reduction can directly determine whether the counterweight can be installed. For high-speed rotating components, density, mass distribution, concentricity, radial runout, and dynamic balancing should all receive close attention. For structures subjected to impact or vibration, strength, toughness, and fatigue performance should be prioritized. For large industrial counterweights, material cost, machining efficiency, and supply stability can receive greater consideration. For tungsten alloy counterweights with different density grades, CTIA GROUP can match the density grade, material system, and counterweight dimensions according to the target mass, available installation space, and structural loading conditions, avoiding unnecessary material and machining costs caused simply by pursuing the highest possible density.

(12) Which parameters should be compared during actual material selection?

To determine whether a particular high-density tungsten alloy counterweight is suitable for a specific project, it is recommended to compare density, W content, binder-phase type, tensile strength, elongation, hardness, magnetic properties, machinability, dimensional tolerances, mass tolerances, surface treatment, material cost, and supply capability. For dynamic counterweights, eccentricity, concentricity, radial runout, center-of-gravity position, and dynamic balance grade should also be considered. Such a comparison has greater engineering value because a counterweight ultimately needs to achieve an integrated balance among mass and space, mass distribution and motion state, material performance, and manufacturing cost.

A high-density tungsten alloy counterweight is therefore not necessarily better simply because its density is higher. The most obvious advantage of increasing density is that the same mass can be achieved in a smaller volume, which is particularly valuable for space-constrained applications such as aerospace systems, unmanned aerial vehicles,



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electronic devices, precision instruments, and miniature machinery. However, increasing density may also involve changes in material cost, machining difficulty, microstructure, and mechanical properties. For an actual product, the more appropriate approach is to select a suitable density grade according to installation space, target mass, mechanical loading, dynamic balancing, magnetic properties, machining accuracy, and cost requirements, rather than simply pursuing the highest possible density.



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IV. Pricing, Procurement, and Customization of Tungsten Alloy

Counterweights

What Are the Main Factors to Consider When Pricing, Procuring, and Customizing Tungsten Alloy Counterweights?

The price of a tungsten alloy counterweight is not calculated simply based on the price per kilogram of tungsten material. Instead, it is determined by a combination of factors including the material system, tungsten content, density, product weight, dimensions and structural complexity, machining difficulty, precision requirements, order quantity, molds and tooling, inspection requirements, surface treatment, and delivery conditions. For customized counterweights, the final quotation is generally a combination of material costs, manufacturing costs, and fixed order-related costs. Based on thirty years of experience in the design, customization, and machining of tungsten alloy products at CTIA GROUP, the main factors can be summarized as follows.

Material and Density Are Fundamental Factors

The tungsten content of a tungsten alloy directly affects material density and raw material cost. Common high-density tungsten alloy counterweights generally have densities in the range of approximately 17–18.5 g/cm³, although specific material grades may differ. For the same dimensions, a higher density results in greater product weight; for the same weight, a higher density requires a smaller material volume. For example, a 1 kg tungsten alloy with a density of 18.0 g/cm³ has a volume of approximately 55.56 cm³, whereas at 17.0 g/cm³, the volume is approximately 58.82 cm³. For space-constrained products, increasing density can



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provide significant engineering value, but the price is also generally affected by tungsten content and material grade.

Common material systems include W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). These two systems may differ in magnetic properties, mechanical properties, machinability, cost. Therefore, procurement decisions should not be based solely on density.

Product Dimensions and Structural Complexity

For tungsten alloy counterweights with the same weight, manufacturing costs can vary significantly if one is a simple cylinder while the other contains steps, holes, grooves, inclined surfaces, and complex curved surfaces. Simple block-shaped, cylindrical, and ring-shaped counterweights are generally easier to produce through powder metallurgy, while complex structures may require more post-sintering CNC machining. A greater number of holes, more complex structures, and more machined surfaces generally result in increased machining time, tool consumption, and inspection costs. If the product requires internal threads, precision holes, positioning grooves, or complex assembly surfaces, the corresponding machining processes also need to be included in the quotation.

Dimensional and Weight Tolerances

Precision requirements are one of the important factors affecting the price of customized products. For example, a conventional structural component may only require general dimensional accuracy, whereas a precision counterweight may simultaneously require dimensional tolerances, weight tolerances, hole-position tolerances, concentricity, radial runout, and center-of-gravity control. If the counterweight is used in rotating machinery, dynamic balancing may also be required. In this case, the supplier must not only ensure product dimensions and weight but also perform dynamic balance testing and adjust the counterweight mass and installation position according to the test results. Naturally, this increases manufacturing and inspection costs. Therefore, when requesting a quotation, it is preferable to specify the weight tolerance clearly, such as a target weight of 100.00 g with an allowable tolerance of ± 0.05 g, rather than simply stating 100 g.

Order Quantity Affects Unit Price

The cost structures of small-batch and large-batch production are significantly different. Small orders need to absorb fixed costs such as mold design, tooling preparation, equipment setup, sintering furnace scheduling, and first-article inspection. If the order contains only dozens or hundreds of pieces, these fixed costs are distributed across relatively few products, resulting in a higher unit price. As production volume increases, mold and tooling costs can be distributed across more products. At the same time, powder mixing, pressing, sintering, machining, and inspection processes can become more stable, while material utilization and production efficiency may improve, generally reducing unit



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cost. Therefore, procurement should not focus only on the price per piece; tiered quotations for quantities such as 100, 500, 1,000, and 5,000 pieces should also be compared.

Mold and Tooling Costs

When powder metallurgy (PM, Powder Metallurgy, 粉末冶金) is used and the product structure is suitable for die pressing, dedicated molds may be required. Mold costs are generally considered upfront fixed costs. If production volume is large, mold costs can be distributed across a large number of products; if the project is limited to prototypes or small-batch production, mold costs can have a significant impact on the unit price. Therefore, procurement should clarify whether mold charges are quoted separately, who owns the molds, whether subsequent orders will incur additional mold charges, and whether product modifications will require new molds.

Post-Sintering Machining Methods

After sintering, tungsten alloy can generally undergo turning, milling, drilling, tapping, grinding, and other machining operations. However, because tungsten alloys have relatively high hardness and multiphase microstructures, cutting-tool wear is generally higher than with conventional steels. If the product only requires sintered forming, post-machining costs are relatively low; if extensive precision turning, milling, and grinding are required, machining costs increase significantly. Small holes, deep holes, precision internal bores, precision threads, and complex curved surfaces in particular generally require longer machining times and stricter process control.

Material Utilization and Product Weight

Because tungsten alloy raw materials have relatively high value, material utilization also affects the final quotation. For example, a structurally simple counterweight that is close to its final sintered shape can reduce machining allowance; if a large amount of material must be removed from a larger sintered blank, additional machining time and material loss will result. For high-volume products, suppliers can generally reduce overall costs through optimized die geometry, near-net-shape forming, and optimized machining allowances.

Inspection and Quality Documentation

If the counterweight is used in a conventional consumer product, dimensional and weight inspection may be sufficient. If it is used in automotive, aerospace, medical equipment, or high-precision rotating machinery applications, more comprehensive quality control may be required. Common inspection items include density, weight, dimensions, hardness, material composition, appearance, hole position, concentricity, radial runout, surface roughness, and dynamic balance. Some projects may also require material certificates, inspection reports, batch traceability, first-article inspection reports, and other documentation. As the number of inspection items and precision requirements increases, the final procurement



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cost generally increases as well.

Surface Treatment and Environmental Requirements

Some tungsten alloy counterweights require nickel plating, coatings, polishing, or other surface treatments to meet requirements for appearance, corrosion resistance, assembly, or environmental adaptability. If the product is used in humid environments, marine environments, automotive chassis, or outdoor equipment, corrosion-protection requirements should also be evaluated according to the actual operating conditions. Surface treatment affects not only cost but potentially the final dimensions and weight. Therefore, for precision counterweights, coating thickness should be incorporated into the dimensional tolerance design.

What Should Be Compared During Procurement?

When procuring tungsten alloy counterweights, the most effective approach is not simply to compare the quoted price per kilogram from different suppliers, but to standardize the quotation conditions. This includes confirming the material system, tungsten content, target density, individual weight and tolerance, dimensions and tolerances, machining methods, surface treatment, inspection requirements, packaging, mold costs, transportation costs, lead time, and quotation validity. For example, if one supplier quotes RMB 1300/kg and another quotes RMB 1500/kg, but the first quotation excludes precision machining and dynamic balancing while the second includes all inspection and machining, directly comparing RMB 300/kg with RMB 350/kg does not accurately reflect the actual procurement cost. For customized projects, buyers should also require suppliers to clarify whether the quotation is calculated according to raw material weight, sintered blank weight, or finished-product weight, because these three quantities may differ significantly.

The More Complete the Information Provided for Custom Quotation, the More Accurate the Price

When requesting a customized quotation from a tungsten alloy supplier, it is recommended to provide at least a 2D engineering drawing, a 3D CAD (Computer-Aided Design) model, the material system or target density, individual product weight, weight tolerance, dimensional tolerances, hole and thread requirements, surface roughness, surface treatment, operating environment, dynamic balancing requirements, prototype quantity, mass-production quantity, and estimated annual demand. If a complete drawing is not yet available, the customer can initially provide the product application, target weight, maximum external dimensions, installation method, and purchase quantity. The supplier can then preliminarily evaluate the material system and manufacturing process and further optimize the design according to DFM (Design for Manufacturing) principles. For tungsten alloy counterweights, the final price can essentially be understood as: material cost + forming cost + machining cost + mold and tooling cost + inspection cost + surface-treatment cost + packaging and transportation cost, combined with order quantity



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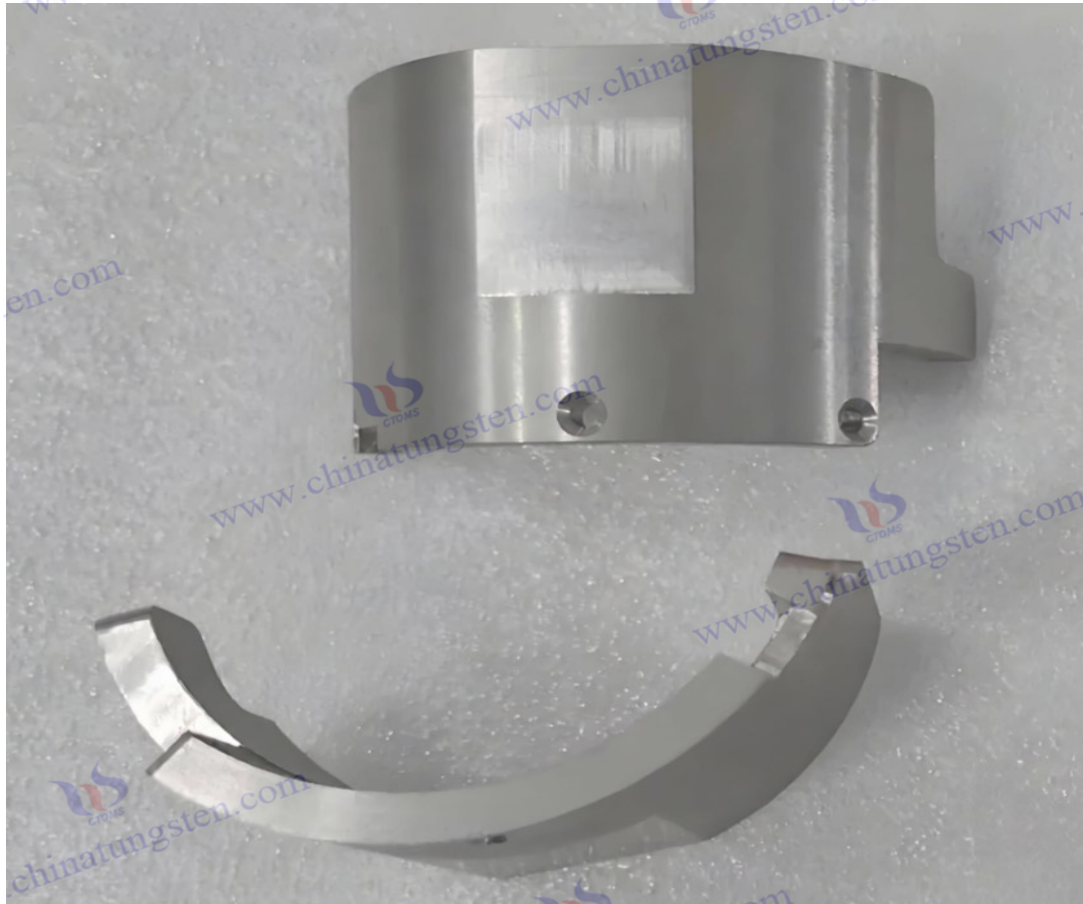
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and production yield. Only after these conditions have been standardized can the effective quotations of different suppliers be compared accurately.



Q23 How Much Does Tungsten Alloy Counterweight Cost per Kilogram?

There is no single fixed price per kilogram for tungsten alloy counterweights. Based on recent publicly available quotations in 2026, public prices for ordinary Tungsten Heavy Alloy materials or counterweight products can generally be found in ranges of approximately US\$50–100/kg and US\$30–150/kg. For products that have already been machined into specific counterweight components, publicly quoted prices may reach US\$100–200/kg. Quotation bases vary among suppliers. Some prices refer to raw materials or standard components, while others already include sintering, machining, surface treatment, and customization costs. Therefore, these figures should not be regarded as a uniform market transaction price. For example, publicly listed quotations for tungsten alloy crankshaft counterweights are approximately US\$60–85/kg, with an MOQ (Minimum Order Quantity) of 10 kg. Another supplier publicly lists tungsten alloy balancing counterweights at US\$30–150/kg, using W-Ni-Fe (Tungsten-Nickel-Iron, 钨-镍-铁) or W-Ni-Cu (Tungsten-Nickel-Copper, 钨-镍-铜) materials with densities of 17–18.5 g/cm³.



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(1) Why Do Tungsten Alloy Counterweight Prices Vary So Much?

The price of a tungsten alloy counterweight is not determined solely by the price of tungsten metal itself. It is jointly affected by the material system, W content, density grade, product dimensions, machining complexity, weight tolerance, purchase quantity, surface treatment, and other factors. For example, for the same 1 kg tungsten alloy product, a standard sintered block is generally less expensive than a finished counterweight that has undergone turning, drilling, threading, grinding, and precision inspection. If the product also requires tight dimensional tolerances, strict weight tolerances, dynamic balancing, special surface treatment, or a complex irregular structure, the unit price per kilogram may increase further.

(2) Does a Higher Material Density Always Mean a Higher Price?

There is generally some correlation, but it cannot simply be assumed that the price per kilogram will always increase in a fixed proportion as density increases. Publicly available product information shows that W-Ni-Fe and W-Ni-Cu materials with different W contents can provide different density grades. For example, some automotive counterweight products list material grades such as 90W, 93W, 95W, and 97W, with corresponding densities ranging approximately from 16.85 to 18.85 g/cm³. Increasing W content generally means higher material cost, but the actual quotation is also affected by powder cost, sintering processes, machining allowance, production yield, and purchase volume. Therefore, when requesting quotations, it is preferable to specify the target density or material grade directly rather than simply requesting a high-density tungsten alloy.

(3) What Is the Price Difference Between W-Ni-Fe and W-Ni-Cu?

W-Ni-Fe and W-Ni-Cu are both common tungsten heavy alloy systems. Their prices do not normally have a fixed difference simply because one uses Fe (Iron, 铁) and the other uses Cu (Copper, 铜). The actual price is determined by factors such as W content, density, material grade, machining condition, and order volume. For example, different W-content grades such as 90W, 93W, 95W, and 97W have different material costs and densities. For W-Ni-Cu products, if low magnetic response is required, additional control of material composition and production processes may also be necessary. Therefore, when comparing quotations from two suppliers, the comparison should be made using the same W content, density, dimensions, tolerances, and machining condition, rather than simply comparing the names W-Ni-Fe and W-Ni-Cu.

(4) Why Are Finished Counterweights More Expensive Than Tungsten Alloy Raw Materials?

This is because the finished-product price includes much more than the material itself. A typical tungsten alloy counterweight may undergo powder mixing, compaction, debinding or pretreatment, liquid-phase sintering, dimensional machining, drilling or milling, grinding, surface treatment, and final inspection. Material utilization and machining efficiency are



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also affected by product geometry. For example, a simple cylindrical counterweight may require only a small amount of turning, while a product with multiple holes, grooves, threads, and complex curved surfaces requires significantly more machining time. Therefore, when purchasing tungsten alloy counterweights, the price per kilogram of raw material should not be directly compared with the price per kilogram of a finished product.

(5) Why Are Small-Batch Custom Products Particularly Expensive?

Small-batch products are usually affected by the allocation of fixed costs. For example, producing 100 pieces and producing 10,000 identical counterweights may both require mold preparation, process setup, equipment adjustment, first-article inspection, and quality confirmation. When only 100 pieces are produced, these fixed costs are distributed over a much smaller number of products. In addition, small orders generally cannot fully utilize the capacity of powder metallurgy tooling, sintering furnaces, and machining equipment, while material purchasing may also fail to achieve volume-based pricing. As a result, the unit price per kilogram of the same tungsten alloy counterweight can be significantly higher for small-batch orders than for large-volume procurement.

(6) How Does Complex Geometry Affect the Price per Kilogram?

Suppose two products both weigh 1 kg. Product A is a simple cylinder with no holes or grooves and has standard dimensional tolerances. Product B also weighs 1 kg but requires multiple precision holes, threads, positioning grooves, irregular curved surfaces, as well as strict control of concentricity and radial runout. Although the two products have the same weight, Product B may require significantly more machining time, greater tool consumption, higher inspection costs, and greater scrap risk. Its final quotation may therefore be substantially higher. This is another reason why tungsten alloy counterweights cannot be priced solely according to the material price per kilogram.

(7) Publicly Listed Prices Should Only Be Used as Budgetary References

Publicly available prices on current websites vary considerably. For example, some suppliers list tungsten heavy alloy at approximately US\$150–200/kg, while some tungsten alloy balancing counterweights are listed at US\$130–250/kg. Certain precision-machined W-Ni-Fe/W-Ni-Cu components are publicly quoted at US\$100–200/kg. Other standard tungsten heavy alloy products, such as cylinders and spheres, may be publicly listed at approximately US\$57–90/kg.

These figures should be understood as publicly listed supplier quotation ranges rather than a universal market benchmark. The quotation date, specifications, trade terms, machining condition, and MOQ (Minimum Order Quantity) may differ between websites, so these prices cannot be directly compared on a like-for-like basis.



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(8) What Price Range Can Be Used Initially to Estimate the Cost of Tungsten Alloy Counterweights?

For preliminary project budgeting, ordinary tungsten alloy counterweights can temporarily be estimated within a range from several tens of US dollars per kilogram to more than one hundred US dollars per kilogram. Standard materials, simple geometries, and volume procurement can generally be referenced against the lower range, while high-density materials, precision machining, complex structures, and small-batch customization may require consideration of higher ranges. For example, publicly listed W-Ni-Fe/W-Ni-Cu balancing counterweights have been quoted at US\$30–150/kg, while precision-machined tungsten alloy components have been publicly quoted at US\$100–200/kg. These figures are only budgetary references and should not be used directly as final procurement prices.

(9) A 1 kg and a 100 g Tungsten Alloy Counterweight Cannot Simply Be Priced Using the Same Unit-Weight Calculation

If a supplier quotes US\$80/kg, the mathematical material reference cost for 100 g would be approximately US\$8. However, a finished 100 g product does not necessarily cost US\$8 because small components may have higher unit machining costs, minimum order quantities, tooling costs, and inspection costs. Therefore, small precision tungsten alloy counterweights often have a per-piece price that is substantially higher than a simple proportional calculation based on weight.

(10) Raw Material Price Fluctuations Also Affect Tungsten Alloy Counterweight Quotations

The cost of tungsten alloys is relatively sensitive to the tungsten raw-material market. Public market information for 2026 indicates that tungsten raw materials and tungsten products have experienced noticeable price fluctuations during the year. Public quotations for certain tungsten alloy rods have also varied according to material composition, dimensional accuracy, and surface treatment. Therefore, for large-volume procurement, suppliers may need to recalculate the quotation based on the raw-material price at the time of inquiry, order volume, and delivery schedule rather than maintaining a fixed price per kilogram over an extended period.

(11) How Should a Quotation from CTIA GROUP Be Understood?

For customized tungsten alloy counterweights, CTIA GROUP can calculate costs according to the target weight, density grade, W-Ni-Fe or W-Ni-Cu material system, structural dimensions, machining tolerances, and purchase quantity of the specific counterweight. Material costs, forming and manufacturing costs, precision machining, and quality inspection can then be considered together to determine the specific quotation rather than simply applying a fixed price per kilogram.



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(12) What Information Should Be Provided to Obtain a More Accurate Price per Kilogram?

When requesting a quotation from a tungsten alloy counterweight manufacturer, it is preferable to provide the material system, target density, W content or material grade, individual piece weight, product dimensions, quantity, drawings, tolerances, hole, groove and thread requirements, surface treatment, packaging method, and delivery requirements. For example, a specification could be stated as follows: W-Ni-Fe, 18.0 g/cm³, individual piece weight of 100 g, dimensions according to drawing, weight tolerance of ± 0.1 g, quantity of 5,000 pieces, with drilling and surface treatment required. With this information, the supplier can determine whether the requirement involves material procurement, a standard counterweight, or a precision customized finished product and can therefore provide a more meaningful quotation.

There is currently no single fixed price per kilogram for tungsten alloy counterweights. Based on recent publicly available quotations in 2026, ordinary tungsten heavy alloy materials or counterweight products can be found in public quotation ranges such as approximately US\$30–150/kg and US\$50–100/kg, while some precision-machined products have publicly listed prices of US\$100–200/kg. For actual procurement, a more appropriate approach is not to ask for a universal price per kilogram for tungsten alloy counterweights, but to specify the W-Ni-Fe or W-Ni-Cu system, W content, density, individual piece weight, dimensional tolerances, machining requirements, and purchase quantity, and then obtain a customized quotation based on those specifications. Only under these conditions does the quoted price have meaningful practical value for procurement.





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Q24 Why Is the Price of Tungsten Alloy Counterweights Higher Than That of Steel Counterweights?

The price of tungsten alloy counterweights is usually higher than that of steel counterweights. The core reasons lie in differences in raw material value, tungsten content, manufacturing processes, processing costs, and quality control requirements. Tungsten alloy counterweights mainly utilize the high-density characteristics of W (Tungsten) to obtain greater mass within a smaller volume, while steel counterweights mainly rely on low-cost steel to achieve mass configuration. From the perspective of product economics, tungsten alloy is not simply intended to replace steel, but rather, in scenarios with limited installation space, high mass concentration requirements, high dynamic balancing accuracy, or obvious special performance requirements, to exchange higher material cost for higher mass per unit volume and greater structural design freedom.

(1) The Main Reason Is That Tungsten Raw Material Itself Has Higher Value

Steel is a material used in large-scale industrial applications. Iron (Fe, Iron) and steel raw materials have mature supply and huge output, and ordinary carbon steel and alloy steel have very mature industrial chains. Tungsten alloy, however, contains a relatively high proportion of W (Tungsten). Common high-density tungsten alloy systems usually contain about 90%–97% W, with the remainder mainly consisting of binder phases such as Ni (Nickel), Fe (Iron), or Cu (Copper). Because tungsten itself is a high-value metal, even if two counterweights have the same final weight, the material cost of the tungsten alloy will usually be significantly higher than that of ordinary steel.

(2) Tungsten Alloy Requires More Specialized Manufacturing Processes

Steel counterweights can be produced through mature processes such as casting, forging, turning, stamping, and welding, and many structures can even be directly machined from standard steel. Tungsten alloy, however, is usually manufactured by the powder metallurgy (Powder Metallurgy) route. A typical process includes powder batching, mixing, press forming, debinding or pretreatment, liquid-phase sintering, precision machining, and final inspection. For high-density tungsten alloys, temperature control, shrinkage control, structural uniformity, and dimensional stability during sintering all affect the final product quality, so the manufacturing cost is usually higher than that of ordinary steel counterweights.

(3) The Processing Cost of Tungsten Alloy Is Usually Higher

The turning, milling, drilling, and tapping technologies for steel are already very mature, and tools and processing parameters are relatively easy to obtain. Tungsten alloy contains a large amount of hard tungsten phase, which may cause obvious tool wear during processing. Processing parameters also need to be adjusted according to the specific W content, binder phase, sintered structure, and product structure. If a tungsten alloy counterweight requires precision holes, threads, grooves, special-shaped curved surfaces,



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or relatively high dimensional accuracy, its processing cost may be significantly higher than that of a steel counterweight with a similar structure.

(4) Although Tungsten Alloy Is Expensive, It Can Reduce Counterweight Volume

A high price for tungsten alloy does not necessarily mean that the cost of use must be higher, because it can reduce product volume through high density. Counterweight volume can be calculated by $V = m / \rho$, where V is volume, m is mass, and ρ is density. For example, to manufacture a 1 kg counterweight, steel calculated at 7.85 g/cm^3 requires $V = 1000 / 7.85 \approx 127.39 \text{ cm}^3$; if an 18.0 g/cm^3 tungsten alloy is used, then $V = 1000 / 18.0 \approx 55.56 \text{ cm}^3$. In other words, for the same 1 kg mass, the material volume required by tungsten alloy is only about 43.6% of that of a steel counterweight, a volume reduction of about 56.4%. If the internal space of the equipment is limited, this volume advantage may offset part of the material price difference.

(5) For Miniature Counterweights, Volume Value May Be More Important Than Material Unit Price

For example, if a small electronic device needs a 100 g counterweight, and 7.85 g/cm^3 steel is used, the theoretical material volume is about 12.74 cm^3 ; if an 18.0 g/cm^3 tungsten alloy is used, only about 5.56 cm^3 is needed. If only 6–7 cm^3 of available installation space exists inside the device, the steel counterweight may not be able to meet the structural requirements, while the tungsten alloy can achieve a more compact design at the same mass. Therefore, for mobile phone vibration components, precision instruments, drones, robot actuators, and certain aerospace components, what the purchaser may care about is not simply the price per kilogram, but how much mass can be obtained per unit of space.

(6) The High Tungsten Content of Tungsten Alloy Also Increases Material Cost

Tungsten content usually has a relatively obvious correlation with tungsten alloy density. Under otherwise similar conditions, increasing W content can usually increase density, but it also means using more high-value tungsten raw material. For example, for tungsten alloy counterweights of 17.5 g/cm^3 and 18.5 g/cm^3 , the 18.5 g/cm^3 material can further reduce the volume of a product of the same mass, but its material composition, manufacturing cost, and final quotation may also differ. Therefore, tungsten alloy counterweights do not have only two choices, high density and low density; rather, an appropriate density grade can be selected according to installation space and performance requirements.

(7) The Quality Control Cost of Precision Tungsten Alloy Counterweights Is Higher

Ordinary steel counterweights sometimes only need to control external dimensions and total weight, while precision tungsten alloy counterweights may need to simultaneously control mass tolerance, dimensional tolerance, hole position, coaxiality, circular runout, flatness, surface roughness, and center-of-mass position. For rotating counterweights, dynamic balancing testing may also be required. The centrifugal force in a high-speed



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rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft. Therefore, even if the total weight of the counterweight is completely correct, if there is eccentricity or an installation position error, an obvious unbalanced force may still be generated. These additional inspection and processing requirements will all enter the final product cost.

(8) Complex Structures Will Further Amplify the Price Difference Between Tungsten Alloy and Steel Counterweights

If both counterweights are simple rectangular blocks, the processing cost of the steel counterweight may be very low. But if the product requires machining multiple precision holes, threaded holes, positioning grooves, counterbores, special-shaped curved surfaces, or special mounting structures, the processing cost of tungsten alloy will become more obvious.

For example, an automobile or aerospace counterweight may simultaneously require fixing hole position accuracy, mass tolerance, and dynamic balancing grade. At this time, the final price is no longer a simple comparison of material prices, but the comprehensive cost of material, forming, processing, inspection, and quality assurance.

(9) What Does the High Price of Tungsten Alloy Buy?

The most direct value of tungsten alloy relative to steel is the high mass-to-volume ratio brought by high density. If an 18.0 g/cm³ tungsten alloy is compared with 7.85 g/cm³ steel, for the same 1 kg mass, tungsten alloy can reduce the theoretical material volume by about 56.4%. For large equipment with sufficient space, this advantage may not be important; for equipment with limited space that needs to concentrate a large amount of mass in a very small area, this advantage may become an important reason for material selection.

(10) Not All Counterweights Are Suitable for Tungsten Alloy

If the product has sufficient installation space, relatively large weight, general precision requirements, and cost is the main constraint, then a steel counterweight can often meet the basic function. For example, large machinery base counterweights, ordinary industrial equipment counterweights, and some low-speed mechanism counterweights do not necessarily need the high-density characteristics of tungsten alloy. Conversely, if the product requires small volume, large mass, precise mass distribution, or special installation space, then the high material cost of tungsten alloy may have actual engineering value.

(11) CTIA GROUP's Cost Evaluation Can Be Combined with Specific Counterweight Structures

For cost comparison between tungsten alloy counterweights and steel counterweights, CTIA GROUP can calculate the material volumes required for tungsten alloy and steel according to the target weight and installation space, and then evaluate the actual manufacturing cost in combination with material grade, structural complexity, processing



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tolerances, surface treatment, and procurement quantity, so that material price can be comprehensively matched with the actual space occupied by the counterweight and performance requirements.

(12) Comparing Two Types of Counterweights Cannot Be Based Only on Price per Kilogram

If only material unit price is compared, tungsten alloy will almost inevitably be at a disadvantage; but if the complete product design cost is compared, then counterweight volume, installation space, structural modification cost, processing cost, service life, and performance requirements should be considered at the same time.

For example:

Comparison Item Tungsten Alloy Counterweight Steel Counterweight

Material cost Usually higher Usually lower

Density Usually about 17–18.5 g/cm³ Ordinary steel about 7.85 g/cm³

Volume for the same mass Small Large

Processing cost Usually higher Usually lower

Material supply Relatively specialized Very mature

High mass/small volume capability Strong Relatively weak

Adaptability to precision counterweights Relatively good Depends on structure and precision

Economy for large ordinary counterweights Not necessarily advantageous Usually has a cost advantage

Counterweights with limited space Has obvious value May be limited by volume

The price of tungsten alloy counterweights is usually higher than that of steel counterweights, mainly because they contain a high proportion of W (Tungsten), the raw material value is higher, and they also involve costs such as powder metallurgy, liquid-phase sintering, precision machining, and quality inspection. However, the advantage of tungsten alloy does not lie in low price, but in high density. Calculated with 18.0 g/cm³ tungsten alloy and 7.85 g/cm³ steel, when manufacturing the same 1 kg counterweight, the theoretical volume of tungsten alloy is about 55.56 cm³, while that of steel is about 127.39 cm³. Tungsten alloy can reduce the theoretical material volume by about 56.4%. Therefore, whether tungsten alloy is worth using cannot be judged only by the price per kilogram. For products with limited space, high mass concentration, precision balancing, and obvious miniaturization requirements, the volume advantage brought by high density may have relatively high engineering value; for ordinary counterweights with sufficient space, simple structure, and cost sensitivity, steel may better meet economic requirements.



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Q25 What Factors Mainly Affect the Price of Tungsten Alloy Counterweights?

The price of a tungsten alloy counterweight is not simply calculated according to the material price per kilogram. Instead, it is jointly determined by multiple factors such as material cost, tungsten content, density grade, product weight and dimensions, structural complexity, processing accuracy, procurement quantity, surface treatment, inspection requirements, and delivery conditions. For customized tungsten alloy counterweights, even if two products have the same weight, the final quotation may still differ significantly if the material grade, density, dimensions, tolerances, processing content, and procurement quantity are different.

(1) Tungsten Content Is One of the Core Material Factors Affecting Price

Tungsten alloy counterweights usually contain a relatively high proportion of W (Tungsten). The W content of common high-density systems can reach about 90%–97%, with the remainder mainly composed of Ni (Nickel), Fe (Iron), or Cu (Copper), etc. Under otherwise similar conditions, a higher W content usually means a larger proportion of tungsten raw material, and the material cost will increase accordingly. At the same time, increasing W content is usually conducive to increasing density, further reducing the volume of a counterweight of the same weight. Therefore, W content actually affects both material cost and product volume, and is an important parameter in quotation.

(2) Material Density Grade Affects Price

The common density of tungsten alloy counterweights can reach about 17–18.5 g/cm³, and different material systems and grades may also have a wider density range. Higher density



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usually means a higher W content or a different binder phase ratio is required. For example, compared with 17.5 g/cm³ material, 18.5 g/cm³ material requires a smaller volume at the same weight, but the material composition and manufacturing cost may also differ. For example, for a 1 kg counterweight using 17.5 g/cm³ material, $V = 1000 / 17.5 \approx 57.14 \text{ cm}^3$ is required; using 18.5 g/cm³ material, $V = 1000 / 18.5 \approx 54.05 \text{ cm}^3$ is required. Therefore, when purchasing, one cannot merely require high density, but should specify the exact density grade.

(3) W-Ni-Fe and W-Ni-Cu Material Systems Affect Quotations

W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) are both common tungsten heavy alloys (Tungsten Heavy Alloy). The binder phases of the two materials are different, and the material composition, powder cost, sintering process, and final performance requirements may also differ. If the product requires specific magnetic properties, such as low magnetic response, a specific W-Ni-Cu material system may be needed; if structural strength and comprehensive mechanical properties are more important, W-Ni-Fe may be chosen. Different material systems will all be reflected in the final quotation.

(4) Individual Piece Weight and Product Dimensions Directly Affect Material Usage

The greater the counterweight weight, the more tungsten alloy material is required, and the material cost will naturally rise. However, tungsten alloy products cannot be simply calculated only by weight, because product external dimensions also affect the manufacturing method. For example, for the same 500 g counterweight, a simple cylindrical product may be completed through relatively simple forming and turning; if the 500 g product uses a thin-wall, special-shaped, or multi-hole structure, the material utilization rate and processing cost may be significantly different.

(5) Product Structural Complexity Significantly Affects Price

Structural complexity is an important factor in quotations for customized tungsten alloy counterweights. Simple cylinders, discs, blocks, and rings usually require fewer processing steps; if counterbores, through holes, threads, keyways, positioning grooves, special-shaped curved surfaces, eccentric structures, or complex mounting interfaces are added, production costs will increase. For example, if a counterweight requires turning, milling, drilling, tapping, and grinding at the same time, its price usually can no longer be calculated according to a simple material price per kilogram.

(6) The Stricter the Dimensional Tolerance, the Higher the Processing Cost Usually Is

Ordinary counterweights may only need to control external dimensions and weight, while precision counterweights may require strict dimensional tolerances, hole diameter tolerances, hole position accuracy, coaxiality, circular runout, and flatness. Tungsten alloy itself is manufactured by powder metallurgy, and the sintering process produces



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dimensional shrinkage. Therefore, high-precision products often require additional subsequent precision machining. For example, if an ordinary counterweight requires ± 0.1 mm, while another counterweight requires ± 0.01 mm, even if the two have exactly the same weight, the latter may require more complex processing and inspection processes.

(7) Mass Tolerance Affects Manufacturing and Inspection Costs

If the customer requires individual piece weight to be accurate to a small range, then material density, sintering shrinkage, machining allowance, and final dimensions need to be controlled more strictly. For example, comparing a 100 g counterweight requiring ± 1 g with one requiring 100.00 ± 0.05 g, the latter has significantly higher requirements for material consistency, processing accuracy, and weighing inspection. For batch products, mass consistency between different batches also needs to be controlled, which also increases production and quality management costs.

(8) Whether Dynamic Balancing Inspection Is Required Affects the Final Price

If a tungsten alloy counterweight is used in high-speed rotating equipment, controlling total weight alone is usually not enough. The centrifugal force in a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft. The eccentricity, installation position, coaxiality, and circular runout of the counterweight all affect dynamic balance. If the customer requires dynamic balancing inspection, special inspection equipment, testing procedures, and corresponding quality judgment standards need to be added, so this part of the inspection cost will also enter the product quotation.

(9) Surface Treatment Adds Extra Cost

Some tungsten alloy counterweights require surface treatment, such as nickel plating, copper plating, passivation, fine grinding, or other protective treatments. The purpose of surface treatment may include improving corrosion resistance, surface appearance, dimensional stability, assembly performance, or contact performance with other parts. If the product also has requirements for surface roughness, for example, requiring a relatively low R_a (Arithmetic Average Roughness) value, grinding, polishing, and other processes may be added.

(10) Procurement Quantity Has a Very Obvious Impact on Unit Price

MOQ (Minimum Order Quantity) and actual procurement quantity are important factors affecting the unit price of tungsten alloy counterweights. In small-batch production, fixed costs such as mold preparation, process debugging, equipment setup, first article inspection, and quality confirmation need to be borne by a relatively small number of products. After the batch increases, these fixed costs can be spread over more products, and powder material procurement, sintering, and mechanical machining are also more likely to form economies of scale, so the cost per piece usually decreases. For example, for



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the same counterweight, quotations for 100 pieces, 1,000 pieces, and 10,000 pieces usually do not simply change in direct proportion to quantity.

(11) Mold Cost Affects Quotations for Powder Metallurgy Counterweights

For tungsten alloy counterweights formed by powder metallurgy pressing, complex structures may require special molds. If the product is only a simple cylinder or block, the mold structure is relatively simple; if the product has steps, holes and grooves, special curved surfaces, or complex cross-sections, mold design and manufacturing costs may increase significantly. For first-time customized small-batch products, how mold costs are allocated to the product unit price also needs to be considered.

(12) Material Utilization Rate Also Affects Actual Cost

Tungsten alloy is a high-value material, so material utilization rate is relatively sensitive to cost. If the product can reduce subsequent cutting allowance through near-net-shape powder metallurgy forming, material waste and processing time can be reduced; if the product needs to be largely cut from a larger sintered blank into the final shape, the material utilization rate may decrease. For complex special-shaped counterweights, optimizing forming dimensions and machining allowance can sometimes significantly improve the cost structure.

(13) Processing Methods Affect Quotations

The cost differences among different processing techniques are relatively large. Turning is suitable for cylindrical, disc, and ring structures; milling is suitable for planes, grooves, and complex contours; drilling is suitable for mounting holes; grinding is suitable for high dimensional accuracy and surface roughness requirements; for certain complex structures, special processing methods such as EDM (Electrical Discharge Machining) may also be required. The more processing steps, the higher the equipment requirements, and the longer the processing time, the higher the final quotation usually is.

(14) The More Inspection Items, the Higher the Quality Cost

Ordinary counterweights may only inspect weight and main dimensions, while high-precision products may need to inspect density, dimensions, mass, hole position, coaxiality, circular runout, surface roughness, hardness, mechanical properties, and even magnetic properties. If the product is used in fields with high consistency requirements such as aerospace, automobiles, medical care, or precision instruments, complete inspection reports, material certificates, and batch traceability may also be required. These quality assurance costs are also part of the product manufacturing cost.

(15) Supplier Production Capacity and Order Model Also Affect Price

For the same tungsten alloy counterweight, quotations from different manufacturers may differ because each company's powder preparation capability, mold capability, sintering



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equipment, processing equipment, inspection equipment, and capacity utilization rate are different. If a supplier has complete material, forming, sintering, processing, and inspection capabilities, some processes can be completed internally; if a large amount of outsourcing is required, the quotation structure may differ. For customized products, it should also be compared whether the supplier can stably control density, weight tolerance, and dimensional consistency, rather than only comparing a lowest quotation.

(16) Delivery Cycle and Order Urgency May Also Affect Quotations

A normal production cycle can usually be arranged according to standard processes. If the customer requires expedited delivery, the supplier may need to adjust the production plan, increase equipment working hours, or arrange expedited processing. Especially for products that require new molds or re-validation of the sintering process, compressing the delivery time may bring additional manufacturing costs. Therefore, when requesting a quotation, it is best to specify at the same time whether the delivery time is normal or expedited.

(17) Transportation and Trade Terms Also Enter the Final Procurement Cost

Tungsten alloy has very high density and is relatively heavy at the same volume, so transportation cost needs to be calculated according to actual weight, packaging method, and transportation distance. If it is international procurement, packaging, insurance, customs declaration, tariffs, exchange rates, and trade terms may also be involved. If the supplier's quotation uses different conditions such as EXW (Ex Works), FOB (Free On Board), and CIF (Cost, Insurance and Freight), the final procurement costs cannot be directly compared horizontally.

(18) The Price of a Tungsten Alloy Counterweight Can Be Understood as a Comprehensive Cost

From the perspective of cost composition, the quotation for a tungsten alloy counterweight can be simplified as: final price $\approx$ raw material cost + forming cost + sintering cost + mechanical processing cost + surface treatment cost + inspection cost + mold and tooling allocation + packaging, transportation, and other expenses. Among them, raw material cost is mainly affected by W content, material system, and raw material market prices; manufacturing cost is mainly affected by structure, dimensions, tolerances, processing steps, and order quantity. This relationship is not a fixed mathematical quotation formula, but a cost framework to help purchasers understand the price formation mechanism.

(19) CTIA GROUP Can Match Costs for Specific Specifications

For tungsten alloy counterweights with different structures, densities, and precision requirements, CTIA GROUP can comprehensively evaluate material usage, forming method, sintering process, and subsequent precision machining according to target weight, W



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content, material system, structural complexity, and procurement quantity, thereby matching the corresponding manufacturing plan and quotation structure.

(20) The More Complete the Information Provided During Inquiry, the More Accurate the Quotation

If an accurate quotation for a tungsten alloy counterweight is desired, it is best to provide at one time the material system, target density, W content or material grade, individual piece weight, external dimensions, product drawing, dimensional tolerances, weight tolerances, hole, groove, and thread requirements, surface treatment, inspection requirements, procurement quantity, and delivery cycle. For example, if only "tungsten alloy counterweight" is provided, it is difficult for the supplier to quote accurately; if it is clearly specified as W-Ni-Fe, 18.0 g/cm³, 100 g per piece, 5,000 pieces, dimensions according to the drawing, weight tolerance ± 0.1 g, requiring drilling and nickel plating, then the quotation will have higher accuracy and comparability.

The price of tungsten alloy counterweights is mainly affected by factors such as W (Tungsten) content, material system, density grade, product weight and dimensions, structural complexity, processing method, dimensional tolerance, mass tolerance, surface treatment, inspection requirements, procurement quantity, mold cost, material utilization rate, delivery cycle, and transportation conditions. Among them, the material side mainly depends on tungsten content, material grade, and density; the manufacturing side mainly depends on structural complexity, processing steps, and precision requirements; the procurement side mainly depends on quantity, delivery time, and trade terms. Therefore, when judging whether the price of a tungsten alloy counterweight is reasonable, one cannot compare only how much it costs per kilogram, but should make a comprehensive comparison on the basis of the same material system, same density, same weight, same dimensional tolerance, same processing content, and same procurement quantity.



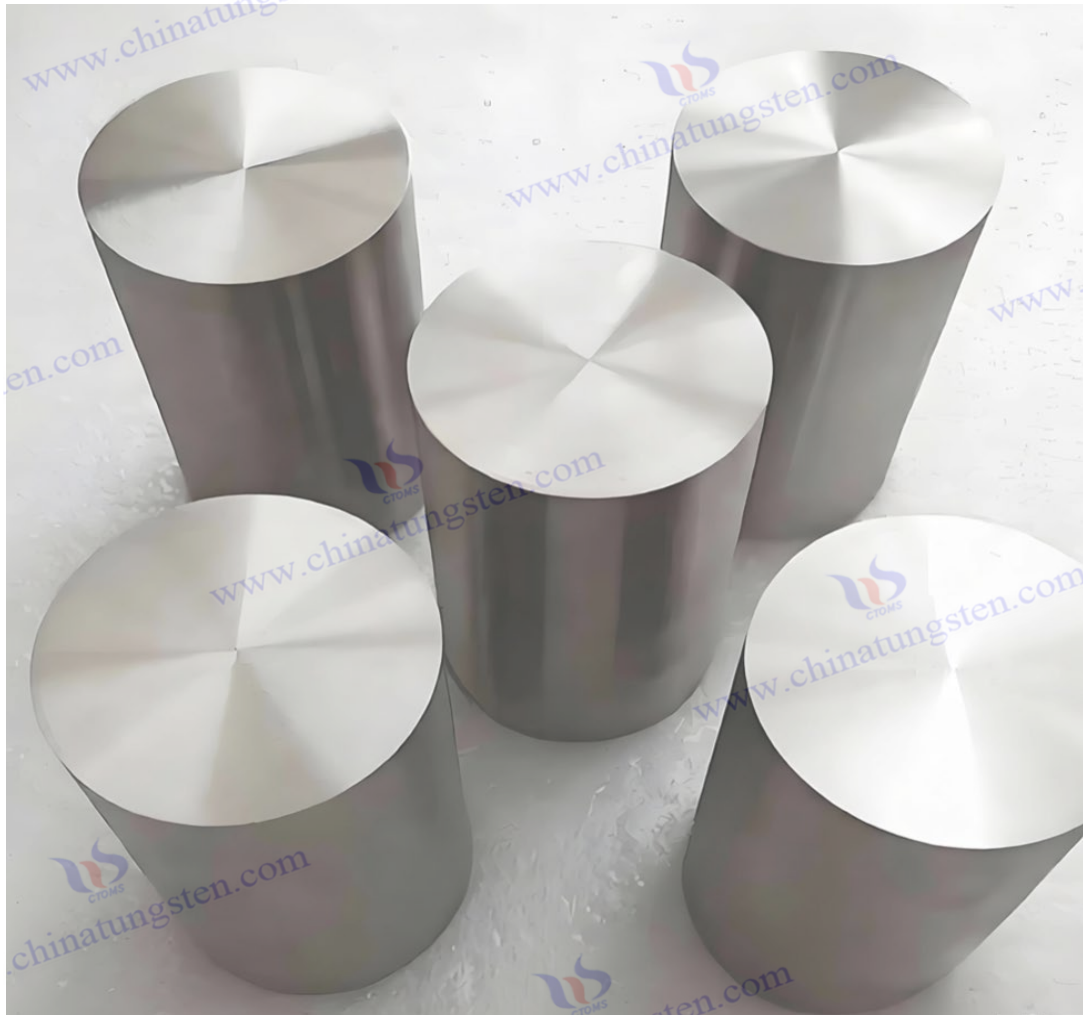
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Q26 Does a Higher Density of Tungsten Alloy Counterweight Mean a Higher Price?

Not necessarily, but under similar material systems, processing conditions, and procurement quantities, a higher density of tungsten alloy counterweight usually means a higher W (Tungsten) content or a larger proportion of high-density phase, and the material cost often increases as well. However, the final price of a tungsten alloy counterweight is not determined by density alone. Product structure, individual piece weight, dimensional tolerances, processing procedures, procurement quantity, mold costs, and inspection requirements can all cause the final unit price of a lower-density product to be higher than that of a higher-density product. Therefore, a more accurate understanding is: high density usually increases material-side cost, but it does not necessarily cause the finished product quotation to rise proportionally with density.

(1) Why Does Increasing Density Usually Increase Material Cost?

The high density of tungsten alloy counterweights mainly comes from W (Tungsten).



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Common high-density tungsten alloys usually contain a relatively high proportion of W, with the remainder being binder phases such as Ni (Nickel), Fe (Iron), or Cu (Copper). Under similar material systems and manufacturing processes, increasing W content can usually increase material density, but it also means using more tungsten raw material. Therefore, from the perspective of material cost, there is usually a certain cost difference among different density grades such as 17.5 g/cm³, 18.0 g/cm³, and 18.5 g/cm³.

(2) High-Density Materials Require a Smaller Volume

Although increasing density may increase the material unit price, it can reduce the volume required for a counterweight of the same mass. Volume can be calculated by $V = m / \rho$, where V is volume, m is mass, and ρ is density. For example, to manufacture a 1 kg counterweight, 17.5 g/cm³ material requires $V = 1000 / 17.5 \approx 57.14$ cm³; 18.0 g/cm³ material requires about 55.56 cm³; and 18.5 g/cm³ material requires about 54.05 cm³. Therefore, after increasing density from 17.5 to 18.5 g/cm³, the theoretical material volume of the same 1 kg counterweight can be reduced by about 3.09 cm³. For products with limited space, this volume reduction may have relatively high engineering value.

(3) Higher Density Does Not Mean the Price per Kilogram Increases Proportionally

Suppose one 17.5 g/cm³ tungsten alloy is quoted at A USD/kg, and another 18.5 g/cm³ material is quoted at B USD/kg. It cannot simply be assumed that B must equal $A \times 18.5 / 17.5$. This is because material price is also affected by W content, Ni-Fe or Ni-Cu ratio, powder cost, production process, material grade, and supplier cost structure. Some different density grades may use similar production routes, while some high-density materials require higher W content and stricter sintering control, so the extent of cost change is not the same.

(4) What Really Affects the Final Quotation Is the Unit Product Cost

For the purchaser, it is more meaningful to compare the cost of one complete counterweight rather than simply comparing the price per kilogram.

For example: Plan A: 18.5 g/cm³, 100 g/piece, 10 USD/kg; Plan B: 17.5 g/cm³, 100 g/piece, 8 USD/kg.

If Plan A can meet very strict installation space requirements while Plan B cannot fit into the equipment, then although A has a higher price per kilogram, it may still be the only solution that meets the structural requirements. Conversely, if both materials can meet the space requirements and the product quantity is very large, then the cost advantage of the lower-density material may become more obvious.

(5) Different Product Weights Also Lead to Different Effects of Density on Total Material Cost

For large counterweights, the difference in material price will be amplified. For example, when purchasing 10 kg of product, if the price per kilogram of material differs by 20 USD,



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then the material itself will create a price difference of about 200 USD. For miniature counterweights of only 10 g or 20 g, the material value difference per piece may be very small, but mold, processing, and inspection costs may instead become more important components of the price. Therefore, the impact of the density factor on the total quotation needs to be judged together with the product weight.

(6) Small Precision Counterweights Are Not Necessarily More Expensive at Higher Density

For micro tungsten alloy counterweights, the product price may include a relatively high proportion of processing and inspection costs. For example, for a 10 g counterweight that requires machining micro holes, fine grooves, or special mounting structures, even if 18.5 g/cm³ material is used, the material itself accounts for only part of the final cost. If another 20 g counterweight uses 17.5 g/cm³ material but has a very complex structure and requires more processing steps, then its final unit price may very well be higher than the former. This shows that density is only one factor in the quotation.

(7) Structural Complexity Is Sometimes More Important Than Density Difference

Suppose two 1 kg counterweights respectively use 17.5 g/cm³ and 18.5 g/cm³ materials. If the 17.5 g/cm³ product is a simple cylinder, while the 18.5 g/cm³ product requires multiple precision holes, threads, counterbores, special-shaped curved surfaces, and tight tolerances, then the processing cost of the latter may be significantly higher than that of the former. In the final quotation, the increased cost from the high-density material is only one part, while the cost increase brought by complex processing may be more obvious.

(8) Procurement Quantity Will Change the Relationship Between Density and Price

For small-batch procurement, fixed costs such as molds, process debugging, equipment preparation, and first-article inspection account for a relatively high proportion. For large-batch procurement, material procurement, sintering, mechanical machining, and inspection can form economies of scale, and unit cost usually decreases. For example, 18.5 g/cm³ material is theoretically higher in material cost, but if the supplier has already formed stable batch production for this specification, while 17.5 g/cm³ material requires new mold opening and process adjustment, then the final quotation is not necessarily directly determined by density level.

(9) The Value of High-Density Materials Is Mainly Reflected in Space Utilization

To judge whether high density is worthwhile, one cannot look only at material price.

If a 1 kg counterweight must be installed within a space of about 55 cm³, the theoretical volume of 18.0 g/cm³ material is about 55.56 cm³, and that of 18.5 g/cm³ material is about 54.05 cm³. At this time, the density difference may directly relate to whether the product can meet the structural space requirements. If the installation space is 100 cm³, then 17.5 g/cm³ material at about 57.14 cm³ can also fully meet the requirements. At this time, in order to reduce about 3.09 cm³ by using a higher-density material, the cost and benefit



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need to be compared again.

(10) Dynamic Counterweights Also Need to Consider Mass Distribution, Not Just Density

For rotating counterweights, higher density only means that the same mass can be achieved with a smaller volume; it does not automatically bring better dynamic balancing effect. The centrifugal force of a rotating system can be expressed as $F = m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft. The moment of inertia can be expressed as $I = \sum m_i r_i^2$, where m_i is a mass unit and r_i is its distance to the rotating shaft. Therefore, high-density counterweights still need to control eccentricity, center-of-mass position, coaxiality, circular runout, and installation position.

(11) Different Material Systems Also Affect Price

The same density does not mean the price is exactly the same. For example, both W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) can be used to manufacture high-density counterweights, but their binder phases, material compositions, manufacturing processes, and performance characteristics are different. If the product simultaneously requires low magnetic response, high strength, specific processing performance, or special thermal performance, then the choice of material system may affect the final price more than a density difference of 0.5 g/cm³.

(12) CTIA GROUP Can Match Costs According to Density and Structural Requirements

For tungsten alloy counterweights of different density grades, CTIA GROUP can compare volume and material usage for density grades such as 17.5 g/cm³, 18.0 g/cm³, and 18.5 g/cm³ according to target weight, installation space, and structural dimensions, and then evaluate the comprehensive cost in combination with W content, forming process, processing tolerances, and order quantity, avoiding unnecessary procurement expenses incurred simply by pursuing higher density.

(13) When Purchasing, Compare Unit Product Cost, Not Just Price per Kilogram

If two tungsten alloy counterweights of different densities are to be compared, the calculation can be carried out according to the following logic:

Product material cost = individual piece weight × material unit price;

Comprehensive cost per unit product = material cost + forming cost + processing cost + surface treatment cost + inspection cost + mold amortization, etc. Then judge whether the volume reduced by the high-density material can solve the installation space problem. For example, the price per kilogram of 18.5 g/cm³ material is higher than that of 17.5 g/cm³, but if 18.5 g/cm³ can make the product smaller, reduce processing material, or avoid redesigning surrounding structures, then its comprehensive economy may be completely different from the simple price per kilogram.



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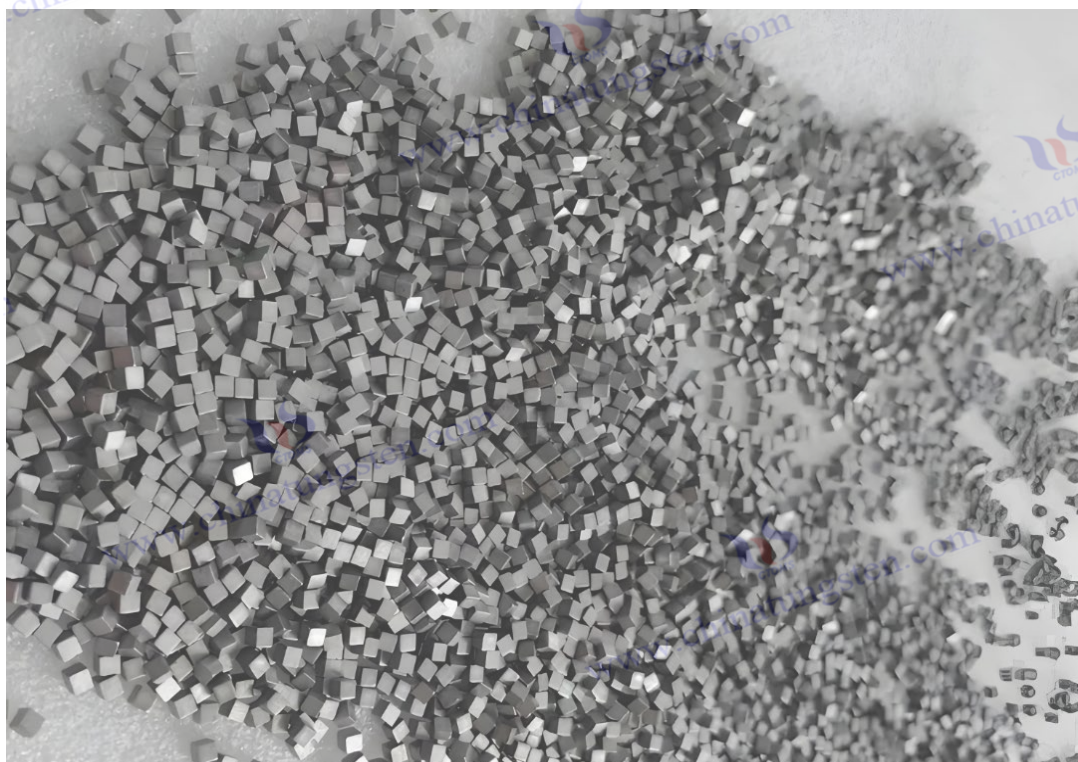
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(14) Under What Circumstances Should High Density Be Given Priority?

If the product has strict space limitations, needs to concentrate a relatively large mass in a very small volume, needs to shorten the counterweight dimensions, or needs to arrange the mass at a position far from the rotating shaft or at a specific spatial position, then high-density materials usually have obvious value. If the product has sufficient installation space, relatively large weight, simple structure, and cost control is the main goal, then there is no need to choose a more expensive material just to pursue the highest density.

For tungsten alloy counterweights, it is not necessarily true that the higher the density, the higher the price. More accurately, under similar material systems, processes, and other conditions, increasing density usually means higher W (Tungsten) content and higher material cost, but the final finished product price is also affected by factors such as product weight, structural complexity, processing precision, procurement quantity, molds, inspection, and delivery conditions.

The real value of high-density tungsten alloy lies in obtaining the same mass with a smaller volume. For example, a 1 kg counterweight using 17.5 g/cm³ material requires about 57.14 cm³, while 18.5 g/cm³ material requires only about 54.05 cm³. Whether it is worth paying higher material cost for this volume reduction should be judged according to the installation space and the overall product cost. Therefore, when selecting tungsten alloy counterweights, the more reasonable principle is not simply to pursue the highest density, but to choose a density grade with suitable comprehensive cost and performance on the basis of meeting mass and space requirements.





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Q27 Why Is the Unit Price of Small-Batch Tungsten Alloy Counterweights Higher?

The unit price of small-batch tungsten alloy counterweights is usually higher than that of large-batch purchases. The main reason is not simply the material price, but that fixed costs such as molds, forming, sintering, equipment setup, mechanical machining, and inspection cannot be diluted over a larger order quantity. For high-density tungsten alloy counterweights, the tungsten (W, Tungsten) raw material itself has relatively high value, and the products often involve relatively high dimensional accuracy and mass accuracy, so the unit cost in small-batch production becomes more obvious.

(1) Fixed Costs Need to Be Shared by a Smaller Quantity

When tungsten alloy counterweights are manufactured by powder metallurgy (PM, Powder Metallurgy), they usually need to go through processes such as powder preparation, mixing, pressing, debinding or pretreatment, liquid-phase sintering, subsequent processing, and inspection. Even if only dozens or hundreds of pieces are produced, equipment preparation, process parameter setting, mold installation, furnace scheduling, and first-piece confirmation may still be required. The unit cost of small-batch products can be simplified as: $\text{unit cost} \approx \text{unit variable cost} + \text{fixed cost} \div \text{order quantity}$. Suppose a batch of products has 3,000 yuan in fixed costs such as molds, machine adjustment, and inspection, and the variable cost per piece for materials and processing is 20 yuan. Then, when producing 100 pieces, the fixed cost amortization is 30 yuan/piece, and the total cost is about 50 yuan/piece; when producing 1,000 pieces, the fixed cost amortization is only 3 yuan/piece, and the total cost is about 23 yuan/piece. This example is only used to illustrate the cost dilution pattern and does not represent an actual market quotation.

(2) Mold and Forming Preparation Costs Account for a Relatively High Proportion

For tungsten alloy counterweights with regular structures and large quantities, powder press forming can improve production efficiency, but dedicated molds are often required. Mold design, manufacturing, trial molding, and equipment debugging are one-time or low-frequency costs, and small-batch orders cannot fully amortize these costs. If the product quantity is very small, sometimes direct machining is actually more reasonable because it can reduce the investment in dedicated molds; however, this method may increase material removal, processing time, and tool consumption, so not all small-batch products are necessarily suitable for direct machining.

(3) The Cost of Tungsten Alloy Raw Materials Themselves Is Relatively High

High-density tungsten alloys often contain a relatively high proportion of tungsten (W, Tungsten). Common material systems include tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron) and tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper). Even if the product quantity is small, the supplier still needs to prepare the corresponding



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tungsten alloy powder or blank. When purchasing raw materials in small batches, the price dilution brought by bulk purchasing is usually lacking, and material preparation, leftover material, and inventory occupation may also enter the cost. For example, when producing a 100 g counterweight, if the actual material density is 18.0 g/cm³, the theoretical material volume is about 5.56 cm³. Although the counterweight itself is very small, due to the high material density and high tungsten content, the material value per unit mass may be significantly higher than that of ordinary steel.

(4) Sintering Furnace Runs and Production Scheduling Are Difficult to Fully Utilize

Tungsten alloys usually require high-temperature sintering, and sintering equipment has a certain furnace chamber capacity and fixed operating cost. Whether dozens or thousands of pieces are sintered at one time, the basic processes such as loading, heating, holding, cooling, and equipment operation all need to be completed. If the order quantity is very small and the furnace chamber is not fully utilized, the furnace run cost borne by each piece will increase. This effect may be even more obvious especially for products with special density, special material systems, or special sizes that cannot simply be co-sintered with other products.

(5) The Proportion of Preparation Time for Small-Batch Machining Is Higher

Tungsten alloy has high density, high hardness, and a special microstructure. During processing, it is usually necessary to select suitable tools, cutting parameters, and processing methods according to the material grade, tungsten content, and microstructure. If a batch contains only dozens of pieces, preparation time such as programming, clamping and positioning, tool preparation, trial cutting, and first-piece confirmation must be shared by very few products. Even if actually cutting dozens of products takes only a few hours, the preliminary preparation work may account for a considerable proportion of the unit cost. If the product also has complex structures such as holes, grooves, threads, steps, and curved surfaces, processing time and tool consumption increase further, and the unit processing cost in small-batch situations is usually more obvious.

(6) Dimensional Tolerance and Quality Inspection Also Push Up Small-Batch Costs

Counterweight products sometimes not only require the weight to reach the target value, but also require dimensions, hole positions, coaxiality, circular runout, flatness, surface roughness (Ra, Arithmetic Average Roughness), and dynamic balancing performance to meet specified requirements. For example, ordinary static counterweights may mainly control weight and external dimensions, while tungsten alloy counterweights used in high-speed rotating components may also require dynamic balancing testing. Costs such as inspection equipment preparation, fixture positioning, first-piece inspection, in-process inspection, and final inspection can be spread over a large number of products in large-batch production, while in small-batch production the inspection cost borne by each unit product is significantly higher.



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(7) Material Utilization and Machining Allowance Also Affect Unit Price

For regular cylindrical, disc-shaped, or block-shaped counterweights, powder pressing can be relatively close to the final shape, and material utilization is usually good. However, if small-batch products are CNC machined from a solid tungsten alloy blank, a large amount of material may need to be removed from a relatively large blank. Suppose the final part weighs only 30 g, but a blank of 50 g or even more needs to be prepared before processing; then the actual procurement and processing cost cannot be calculated only according to the final 30 g. The lower the material utilization, the higher the material cost borne by each finished product.

(8) Small Batch Does Not Mean That All Costs Will Decrease Proportionally with Quantity

Tungsten alloy counterweight costs can be roughly divided into materials, forming, cost, machining, mold and tooling costs, inspection costs, surface treatment costs, packaging and transportation costs, etc. Among them, materials and part of the processing costs have relatively obvious variable cost attributes, while molds, machine adjustment, programming, inspection preparation, and furnace runs are relatively fixed or semi-fixed costs. Therefore, when an order increases from 100 pieces to 1,000 pieces, the cost usually will not simply increase by 10 times; instead, the unit cost may decrease significantly.

(9) How to Judge Whether a Small-Batch Quotation Is Reasonable

When comparing quotations for small-batch tungsten alloy counterweights, it is not advisable to look only at the price per kilogram. A more reasonable approach is to compare the total cost per piece under the same conditions, including density, W content, weight, dimensions, tolerances, structural complexity, processing method, surface treatment, inspection requirements, mold costs, packaging and transportation, and order quantity. In particular, it is necessary to confirm whether the mold fee in the supplier's quotation has already been included in the unit price. Some quotations list the mold fee separately, while others directly amortize it into the product unit price. The two quotation forms may look very different, but the actual total cost of the first purchase may not differ to the same extent. For small-batch orders, CTIA GROUP can evaluate whether powder metallurgy forming, production with existing molds, or direct machining is more suitable according to product quantity, structural complexity, and precision requirements, and formulate a corresponding manufacturing plan in combination with material utilization, processing hours, and inspection requirements.

(10) How to Reduce the Unit Cost of Small-Batch Tungsten Alloy Counterweights

If the main goal is to reduce small-batch procurement costs, this can be started from two aspects: design and procurement. In terms of design, try to reduce ultra-high-precision tolerances, complex curved surfaces, special holes and grooves, and special surface treatments that have no actual functional requirements; in terms of procurement,



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appropriately consolidate quantities, use the supplier's existing material grades or mature molds, calculate mold costs and product unit prices separately, and accept a reasonable delivery cycle while meeting functional requirements. If it is subsequently determined that mass production will be entered, a strategy of separating the sample stage from the mass production stage can also be adopted: in the early stage, dozens of pieces are machined to verify the structure, and after the design is finalized, powder metallurgy die pressing and mass sintering are used to reduce unit costs. Overall, the core reason for the higher unit price of small-batch tungsten alloy counterweights is insufficient dilution of fixed costs, while also being affected by factors such as high-value tungsten raw materials, sintering furnace runs, processing preparation, tool consumption, and precision inspection. After the order quantity increases, costs such as molds, machine adjustment, programming, furnace runs, and inspection can be spread over more products, and the unit price usually decreases; however, the specific extent of the decrease depends on product structure, density, material system, precision, and manufacturing process, rather than simply decreasing proportionally with quantity.



Q28 How Can the Cost of Tungsten Alloy Counterweights Be Reduced in Large-Volume Procurement?

In large-volume procurement of tungsten alloy counterweights, the core of cost reduction is not simply to press down the supplier's quotation per kilogram, but to reduce the comprehensive unit cost over the entire product life cycle through material specification standardization, bulk purchasing, process optimization, mold amortization, improved processing efficiency, and supply chain management. For high-density tungsten alloy counterweights, the material itself has relatively high value, and rationally optimizing



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material usage and manufacturing methods is often more effective than simply bargaining.

(1) First Determine the Appropriate Density Grade

A higher tungsten alloy density does not necessarily mean that the comprehensive unit cost of the product will be lower. For a counterweight of the same mass, the volume calculation formula is $V=m/\rho$, where V is volume, m is mass, and ρ is density. For example, for a 1 kg counterweight, when a 17.5 g/cm³ material is used, the theoretical volume is about 57.14 cm³; when an 18.5 g/cm³ material is used, it is about 54.05 cm³, a reduction of only about 3.09 cm³. If the installation space itself is sufficient, then choosing a higher-density material for this amount of volume reduction may not be able to offset the increase in material cost. In bulk procurement, the minimum density grade that meets the requirements should first be determined according to the installation space, and then supplier quotations should be compared.

(2) Reduce Procurement Costs by Unifying Material Grades

If there are many material specifications with different densities and different compositions in the same project, powder procurement, inventory, production switching, and quality management costs will increase. For example, products can uniformly adopt a certain mature tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron) or tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper) material system, and reduce the number of unnecessary grades on the premise of meeting design requirements. This is usually conducive to forming a more stable procurement batch.

(3) Increase Order Quantity So That Fixed Costs Are Fully Amortized

The most direct cost advantage of large volumes comes from the amortization of fixed costs. Unit cost can be approximately expressed as: unit cost = unit variable cost + fixed cost ÷ batch size. Suppose the fixed costs for a certain set of molds, tooling, program development, and first-article inspection are 30,000 yuan. If 1,000 pieces are produced, each piece bears 30 yuan; if 10,000 pieces are produced, each piece bears only 3 yuan. For tungsten alloy counterweights, the larger the batch, the easier it is to amortize costs such as molds, tooling, equipment debugging, process verification, and inspection preparation.

(4) Use Powder Metallurgy Processes Suitable for Mass Production as Much as Possible

For regular counterweights in large quantities, powder metallurgy (PM, Powder Metallurgy) is usually more suitable than relying entirely on CNC mechanical machining. Through die pressing, the product can be made close to its final shape before sintering, thereby reducing the amount of subsequent material removal. In particular, for cylindrical, disc-shaped, block-shaped, ring-shaped products and products with repeated hole positions, it is easier to leverage the efficiency advantages of molds and forming processes in mass production. For products with very large quantities, even if special molds need to be invested in upfront, the mold cost can be quickly amortized as output increases.



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(5) Optimize Product Structure and Reduce Unnecessary Machining

The final price of a tungsten alloy counterweight depends not only on weight but also on processing time. For example, a simple cylindrical counterweight and a counterweight with multiple steps, multiple special-shaped grooves, and complex curved surfaces may have significantly different manufacturing costs even if they weigh the same. In bulk procurement, the number of holes and grooves, chamfers, fillets, steps, and machining datums can be optimized at the design stage, and structures that can be achieved by press forming should be moved forward into the forming process as much as possible, thereby reducing subsequent processing such as turning, milling, and drilling.

(6) Control Tolerances and Do Not Pursue Excessively High Precision Unnecessarily

The stricter the dimensional tolerances, the higher the processing and inspection requirements are usually. If a certain counterweight only needs to control mass and basic installation dimensions, there is no need to apply very strict precision tolerances to all dimensions. For high-speed rotating counterweights, the focus should be on controlling dimensions, coaxiality, circular runout, mounting datums, and mass distribution that are directly related to balancing performance, rather than uniformly raising all dimensions to the same precision grade. This function-oriented tolerance design can directly reduce machining and inspection costs.

(7) Improve Material Utilization

When the price of tungsten alloy is relatively high, the impact of material utilization on the total cost of bulk procurement is especially obvious. For example, if the final product mass is 100 g, and a powder-pressed blank close to the final shape is used, the material utilization rate may be better than cutting a large amount from a larger blank. If machining is used, the blank dimensions and machining allowance should be optimized as much as possible. For large-volume products, material loss can be further reduced through layout optimization, standardization of blank specifications, and reduction of cutting allowance.

(8) Account for Mold Costs Separately from Product Unit Price

In bulk procurement, it is recommended to require suppliers to list cost items such as materials, molds, forming, sintering, machining, inspection, and surface treatment separately. In this way, it can be determined whether the decline in product unit price comes from true economies of scale or merely transfers part of the fixed costs to other quotation items. Especially for projects expected to procure tens of thousands of pieces or even more, suppliers can be asked to provide tiered quotations for different years or different quantity ranges, so as to analyze unit cost changes at 1,000 pieces, 5,000 pieces, 10,000 pieces, and larger batches.

(9) Stabilize Prices Through Annual Procurement Agreements

If the product is a continuously consumed counterweight rather than a one-time project,



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annual framework procurement or delivery in batches can be considered. For example, an annual demand of 50,000 pieces can be determined at one time, and then delivered in batches according to actual monthly or quarterly demand. This not only allows the supplier to arrange materials and production plans according to the larger annual demand, but also prevents the purchaser from bearing all inventory pressure at once. Whether a price discount can be obtained specifically needs to be negotiated and determined according to material prices, production capacity, payment terms, and the supplier's inventory strategy.

(10) Reduce Frequent Mold Changes and Specification Changes

The biggest fear in mass production is that product specifications are too scattered. Suppose the total demand is 20,000 pieces, but it includes 20 different sizes, with only 1,000 pieces of each. Then mold changes, equipment adjustments, and process switching may occur frequently during production. If it can be compressed into 5 main specifications through product seriesization, with each reaching 4,000 pieces, production efficiency is usually easier to improve. Therefore, the cost-reduction focus of bulk procurement is not only the total quantity, but also the continuous production quantity of a single specification.

(11) Divide Inspection Requirements into First-Article, In-Process, and Final Inspection

High-density tungsten alloy counterweights may need to be tested for indicators such as density, dimensions, mass, hardness, surface condition, and dynamic balance. If every product adopts the same full-dimensional inspection method as the first article, the inspection cost in mass production may be relatively high. According to the quality control plan, the project can be divided into first-article confirmation, in-process sampling inspection, and final inspection, while setting necessary full inspection items for key quality characteristics. For example, for counterweights with very strict mass tolerances, mass can be inspected at a relatively high proportion or even 100%, while sampling inspection can be used for some dimensions that do not affect function. The specific inspection proportion should be determined according to the product quality agreement and application risk.

(12) Choose a Supplier Manufacturing Model Suitable for Bulk Orders

In large-volume procurement, the supplier's actual manufacturing capability is more important than a simple quotation. Key considerations should include its powder metallurgy equipment, sintering furnace capability, mold manufacturing capability, machining capability, quality inspection capability, and stability of bulk delivery. For large-volume tungsten alloy counterweights, CTIA GROUP can carry out mass-production optimization of powder metallurgy forming, sintering, subsequent machining, and inspection processes according to annual demand, single-batch quantity, material system, target density, structural dimensions, and mass tolerances, so as to reduce costs caused by repeated machine adjustment and process switching.



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(13) Do Not Compare Only the Price per Kilogram

This is a particularly important point in large-volume procurement. For example, Supplier A quotes 60 yuan/kg, and Supplier B quotes 65 yuan/kg. It appears that A is cheaper, but if A's product requires more subsequent machining, has lower material utilization, unstable dimensional tolerances, or higher packaging, transportation, and inspection costs, then the final landed cost may not have an obvious advantage. A more reasonable comparison method is to calculate the comprehensive unit product cost, that is, total procurement cost $\div$ number of qualified products. The total procurement cost should include materials, forming, sintering, machining, mold amortization, inspection, surface treatment, packaging, transportation, and necessary after-sales quality costs.

(14) Establish a Cost-Reduction Model for Bulk Procurement

If the procurement volume is relatively large, a simple cost model can be established:

Total cost $\approx$ material cost + forming cost + sintering cost + machining cost + inspection cost + mold and tooling cost + surface treatment cost + packaging and transportation cost.

Further calculate the unit cost: unit cost $\approx$ total cost $\div$ number of qualified products. The number of qualified products is very important because if a certain manufacturing solution has a low production cost per piece but a low batch qualification rate, the cost ultimately allocated to each qualified product may still be relatively high.

(15) Cost Reduction in Bulk Procurement Can Be Carried Out Simultaneously from These Stages

If the procurement quantity has already reached a relatively large scale, optimization can be carried out simultaneously in the stages of materials, design, forming, sintering, processing, inspection, and supply chain. In terms of materials, unify grades and centralize procurement; in terms of design, reduce unnecessary complex structures and excessively high tolerances; in terms of manufacturing, adopt molds and powder metallurgy processes suitable for mass production; in terms of processing, reduce cutting volume and tool changes; in terms of inspection, establish reasonable first-article, in-process, and final inspection plans; in terms of supply chain, reduce comprehensive costs through annual demand forecasting, tiered quotations, and stable delivery plans.

The cost-reduction logic of large-volume procurement of tungsten alloy counterweights can be summarized as: increase procurement scale $\rightarrow$ amortize fixed costs of molds and processes $\rightarrow$ improve material utilization $\rightarrow$ improve forming and sintering efficiency $\rightarrow$ reduce subsequent machining $\rightarrow$ optimize inspection $\rightarrow$ reduce supply chain and inventory costs. Truly effective bulk cost reduction is not simply asking suppliers to lower quotations, but enabling the same specification to be produced stably, continuously, and with a high qualification rate. For high-density tungsten alloy counterweights, material price is usually only part of the cost structure. Design standardization, mold amortization, and production efficiency will also significantly affect the final unit procurement cost.



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Q29 What Drawing Information Is Required for Customizing a Tungsten Alloy Counterweight?

When customizing a tungsten alloy counterweight, the more complete the drawing information, the easier it is for the supplier to accurately determine the material, forming method, processing technology, quality control, and quotation. For simple cylindrical or disc-type counterweights, a complete two-dimensional engineering drawing is usually sufficient to meet basic production requirements; for special-shaped counterweights, high-precision counterweights, or products requiring dynamic balancing, it is recommended to provide both a two-dimensional engineering drawing and a three-dimensional model.

(1) Basic Product Dimensions

The drawing should first clearly define the overall external dimensions of the counterweight, including length, width, height, diameter, thickness, step dimensions, etc. For example, a cylindrical counterweight should at least be marked with the outer diameter and height; a disc-shaped counterweight needs to be marked with the outer diameter, thickness, and central hole dimensions; a rectangular counterweight needs to be marked with length, width, and height. If the product has multiple steps or different diameter regions, the dimensions of each section should be marked separately, avoiding the provision of only one maximum external dimension.

(2) Material and Density Requirements

The drawing or technical requirements should clearly define the material system, such as tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron) or tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper), and at the same time indicate the target density or material grade. For example, the target density can be specified as 18.0 g/cm³, or a material grade



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recognized by the supplier can be directly specified. If only "high-density tungsten alloy" is written without a clear density grade, the supplier may choose different formulations according to its own material system, resulting in differences in final weight, volume, and quotation.

(3) Product Target Weight and Weight Tolerance

For counterweight parts, weight is often one of the core technical parameters. The drawing should preferably clearly define the target mass and allowable deviation, for example $100.00\text{ g} \pm 0.10\text{ g}$, rather than merely marking the product name as a 100 g counterweight. The stricter the mass tolerance, the higher the requirements usually are for material consistency, machining removal amount, and final inspection, so it will directly affect the manufacturing cost. If the product is used for dynamic balancing, the mass distribution and unbalance requirements should also be further clarified, rather than controlling only the total weight.

(4) Holes, Grooves, and Mounting Structures

If the counterweight needs to be mounted on other parts, all mounting features should be marked in detail, including central holes, threaded holes, counterbores, through holes, positioning holes, keyways, mounting grooves, screw holes, and other positioning structures. For example, for a ring-shaped tungsten alloy counterweight, in addition to the outer diameter and inner diameter, the number of holes, hole diameter, bolt circle diameter, hole position angle, and hole position datum should also be clearly defined. For circumferentially equally spaced holes, the number of holes and angular relationship can be marked, for example, $6 \times \Phi 5$ holes equally spaced on a specified pitch circle.

(5) Dimensional Tolerances

It is not enough to provide only basic dimensions; allowable deviations for key dimensions should also be clearly defined. For example, for an outer diameter of $\Phi 20\text{ mm}$, if $\Phi 20.00 \pm 0.02\text{ mm}$ is required, it is completely different from an ordinary $\Phi 20\text{ mm}$ dimensional requirement. For tungsten alloy counterweights, it is recommended to focus on marking the dimensional tolerances that truly affect assembly and function, including outer diameter, inner diameter, thickness, mounting holes, positioning surfaces, shaft holes, etc., rather than setting very strict tolerances on all dimensions. This not only helps ensure product function but also avoids unnecessarily increasing processing costs.

(6) Geometric Tolerances

If the counterweight is used for high-speed rotating components, geometric tolerances are often more important than ordinary dimensional tolerances. Requirements such as coaxiality, circular runout, end face runout, flatness, perpendicularity, and position tolerance can be marked according to actual needs. For example, if there is a large coaxiality error between the central hole and the outer circle of a rotating counterweight,



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even if the total weight is completely correct, obvious unbalance may still occur after installation on the rotating shaft.

(7) Surface Roughness and Surface Treatment

The drawing should indicate the surface roughness of key machined surfaces, such as Ra (Arithmetic Average Roughness) 1.6 μm , 3.2 μm , etc. If the product requires surface treatment, it should also be indicated in the drawing or technical documents, such as anti-corrosion treatment, plating, coating, polishing, or other special surface requirements. If there are no special requirements, it can also be clearly stated that delivery is based on normal processing conditions, avoiding the supplier quoting according to a higher-grade surface treatment scheme.

(8) Chamfer, Fillet, and Burr Requirements

The edges of the counterweight usually need chamfering or fillet treatment. For example, the drawing can specify dimensions such as Co.5 and Ro.5, and at the same time indicate whether machining burrs need to be removed. For counterweights requiring manual assembly, reasonable chamfers can improve assembly safety; for high-speed rotating parts, burrs that may affect balance or create a risk of detachment should be avoided.

(9) Counterweight Center and Center-of-Gravity Requirements

If the product is an ordinary static counterweight, it is usually only necessary to control mass and installation position; if it is used in a rotating system, it is recommended to clearly define the center-of-gravity position. For example, it can be specified that the mass center of the counterweight must be located on a specified axis, or the distance from a certain reference plane to the center of gravity can be specified. For irregularly shaped counterweights, it is best to clearly define the mass center or design datum in the three-dimensional model, which is especially important for subsequent dynamic balancing design.

(10) Dynamic Balancing Requirements

If the tungsten alloy counterweight is used in equipment such as motor rotors, engine rotating components, industrial rotors, and high-speed main shafts, the dynamic balancing requirements should be clearly defined in the drawing. In addition to total mass, residual unbalance, balancing grade, rotational speed, number of correction planes, and test conditions may also need to be specified. The centrifugal force in a dynamic system can be expressed as $F = m\omega^2 r$, where F is centrifugal force, m is mass, ω is angular velocity, and r is the mass eccentricity distance. Therefore, for counterweights of the same mass, if the installation position or mass distribution is different, the actual balancing effect may also differ.



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(11) Machining Datum and Assembly Datum

The engineering drawing should preferably clearly define the main datum planes, datum axes, and positioning surfaces. For example, the central hole axis can be used as datum A, the end face as datum B, and a certain side face as datum C. In this way, the supplier can control product accuracy according to a unified datum during turning, milling, drilling, and final inspection. For high-precision tungsten alloy counterweights, unclear datum definitions may lead to cumulative dimensional errors between different processes.

(12) It Is Best to Provide Both a 2D Engineering Drawing and a 3D Model

If the structure is relatively simple, a two-dimensional engineering drawing can usually serve as the main production basis. If the product has complex curved surfaces, eccentric structures, porous structures, or spatial mounting features, it is recommended to also provide a three-dimensional CAD (Computer-Aided Design) model. The three-dimensional model can help the supplier understand the overall product structure, while the two-dimensional engineering drawing is responsible for defining dimensions, tolerances, datums, and technical requirements. If there are differences between the two, it should be clearly stated which file is the final production basis.

(13) Technical Requirements and Inspection Requirements

The drawing should finally also explain special technical requirements, such as density range, mass tolerance, hardness, material composition, internal defect requirements, surface condition, dimensional inspection, quality inspection, and dynamic balancing testing. If the product is a key functional part, the supplier can also be required to provide material certificates, dimensional inspection reports, weight inspection records, or other quality documents.

(14) What Information Can a Complete Tungsten Alloy Counterweight Drawing Contain?

When actually submitting a drawing to a supplier, it can be organized according to the following logic: product name, part number, material system, target density, target weight and weight tolerance, overall dimensions, hole and groove dimensions, thread specifications, dimensional tolerances, geometric tolerances, surface roughness, chamfers and fillets, machining datum, assembly datum, center-of-gravity requirements, dynamic balancing requirements, surface treatment, inspection requirements, and packaging or special delivery requirements. The most core information is usually the material system, density, weight, external dimensions, mounting dimensions, tolerances, and quantity. If these parameters are already clear, the supplier can usually carry out preliminary process analysis and quotation.

For tungsten alloy counterweight customization, CTIA GROUP can match material selection, powder metallurgy forming, sintering, mechanical machining, and final inspection schemes according to two-dimensional engineering drawings, three-dimensional CAD models, and



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target weight, density, dimensional tolerances, and application requirements.

A good tungsten alloy counterweight drawing is not one with as many dimensions as possible, but one that clearly defines the parameters that truly affect material selection, manufacturing process, assembly performance, and final quality. For ordinary counterweights, the focus is on weight, dimensions, and mounting structure; for precision counterweights, geometric tolerances, center-of-gravity, and mass distribution requirements should also be added; for high-speed rotating counterweights, key indicators such as dynamic balancing, coaxiality, and runout should be further clarified.



Q30 What Technical Parameters Need to Be Provided When Requesting a Quote for Tungsten Alloy Counterweights?

When requesting a quote for tungsten alloy counterweights, the more complete the information provided, the easier it is for the supplier to accurately judge material costs, forming methods, processing difficulty, inspection requirements, and delivery cycles, and the more it can reduce quotation deviations caused by repeated confirmation. For simple standard counterweights, providing weight, dimensions, density, and quantity is usually enough for a preliminary quote; for precision counterweights or customized batch products, it is best to also provide complete engineering drawings, three-dimensional models, and technical requirements.

(1) Product Name and Application

First, it should be explained what product the counterweight is specifically used for, such as



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automotive parts, industrial rotors, aerospace equipment, drones, motors, precision instruments, electronic equipment, etc. The application will affect the material system, density grade, mechanical properties, magnetic properties, machining accuracy, and whether dynamic balancing testing is required. For example, the technical requirements for an ordinary fixed counterweight and a high-speed rotating counterweight may be completely different.

(2) Material System

It should be clearly specified which material system is desired, such as tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron) or tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper). If there is no requirement for a specific material grade, it can also be noted that the supplier should recommend a material according to the target density, mechanical properties, magnetic properties, and processing requirements.

(3) Target Density

Target density is one of the important parameters when requesting a quote for tungsten alloy counterweights, for example 17.5, 18.0, or 18.5 g/cm³. At the same weight, the higher the density, the smaller the required volume. The basic relationship is $V=m/\rho$, where V is the counterweight volume, m is the mass, and ρ is the material density. For example, for a 1 kg counterweight using an 18.0 g/cm³ material, the theoretical volume is about 55.56 cm³; when using a 17.5 g/cm³ material, it is about 57.14 cm³. If the installation space is limited, the minimum density requirement should be clearly specified, rather than simply writing high-density tungsten alloy.

(4) Single-Piece Weight and Weight Tolerance

The target weight should be provided, for example 10 g, 100 g, 500 g, or 1 kg, and the allowable deviation should be clearly specified. For example, 100.00 g $\pm$ 0.10 g and 100 g $\pm$ 2 g are completely different quality control requirements. The stricter the weight tolerance, the higher the requirements for material consistency, machining removal amount, and final inspection are usually, and the quotation may increase accordingly.

(5) Product Dimensions

At least the main dimensions such as length, width, height, outer diameter, inner diameter, and thickness should be provided. If it is a cylindrical, disc-shaped, ring-shaped, or rectangular counterweight, the basic external dimensions can be provided directly; if it is a special-shaped product, it is recommended to provide a complete two-dimensional engineering drawing and a three-dimensional CAD (Computer-Aided Design) model.

(6) Mounting Structure

It is necessary to clarify how the counterweight is installed, including center holes, threaded holes, positioning holes, counterbores, through holes, keyways, mounting



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grooves, screw holes, and other connecting structures. For example, for a ring-shaped counterweight, it is best to also provide the outer diameter, inner diameter, thickness, hole diameter, number of holes, bolt circle diameter, and hole position angle. The more complex the mounting structure, the higher the machining cost is usually.

(7) Dimensional Tolerances

When requesting a quote, it is not enough to provide only basic dimensions; the tolerances of key dimensions should also be specified. For example, $\Phi 20$ mm and $\Phi 20.00 \pm 0.02$ mm may differ significantly in manufacturing cost. It is recommended to focus on marking the key dimensions that truly affect assembly and performance, rather than imposing excessively high precision requirements on all dimensions.

(8) Geometric Tolerances and Datum Requirements

If the product requires high-precision assembly, requirements such as coaxiality, circular runout, face runout, flatness, position tolerance, and perpendicularity should be provided, and the machining datum should be clearly specified. Especially for tungsten alloy counterweights installed on rotating shafts, if there is a relatively large coaxiality error between the center hole and the outer circle, even if the total weight of the product is correct, it may cause unbalance in the rotating system.

(9) Dynamic Balancing Parameters

If the counterweight is used in high-speed rotating equipment, it should be clearly specified during the inquiry whether dynamic balancing is required. Parameters such as operating speed, balancing grade, allowable residual unbalance, number of correction planes, and testing method can be provided. The centrifugal force in a rotating system can be expressed as $F = m\omega^2 r$, where F is centrifugal force, m is mass, ω is angular velocity, and r is eccentric distance. Therefore, the quotation for a high-speed rotating counterweight cannot be calculated only based on weight; mass distribution and machining accuracy also need to be considered.

(10) Surface Roughness and Surface Treatment

If there are special surface requirements, the surface roughness should be clearly specified, for example R_a (Arithmetic Average Roughness) 1.6 μm , 3.2 μm , etc. At the same time, it should be noted whether polishing, plating, coating, anti-corrosion treatment, or other special surface treatment is required. If there are no special requirements, it can also be clearly stated that a normal machined surface condition will be used, so as to avoid the supplier calculating costs according to a higher-grade surface requirement.

(11) Quantity and Procurement Batch

Quantity has a very large impact on the quotation, so at least the trial production quantity, first batch quantity, and estimated annual demand should be provided. For example, if the



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inquiry also states 100 pieces for the first batch, 1000 pieces per month thereafter, and an estimated annual demand of 12,000 pieces, the supplier can evaluate molds, powder metallurgy forming, and batch processing plans according to long-term demand. For the same product, purchasing 10 pieces, 1000 pieces, and 100,000 pieces will usually not have the same unit cost.

(12) Manufacturing Process Requirements

If the purchaser has already specified the process, it should be clearly required to use powder metallurgy, die pressing and sintering, machining, or other manufacturing methods. If no process is specified, then only the product performance and dimensional requirements can be proposed, allowing the supplier to choose a more economical manufacturing solution according to the batch size and structure. For large-batch regular counterweights, powder metallurgy forming usually has good large-scale production potential; for small quantities of complex products, direct machining is sometimes more suitable.

(13) Material Performance Requirements

If the product not only requires high density but also has performance requirements, the corresponding indicators should be clearly specified, such as hardness, tensile strength, elongation, magnetic properties, thermal properties, etc. Magnetic properties are especially worth specifying separately. Iron-containing W-Ni-Fe systems usually have a more obvious magnetic response, while W-Ni-Cu systems usually have a lower magnetic response, but the specific result still depends on material composition, impurities, and manufacturing process. If the product is close to magnetic sensors, precision instruments, or other sensitive equipment, it is recommended to propose magnetic performance requirements at the inquiry stage.

(14) Inspection and Quality Documents

It needs to be clearly specified whether the supplier is required to provide material certificates, density inspection reports, dimensional inspection reports, weight inspection reports, hardness inspection reports, or dynamic balancing reports. If it is an aerospace, medical equipment, or other product with relatively high quality management requirements, the quality system, batch traceability, and document requirements should also be explained in advance.

(15) Drawings and Three-Dimensional Models

If formal engineering drawings are already available, it is best to directly provide PDF two-dimensional engineering drawings and three-dimensional models in formats such as STEP and IGES when requesting a quote. The two-dimensional drawing is mainly used to determine dimensions, tolerances, materials, and technical requirements, while the three-dimensional model helps the supplier understand complex structures and calculate



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material usage. For special-shaped counterweights, it is usually difficult to accurately judge processing costs based only on text descriptions.

(16) Delivery and Packaging Requirements

When requesting a quote, information such as the expected delivery date, delivery batch, packaging requirements, and transportation method should also be provided. If the product surface is prone to impact damage, has relatively high dimensional accuracy, or is a small precision counterweight, it should be stated whether independent packaging, anti-collision packaging, or special protection is required.

(17) A Parameter Table Can Be Directly Prepared When Requesting a Quote

When actually sending an inquiry, the following can be provided in the following order: product name and application, material system, target density, single-piece weight, weight tolerance, product dimensions, mounting structure, dimensional tolerances, geometric tolerances, surface roughness, surface treatment, dynamic balancing requirements, material performance requirements, inspection requirements, single batch quantity, annual demand, engineering drawings, three-dimensional models, target delivery date, and packaging requirements. Among them, the most core parameters are usually: material system, density, single-piece weight, weight tolerance, external dimensions, mounting structure, key dimensional tolerances, and procurement quantity. For high-speed rotating counterweights, information such as rotational speed, balancing grade, or allowable residual unbalance must be further provided.

In the process of tungsten alloy counterweight inquiry and customization, CTIA GROUP can comprehensively evaluate powder metallurgy forming, sintering, machining, and inspection plans according to the weight, density, dimensions, quantity, material system, and precision requirements provided by the customer, and determine material usage and manufacturing costs accordingly. An effective tungsten alloy counterweight inquiry document should answer several core questions: what material is used, what density is required, how much does each piece weigh, what are the dimensions, how high is the precision requirement, how is it installed, is dynamic balancing required, how many pieces are needed, and when is delivery required. The closer the information is to complete engineering technical conditions, the more accurate the supplier's quotation will usually be, and the easier it will be to make like-for-like cost comparisons among different suppliers.



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Q31 How Should Quotations from Different Suppliers of Tungsten Alloy Counterweights Be Compared?

When comparing quotations from different suppliers for tungsten alloy counterweights, it is not possible to judge simply by price per kilogram or price per piece. The final cost of a tungsten alloy counterweight is simultaneously affected by material density, tungsten (W, Tungsten) content, material system, product weight, structural complexity, machining accuracy, mold costs, inspection requirements, procurement quantity, and delivery conditions. The most reasonable method is to first convert all suppliers' quotations into a comprehensive procurement cost under the same technical conditions, and then compare materials, manufacturing, quality, and delivery conditions.

(1) First Confirm Whether the Same Material Is Being Compared

When different suppliers quote, the first step should be to confirm whether the material system is consistent. For example, if all are tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron), it is still necessary to further confirm the tungsten content, target density, and material grade; if one uses W-Ni-Fe and another uses tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper), even if their densities are close, they cannot be directly compared by price per kilogram. Different material systems may bring differences in density, magnetic properties, mechanical properties, thermal properties, processing performance, and cost.

(2) Confirm Whether the Density Is Consistent

Density directly affects the material volume at the same weight. For example, to produce the same 1 kg counterweight, a 17.5 g/cm³ material requires 57.14 cm³, while an 18.5 g/cm³ material requires only 54.05 cm³. Therefore, if Supplier A quotes a lower price but uses a 17.5 g/cm³ material, while Supplier B quotes a higher price but uses an 18.5 g/cm³ material,



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then simply comparing yuan/kg can't fully reflect the actual value of the two solutions. If there is no limitation on the product installation space, the focus can be on comprehensive cost; if the space is very limited, then volume occupation needs to be included in the technical and cost analysis.

(3) Do Not Look Only at Price per Kilogram

For tungsten alloy counterweights, it is best to compare at the same time: material unit price, price per piece, mold costs, machining costs, inspection costs, surface treatment costs, packaging costs, transportation costs, and other one-time costs. For example, Supplier A quotes 80 yuan/kg but requires an additional 10,000 yuan mold fee; Supplier B quotes 85 yuan/kg and already includes mature molds and part of the inspection costs. The two cannot be judged directly based on 80 and 85 yuan/kg. Especially in large-batch procurement, after the mold fee is amortized, its impact on the unit cost will change significantly.

(4) Calculate the True Comprehensive Cost per Piece

A relatively practical formula can be used: Comprehensive cost per piece = product procurement amount + amortized mold and tooling costs + inspection costs + packaging and transportation costs + other related costs ÷ number of qualified products. If the quotation conditions of different suppliers are completely consistent, it can be further simplified to a comparison of price per piece; but in actual inquiries, certain costs are often quoted separately, so it is best to first restore the cost structure. For example, if Supplier A's product unit price is lower, but the purchaser must bear higher mold and transportation costs, then the final delivered cost may be close to that of Supplier B.

(5) Compare the Same Weight and Weight Tolerance

For counterweight products, it must be confirmed whether the target weight is consistent. For example, Supplier A provides 100 g ± 1 g, and Supplier B provides 100 g ± 0.1 g. Although the target weight is the same, the quality control requirements are not the same. If the actual application only requires ±1 g, then purchasing the stricter ±0.1 g product may add unnecessary cost; conversely, if the equipment requires ±0.1 g, then a low-precision product cannot be compared as an equivalent solution even if its quotation is lower.

(6) Compare Key Dimensions and Tolerances

For the same Φ20 mm tungsten alloy counterweight, if one supplier machines it according to ordinary dimensional tolerances and another according to high-precision tolerances, the manufacturing cost may differ significantly. Therefore, it should be ensured that suppliers quote using the same engineering drawing, the same drawing version, and the same technical requirements. In particular, it should be checked whether key parameters such as outer diameter, inner diameter, thickness, mounting holes, hole positions, coaxiality, circular runout, and flatness are completely consistent.



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(7) Compare How Mold Costs Are Handled

For powder metallurgy (PM, Powder Metallurgy) products, mold costs may be an important source of quotation differences. When suppliers quote, three situations may occur: the mold fee is charged separately, the mold fee has already been amortized into the product unit price, or the supplier uses existing molds and no longer charges a new mold fee. Therefore, when comparing quotations, mold costs should be uniformly converted into the estimated procurement quantity. For example, if 10,000 pieces are expected to be purchased, then a 10,000 yuan mold fee is equivalent to 1 yuan/piece; if only 100 pieces are purchased, it is equivalent to 100 yuan/piece. The same mold cost has a completely different impact on the final price under different procurement quantities.

(8) Compare Whether the Manufacturing Processes Are the Same

The same product can use different manufacturing routes. For example, powder pressing followed by sintering and finishing can be used, or tungsten alloy blanks can be directly turned, milled, or drilled. Different processes have different material utilization rates, production efficiencies, mold costs, and processing costs. For small-batch complex products, direct machining may reduce mold investment; for large-batch regular products, powder metallurgy forming may more easily reduce unit manufacturing costs. Therefore, it is best to require the supplier to explain the basic manufacturing process in the quotation.

(9) Compare Material Utilization Rates

Tungsten alloy materials are relatively valuable, so the material utilization rate deserves separate attention. If Supplier A needs to use a larger tungsten alloy blank for a large amount of cutting, while Supplier B can reduce machining allowance through near-net shaping, then even if the raw material unit prices of the two are the same, the final product cost may differ. It is possible to further compare how much material is actually consumed per qualified product, rather than only comparing the material procurement unit price.

(10) Compare the Scope of Machining and Inspection

The quotation should clearly specify whether it includes mechanical machining such as turning, milling, drilling, tapping, and grinding, and whether it includes dimensional inspection, weight inspection, density inspection, and dynamic balancing testing. For high-speed rotating counterweights, it should also be confirmed whether dynamic balancing testing is included in the quotation, because dynamic balancing involves mass distribution, not simply measuring product weight. If Supplier A's quotation includes complete dynamic balancing testing, while Supplier B provides only dimensional and weight inspection, then the two are actually not the same scope of service.

(11) Compare Quality Standards and Qualification Rates

A lower price does not necessarily mean a lower comprehensive procurement cost. If a supplier's batch products have relatively poor dimensional consistency and require the



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purchaser to increase incoming inspection, rework, or screening, then the low quotation may be offset by subsequent quality costs. For large-batch procurement, particular attention should be paid to batch stability, process control capability, quality traceability, and defective product handling mechanisms. Suppliers can be asked to explain inspection standards, key dimension inspection methods, and nonconforming product handling methods.

(12) Compare Delivery Cycles and Production Capacity

If two suppliers have similar prices, actual production capacity and delivery capability should also be compared. For example, if one supplier can stably deliver 10,000 pieces per month, while another can deliver only 2,000 pieces per month, then even if the latter's quotation is slightly lower, it may increase the purchaser's costs in inventory, line stoppage, and planning management. For long-term projects, it should also be understood whether the supplier can continuously supply the same material grade and density grade.

(13) Compare Quotation Validity and Raw Material Price Mechanisms

The raw material cost of tungsten alloy is affected by the prices of tungsten raw materials, powders, and other alloying elements, so long-term orders are not necessarily suitable for simply adopting a permanently fixed price. If the project cycle is relatively long, the quotation validity period, raw material price adjustment mechanism, exchange rate impact, and subsequent batch price adjustment method should be confirmed. This can avoid a situation where the first batch quotation appears relatively low, but the subsequent batch price changes significantly.

(14) Calculate Prices Under Different Procurement Quantities

The quotation of the same supplier should also be compared according to procurement quantity. For example, by inquiring separately for 100 pieces, 1,000 pieces, 10,000 pieces, and 100,000 pieces, the scale effects brought by mold amortization, material procurement, and production efficiency can be observed. If the supplier provides tiered pricing, the comprehensive unit cost of each quantity interval can also be calculated, rather than only looking at the lowest unit price corresponding to the highest procurement quantity.

(15) CTIA GROUP Can Serve as a Technical Benchmark in Quotation Comparison

CTIA GROUP can comprehensively evaluate material usage, forming process, sintering, mechanical machining, and inspection plans according to the material system, target density, product weight, dimensional tolerances, procurement quantity, and processing requirements of tungsten alloy counterweights. When comparing prices among multiple suppliers, such technical parameters can serve as unified inquiry conditions, reducing quotation distortion caused by differences in material grades or manufacturing processes.



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(16) What Should Ultimately Be Compared Is the Total Cost of Ownership

If the procurement volume is relatively large, it is best not to calculate only the one-time purchase price, but to further consider the cost of the entire service cycle. It can be understood as: Total cost of ownership = product procurement cost + molds and tooling + transportation and warehousing + incoming inspection + rework and screening + defective product losses + quality problem handling costs. For example, Supplier A's price per piece is 5% lower, but the product batch consistency is relatively poor and requires a large amount of additional screening; Supplier B's price is slightly higher, but the dimensions are stable, the inspection data are complete, and delivery is stable. Then the actual procurement cost difference between the two may not be the same as the unit price difference on the quotation sheet. Therefore, when comparing quotations from tungsten alloy counterweight suppliers, the most important thing is to achieve three unifications: unified material system and density, unified drawings and quality requirements, and unified quantity and delivery conditions. On this basis, by then comparing price per piece, mold amortization, processing costs, inspection costs, transportation costs, and quality costs, a supplier quotation comparison result with actual reference value can be obtained.



Q32 How to Choose a Tungsten Alloy Counterweight OEM (Original Equipment Manufacturer) Supplier?

When choosing a tungsten alloy counterweight OEM (Original Equipment Manufacturer) supplier, one should not only look at whether the quotation is high or low, but should focus on judging whether the supplier truly has the capabilities of material design, powder metallurgy forming, sintering, precision machining, inspection, and batch delivery. For ordinary counterweights, the focus is on cost and delivery time; for high-precision, high-speed rotating, or aerospace-type counterweights, it is also necessary to further



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examine dimensional stability, quality consistency, dynamic balancing, and batch traceability capabilities.

(1) First Confirm Whether the Supplier Has Professional Tungsten Alloy Manufacturing Capability

A supplier truly suitable for a tungsten alloy counterweight OEM project should be able to explain the material system used, density range, tungsten content, and main manufacturing process, rather than simply purchasing finished products from other manufacturers and then performing simple processing. Common material systems include tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron) and tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper). The supplier should at least be able to select a suitable material according to product weight, installation space, magnetic properties, and mechanical performance requirements.

(2) Examine Material Density Control Capability

One of the most core material indicators of a tungsten alloy counterweight is density. For example, when the target density is 18.0 g/cm^3 , the theoretical volume of 1 kg of material is about 55.56 cm^3 . The actual product quality depends not only on the theoretical density, but also on porosity, sintering state, and final machined dimensions. Therefore, when requesting a quote, the supplier can be asked to provide density testing methods, typical density ranges, and batch stability, rather than only looking at the highest density in product promotion.

(3) Confirm Whether the Supplier Has Powder Metallurgy and Sintering Capability

For batch tungsten alloy counterweights, powder metallurgy (PM, Powder Metallurgy) is usually an important manufacturing route. Complete capability usually includes powder proportioning, mixing, press forming, debinding or pretreatment, liquid-phase sintering, and post-sintering processing. If the supplier can cover the main production stages, control over material consistency and delivery stability is usually more direct. For complex counterweights, it is also necessary to further understand whether the supplier has dedicated mold design and manufacturing capability.

(4) Confirm Machining Capability

Tungsten alloy counterweights often require subsequent processing such as turning, milling, drilling, tapping, and grinding. The supplier should formulate reasonable tools and processing parameters according to the characteristics of tungsten alloy materials and be able to stably control key dimensions. If the product has a large number of holes, grooves, threads, steps, or high-precision mounting surfaces, the focus should be on understanding whether the supplier has corresponding CNC machining equipment and batch processing experience.



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(5) Focus on Examining Dimensional and Quality Tolerance Control

Counterweight products cannot be considered only in terms of material density. For example, for a 100 g counterweight, if ± 0.1 g is required, the quality control requirement is obviously higher than 100 g ± 2 g; if the outer diameter, center hole, coaxiality, and circular runout are also required to reach relatively high precision, the manufacturing and inspection difficulty will further increase. Therefore, the supplier can be asked to provide dimensional inspection reports, weight inspection records, or typical quality control plans for similar products.

(6) For High-Speed Rotating Products, Examine Dynamic Balancing Capability

If the tungsten alloy counterweight is used in rotating equipment such as motor rotors, engine crankshafts, industrial rotors, and high-speed main shafts, dynamic balancing capability must be examined as a key point. The centrifugal force in a rotating system can be expressed as $F = m\omega^2 r$, where F is centrifugal force, m is mass, ω is angular velocity, and r is eccentric distance. Therefore, for the same product weight, if the center-of-gravity position, coaxiality, or mass distribution differs, the actual operating state may differ significantly. Whether the supplier has a dynamic balancing machine, dedicated fixtures, and corresponding testing standards is an important basis for selecting this type of OEM supplier.

(7) Check Whether Complete Quality Documents Can Be Provided

Different projects have different requirements for quality documents. Ordinary products may only require a shipping inspection report; high-requirement projects may require material certificates, density reports, dimensional reports, weight reports, hardness reports, dynamic balancing reports, and batch traceability records. If the product is used in fields such as aerospace, medical equipment, and precision instruments, it should also be confirmed in advance whether the supplier can meet the quality system and document management requirements specified by the project.

(8) Examine Batch Production Capability

An OEM project is different from ordinary small-batch procurement. It is not enough to see only whether the supplier can make a sample; it is also necessary to see whether it can produce stably over the long term. Key questions can include: What is the monthly production capacity? What is the current equipment load? Are there backup devices? What is the mold life? Are there capacity bottlenecks in key processes? What is the normal batch defect rate? Can continuous delivery be met? For projects with a relatively large estimated annual procurement volume, it is best to have the supplier provide a capacity plan according to actual demand.

(9) Compare the Connection Capability Between Small-Batch Trial Production and Large-Batch Mass Production



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An excellent OEM supplier should not only be able to make samples, but should also be able to transform the sample process into a stable batch production process. A relatively reasonable process is usually: drawing review → material confirmation → process design → sample manufacturing → dimensional and performance verification → small-batch trial production → process optimization → mass production → batch quality control. If a special temporary process is used at the sample stage, and the process is completely changed at the mass production stage, then the reference value of the sample data for mass production may be limited.

(10) Do Not Ignore Mold and Tooling Capability

For powder metallurgy counterweights, mold design directly affects product dimensions, material utilization, and production efficiency. It is necessary to confirm who bears the mold cost, who owns the mold property rights, what the mold life is, who is responsible for mold maintenance, and how it will be handled after the project is terminated. If the estimated procurement volume is very large, mold life and backup mold plans should also be considered to avoid affecting delivery due to mold wear during mass production.

(11) Examine Design and Process Optimization Capability

An excellent OEM supplier should not only process according to drawings, but should also be able to identify problems between design and manufacturing. For example, a certain hole and groove structure may cause pressing difficulties, an extremely small fillet may increase tool wear, or an excessively strict tolerance may have no actual functional value. If the supplier can raise these issues before formal production and provide optimization suggestions in DFM (Design for Manufacturability), subsequent trial production and mass production risks can be reduced.

(12) Unify Technical Conditions When Comparing Quotations

When choosing an OEM supplier, at least all suppliers should be asked to quote using the same engineering drawing, the same material requirement, the same density grade, the same weight tolerance, the same quantity, and the same inspection standards. Otherwise, if one supplier quotes for an 18.0 g/cm³, ±0.1 g product, and another quotes for a 17.5 g/cm³, ±1 g product, the prices of the two are not directly comparable. When comparing, mold costs, processing fees, inspection fees, packaging and transportation fees, etc. should also be included on a unified basis.

(13) Examine Delivery Time and Supply Chain Stability

For long-term OEM projects, supply stability is sometimes more important than a one-time quotation difference. It is necessary to understand the supplier's raw material procurement channels, inventory strategy, production cycle, normal delivery time, emergency order handling capability, and whether there is a single source for key raw materials. If the product is a key counterweight on a production line, once supply is interrupted, the loss



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caused may be far higher than the procurement price difference of the product itself.

(14) Confirm Intellectual Property and Drawing Confidentiality Mechanisms

OEM projects usually involve the customer's own product structure and engineering drawings, so it should be confirmed whether the supplier has a clear drawing confidentiality system. If the product has a proprietary structure, a confidentiality agreement can also be used to clarify the scope of use of drawings, three-dimensional models, material formulas, process parameters, and product data. For projects in which mold costs have already been invested, the ownership of molds and dedicated tooling should also be agreed in advance.

(15) Verify the Supplier Through Samples and Small Batches

If the project is important, it is not recommended to choose a supplier based only on a quotation sheet. Samples or small-batch trial production can be carried out first, and the material density, weight tolerance, dimensional accuracy, surface quality, installation fit, and dynamic balancing performance can be verified through actual products. For batch projects, the quality consistency of the supplier over several consecutive batches can be further observed. The qualification of a single sample cannot fully prove its batch production capability.

(16) CTIA GROUP Can Be Evaluated as a Comprehensive Capability-Type OEM Supplier

With thirty years of successful experience in tungsten alloy counterweight design, customization, and processing, CTIA GROUP can provide supporting manufacturing solutions from material selection, powder metallurgy forming, and sintering to mechanical machining and quality inspection according to the material system, target density, product structure, quality tolerance, and procurement quantity of a tungsten alloy counterweight project. For projects requiring customized counterweights, the manufacturability and batch production plan of the product can be evaluated in combination with engineering drawings and three-dimensional models.

(17) A Supplier Evaluation Framework Can Be Established

In actual selection, a comprehensive examination can be carried out from several dimensions: material capability, powder metallurgy capability, sintering capability, mechanical machining capability, mold capability, dimensional control capability, weight control capability, dynamic balancing capability, inspection capability, batch production capacity, quality system, delivery stability, quotation structure, technical support, and intellectual property protection. It is not recommended to simply use a total score to mechanically determine the supplier; rather, key indicators should be determined according to the product application. For example, ordinary fixed counterweights can focus more on material cost, dimensions, and delivery time; high-speed rotating counterweights should focus on checking dynamic balancing, coaxiality, and mass distribution; high-precision



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instrument counterweights should focus on confirming dimensional stability, weight tolerance, and magnetic properties.

When choosing a tungsten alloy counterweight OEM (Original Equipment Manufacturer) supplier, checks can be carried out layer by layer in terms of manufacturing capability, material capability, precision machining capability, inspection capability, batch delivery capability, quality stability, and comprehensive cost. What truly needs to be compared is not who has the lowest quotation, but who can continuously and stably manufacture products that meet weight, density, dimensional, and functional requirements under clearly defined technical conditions, and maintain consistency in subsequent batch production.



V. Processing and Manufacturing of Tungsten Alloy Counterweights

How Are Tungsten Alloy Counterweights Customized, Processed, and Manufactured?

A tungsten alloy counterweight is not simply tungsten powder pressed into a part with a certain weight. Rather, it is a complete manufacturing system that includes material design, powder preparation, formula control, forming, sintering densification, mechanical machining, surface treatment, and final inspection. Public information shows that China Tungsten Online began engaging in the research and development, production, and e-commerce trade of tungsten products in 1997 and has continuously accumulated design



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and manufacturing experience in the field of tungsten and molybdenum materials; its manufacturing platform, CTIA GROUP, further carries out customized design and manufacturing for tungsten and molybdenum materials such as high-specific-gravity alloys. For tungsten alloy counterweights, what truly determines product quality is not any single process step, but whether the entire manufacturing chain can achieve consistent control of material composition, density, structure, dimensions, weight, and mass distribution. This article introduces the manufacturing of alloy counterweights as a complete manufacturing route divided into several stages, including raw material preparation, mixing, forming, sintering, mechanical machining, surface treatment, and quality inspection.

(I) . Why Tungsten Alloy Counterweights Are Usually Manufactured by Powder Metallurgy

The melting point of tungsten (W, Tungsten) is about 3422 °C. If the ordinary melting and casting route commonly used for metal materials were adopted to manufacture high-tungsten-content alloys, it would be necessary to face extremely high melting temperatures, equipment requirements, and difficulties in composition and structure control. Therefore, high-specific-gravity tungsten alloys usually adopt the powder metallurgy (PM, Powder Metallurgy) route, achieving densification through powder mixing, press forming, and sintering. Relevant public technical materials also clearly point out that the industrial preparation of tungsten and tungsten alloys mainly relies on the powder metallurgy route. Its basic manufacturing logic can be summarized as: tungsten powder and binder phase powder → batching → mixing → forming → debinding or pretreatment → liquid-phase sintering → sintered blank → precision mechanical machining → surface treatment → dimension, weight, and performance inspection. For typical high-specific-gravity alloys such as W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper), this process route is especially suitable for manufacturing counterweight parts with high density, small volume, and complex mass distribution requirements.

(II) . The First Step Is Material System Design, Not Directly Opening a Mold for Production

The manufacturing of tungsten alloy counterweights first requires determining the material system. Usually, tungsten is used as the main high-density phase, and a composite structure with certain strength and toughness is formed through binder phases such as nickel, iron, or copper. Material design needs to determine the target density, mechanical properties, magnetic properties, processing performance, and environmental adaptability according to the final use of the product. For example, ordinary industrial counterweights may focus mainly on density and cost; automotive crankshaft counterweights need to pay attention to strength, vibration resistance, and processing performance; high-speed rotor counterweights place more emphasis on material uniformity, mechanical reliability, and dynamic balance; and counterweights for electronic equipment close to magnetic sensors



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need to additionally consider magnetic response. Therefore, when a customer proposes 18.0 g/cm³, it does not mean that the material selection work has already been completed. True engineering design also requires determining the specific alloy system, powder specifications, binder phase ratio, and sintering process window.

(III). Raw Material Quality Directly Affects Final Counterweight Performance

High-quality tungsten alloy counterweights need to be controlled starting from the powder. A typical raw material system includes tungsten powder and alloying element powders such as nickel, iron, and copper. Some industrial routes prepare tungsten powder from ammonium paratungstate (APT, Ammonium Paratungstate) through tungsten oxide (WO₃, Tungsten Trioxide) and then reduction. The particle size, purity, morphology, oxygen content, and batch consistency of the powder all affect subsequent pressing performance, sintering shrinkage, final density, and microstructure. For counterweights, it is especially necessary to control density stability between different batches of material. If there is obvious material density fluctuation in the same batch of products, the final weight may deviate even if the external dimensions are exactly the same.

(IV). Batching and Mixing Determine Whether the Material Composition Is Uniform

After the material formula is determined, each component needs to be accurately weighed according to the mass ratio and then fully mixed. This process looks simple, but it is actually an important step in tungsten alloy manufacturing. If the tungsten powder and binder phase are not mixed uniformly, local composition differences may appear after sintering, further causing inconsistencies in density, hardness, strength, and processing performance. Industrial production usually combines mixing, ball milling, and other methods to improve powder uniformity, but mixing intensity and time also need to be controlled according to the material system. Excessive mechanical action may change powder morphology or even introduce contamination; insufficient mixing may lead to compositional segregation. Therefore, the core of batching control is not simply mixing various powders together, but establishing a stable and repeatable powder system.

(V). Forming Determines the Basic Dimensions and Structure of the Counterweight Blank

The mixed powder needs to be formed into a green compact with a certain strength through a forming process. Common methods include uniaxial pressing, cold isostatic pressing (CIP, Cold Isostatic Pressing), and metal injection molding (MIM, Metal Injection Molding), etc. Public information also lists uniaxial pressing, cold isostatic pressing, and injection molding as important forming methods for tungsten alloy counterweights. For regular counterweights such as cylinders, blocks, and rings, mass production can give priority to die pressing, directly obtaining a blank close to the final shape through a mold. For products with complex structures, small dimensions, or multiple fine features, more flexible forming solutions may be required. Here there is a very important concept: the green compact dimensions before sintering are not equal to the final finished product



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dimensions.

(VI). Sintering Is the Core Step in the Manufacturing of Tungsten Alloy Counterweights

After forming, the green compact still contains a large number of pores, and densification is required through sintering. For high-specific-gravity tungsten alloys, liquid-phase sintering is a very important process route. During sintering, the binder phase forms a liquid phase under certain temperature conditions and promotes the rearrangement, dissolution, and precipitation of tungsten particles, gradually densifying the material. The density, microstructure, porosity, tungsten particle distribution, and mechanical properties of the final product are all closely related to the sintering process. Therefore, sintering temperature, holding time, heating and cooling schedules, furnace atmosphere, loading method, and sintering batch management all need to be controlled. Especially for precision counterweights, sintering shrinkage must be incorporated into mold and process design in advance. Designers need to predict the sintering shrinkage rate according to the material system and historical process data, and then reverse-design the green compact dimensions. In other words, if the final required finished product diameter is 20 mm, it does not mean that the mold is simply manufactured at 20 mm; rather, the dimensional shrinkage after sintering needs to be considered.

(VII). Why Tungsten Alloy Still Needs Mechanical Machining After Sintering

Powder metallurgy can obtain a sintered blank close to the final shape, but for precision tungsten alloy counterweights, mechanical machining is usually still required. Common processing methods include turning, milling, drilling, tapping, grinding, and local finishing. For example, for a simple cylindrical counterweight, if the sintered dimensions already meet the requirements, only a small amount of finishing may be needed; but if the product has mounting holes, threads, positioning grooves, steps, inclined surfaces, or precision fitting surfaces, further processing is usually required. This combined method of sintering plus finishing can take into account both material utilization and dimensional accuracy, and is also a very practical manufacturing mode in customized production of tungsten alloy counterweights.

(VIII). Why Tungsten Alloy Is More Difficult to Machine Than Ordinary Steel

Although tungsten alloy is not cemented carbide, due to its high tungsten content, multi-phase structure, and relatively high hardness, its processing generally places higher requirements on tools and equipment than ordinary steel. During turning and milling, it is necessary to comprehensively control tool material, cutting parameters, machine tool rigidity, fixture rigidity, cooling and lubrication, and chip removal conditions. Ordinary steel parameters cannot simply be applied during processing. Excessive cutting parameters may cause rapid tool wear, edge chipping, and dimensional drift; parameters that are too low may reduce processing efficiency. Therefore, actual production usually requires formulating process parameters according to the specific tungsten alloy grade, density, hardness, and



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processing features. For critical dimensions, rough machining and finish machining usually also need to be considered separately to avoid loss of dimensional control caused by excessive material removal in one pass.

(IX). Holes, Grooves, and Threads Are Key Points in Customized Counterweight Processing

Many tungsten alloy counterweights are not simple solid blocks but need to be installed into mechanical structures, so holes, grooves, and threads are very common. For example, automotive counterweights may require mounting holes, rotor counterweights may require positioning holes or threaded structures, and electronic device counterweights may require micro mounting features. For simple holes, drilling can be performed after sintering; for high-precision holes, subsequent processing such as reaming, honing, or grinding may also be required. Internal threads can likewise be achieved by tapping, thread milling, and other methods. The specific process needs to be determined according to thread size, material grade, hole depth, and precision requirements, and a certain general tapping parameter cannot be directly applied to all tungsten alloy products.

(X). Dimensional Accuracy Is Not the Only Quality Indicator

There is an obvious difference between tungsten alloy counterweights and ordinary structural parts: they ultimately perform a mass distribution function. Therefore, even if all dimensions of the product are qualified, if the weight does not meet the requirements, it still cannot be used as a qualified counterweight. For example, if a counterweight is designed to require 100.00 g, and the final actual weight deviation is relatively large, it will directly affect the mass distribution of the system. For rotating machinery, further control is also required over: weight, external dimensions, hole position, coaxiality, circular runout, center-of-gravity position, installation position, and dynamic balance. This is also why the manufacturing of counterweights for automotive crankshafts, industrial rotors, drone rotor assemblies, and precision inertial components is more complex than that of ordinary static counterweights.

(XI). Dynamically Balanced Products Require Combining Manufacturing and Testing

If a tungsten alloy counterweight is installed on a high-speed rotating assembly, it is not enough to test only the weight of the individual counterweight. The complete rotating assembly needs to undergo dynamic balancing testing at a specified speed, measuring the unbalance amount and its phase, and then determining the correction mass and correction angle.

The centrifugal force generated by a rotating counterweight can be expressed as $F=m\omega^2r$, where F is centrifugal force, m is counterweight mass, ω is angular velocity, and r is the distance from the center of mass to the rotating shaft. This relationship explains why high-speed equipment is very sensitive to counterweight mass and installation position: as the rotational speed increases, centrifugal force grows with the square of angular velocity. Therefore, industrial rotor-type products usually need to undergo processes such as initial



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balancing testing, counterweight installation, retesting, and confirmation of residual unbalance.

(XII). Surface Treatment Is a Later-Stage Process in Product Manufacturing

Some tungsten alloy counterweights also require surface treatment after sintering and mechanical machining. Surface treatment may be used to improve appearance, corrosion resistance, surface roughness, or assembly performance. The specific method needs to be selected according to the service environment and material system. If the product has strict dimensional requirements, the surface treatment thickness must also be incorporated into the dimensional tolerance design. For example, precision holes, shaft holes, and threads cannot wait until surface treatment is completed to consider the final dimensions; instead, overall planning should be carried out from the machining allowance stage.

(XIII). Quality Inspection Actually Runs Through the Entire Manufacturing Process

Professional manufacturing of tungsten alloy counterweights does not end with measuring dimensions with a caliper at the end. Starting from raw materials, powder quality and batch control are required; in the forming stage, attention is paid to green compact weight and dimensions; in the sintering stage, attention is paid to sintering shrinkage, density, and structure; in the processing stage, attention is paid to dimensions and surface quality; and the final product is comprehensively inspected according to application requirements. Common inspection items include density, weight, dimensions, hardness, chemical composition, metallographic structure, surface roughness, and necessary non-destructive testing. Public technical materials on tungsten alloy counterweights also list density, mechanical properties, metallographic structure, chemical composition, surface quality, and non-destructive testing as important contents of quality evaluation. For rotating counterweights, inspection items such as coaxiality, circular runout, center of gravity, and dynamic balance also need to be added.

(XIV). Why Counterweights with the Same 18 g/cm³ Requirement May Have Completely Different Manufacturing Difficulty

Suppose two products both require a density of about 18.0 g/cm³. Product A is a simple cylinder and only requires weight and outer diameter; Product B also requires 18.0 g/cm³, but at the same time has multiple mounting holes, precision threads, positioning steps, and requires key dimensions at the ± 0.01 mm level and high-speed dynamic balancing. Although the material density is the same, the manufacturing cost and process complexity are completely different. Product A can make more use of the near-net-shape advantages of powder metallurgy; Product B needs to establish a complete process chain among material, sintering, processing, inspection, and dynamic balancing. Therefore, the manufacturing price of a tungsten alloy counterweight cannot be calculated simply by multiplying the price per kilogram of tungsten alloy by the product weight.



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(XV). More Than 30 Years of Experience Embodied by CTIA GROUP

China Tungsten Online was founded in 1997 and has long been engaged in the research and development, production, and industry services of tungsten products; CTIA GROUP, relying on this long-term accumulation in the tungsten and molybdenum industry, further carries out the design, research and development, and manufacturing of products such as high-specific-gravity alloys. For tungsten alloy counterweights, the value of this kind of long-term experience is not only reflected in possessing a certain type of production equipment, but more in material system selection, powder control, mold design, sintering shrinkage experience, accumulation of processing parameters, product structure optimization, and process matching among different application scenarios. For example, when a customer proposes the need for a 1 kg counterweight, a professional manufacturing enterprise first needs to judge the installation space, target density, shape, fixing method, service temperature, vibration environment, and whether it rotates, rather than directly starting to calculate how much tungsten powder is needed. If it is a high-speed rotor, the center of mass and dynamic balancing requirements need to be further judged; if it is an aviation control surface, the installation position and mass moment need to be considered; if it is a mobile phone vibration structure, dimensions, mass consistency, and moment of inertia (MOI, Moment of Inertia) need to be considered; if it is a golf club, the center of gravity (CG, Center of Gravity) and overall mass distribution need to be considered. At the same time, the customer's requirements for strength, magnetism, and other properties must also be considered. This is the core of the transformation from material supply to engineering manufacturing.

(XVI). From Customer Drawings to the Final Tungsten Alloy Counterweight, What Process Is Generally Experienced

A complete customization project can usually be carried out according to the following engineering logic: the customer provides drawings or product requirements → determine the material system and target density → conduct manufacturability analysis → determine the forming method → design molds or tooling → powder batching and mixing → press forming → sintering densification → obtain sintered blank → CNC (Computer Numerical Control) mechanical machining → surface treatment → weight and dimension inspection → dynamic balancing if necessary → final inspection → packaging and delivery. A deviation in any one of these links may affect the final counterweight performance. For example, changes in powder batch may affect density, changes in forming pressure may affect green compact consistency, changes in the sintering schedule may affect shrinkage and structure, changes in processing parameters may affect dimensions and surface quality, and deviations in final weight or installation position may affect the balance of the entire machine. Therefore, the true manufacturing technology of tungsten alloy counterweights is essentially a system engineering in which materials, processes, processing, and inspection are coupled with one another.



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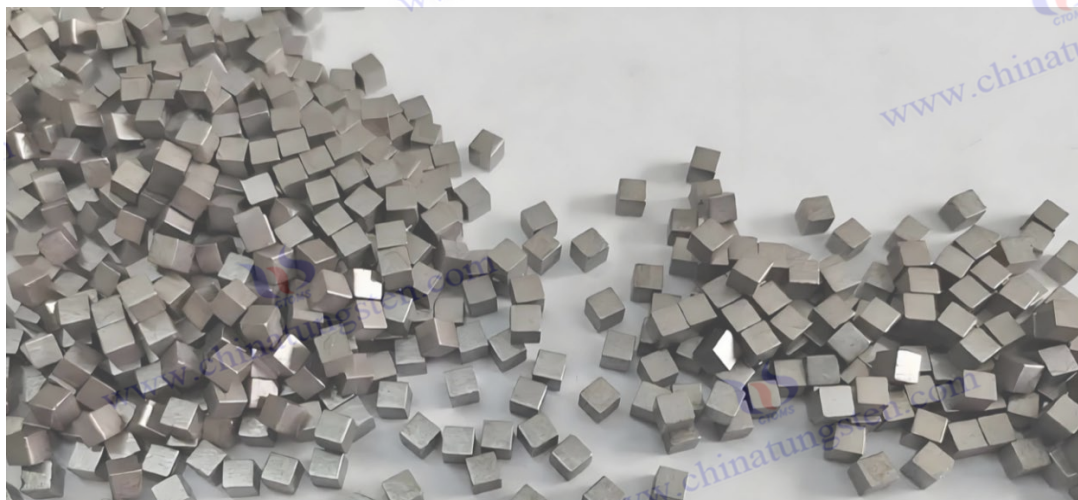
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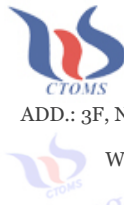
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(XVII). How to Understand the Processing and Manufacturing Level of Tungsten Alloy Counterweights

The manufacturing capability for a tungsten alloy counterweight can be understood at three levels. The first level is being able to make tungsten alloy, that is, achieving basic material formulation, pressing, and sintering. The second level is being able to stably produce products that meet drawing requirements, including density, weight, dimensions, tolerances, hole positions, and surface quality. The third level is being able to carry out engineering optimization according to specific applications, for example, reducing volume while meeting the target weight, optimizing the mounting structure, controlling the center of gravity, lowering processing costs, and formulating corresponding quality control plans for different applications such as high-speed rotation, aviation, automobiles, electronics, and precision instruments.

For true customization projects, third-level capability is often more important than merely possessing a certain processing equipment. Overall, the manufacturing core of tungsten alloy counterweights can be condensed into one sentence: first obtain the required density and comprehensive performance through material design, then achieve stable densification through powder metallurgy, and finally achieve accurate control of dimensions, weight, and mass distribution through precision mechanical machining and quality inspection. The high-specific-gravity alloy business displayed in the public information of China Tungsten Online and CTIA GROUP is also carried out around this complete chain of materials, design, research and development, manufacturing, and customized applications. If a tungsten alloy counterweight is regarded as a final product, then powder is not the end point, sintering is not the end point, and processing is not the end point either; the true end point is to enable the finished product to stably realize the design function under the specified dimensions, weight, density, center of gravity, strength, and service environment.





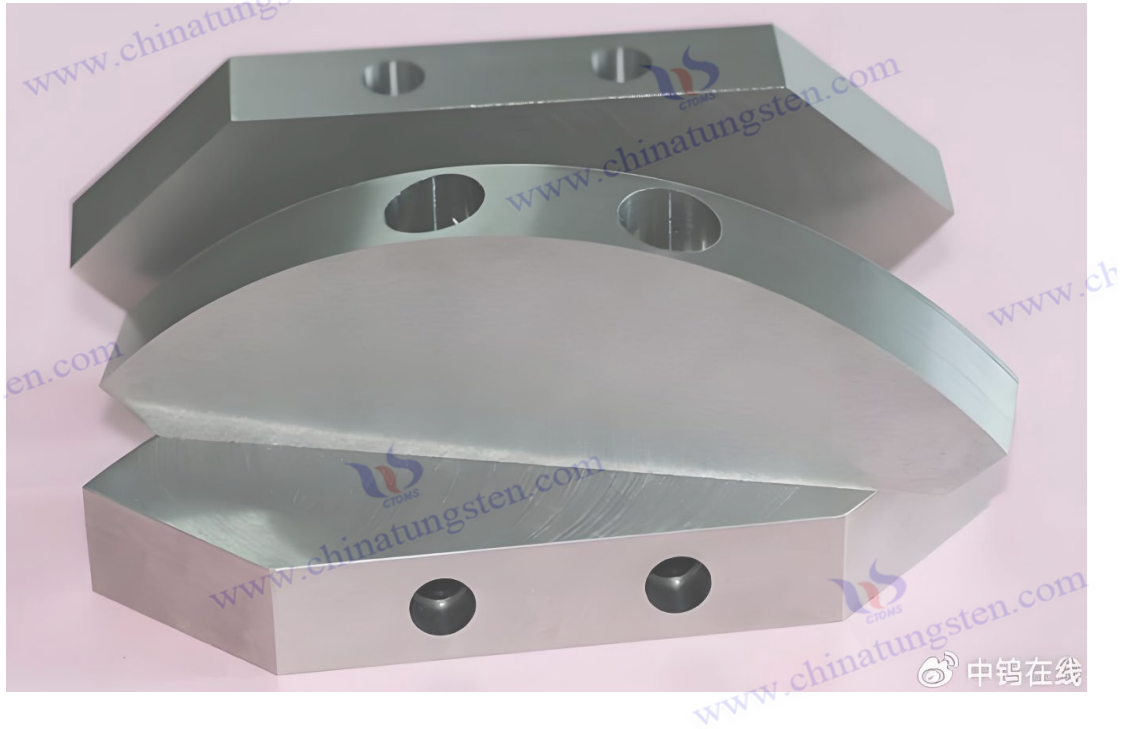
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Q33 How Are Tungsten Alloy Counterweights Manufactured?

Tungsten alloy counterweights are usually manufactured by the powder metallurgy (PM, Powder Metallurgy) route. The typical process is: preparation of tungsten powder and binder phase powder → mixing → press forming → debinding or pretreatment → high-temperature liquid-phase sintering → post-sintering mechanical machining → surface treatment → dimension, weight, and performance inspection. For products with simple structures and small quantities, tungsten alloy sintered blanks can also be directly machined; for large-batch counterweights with regular structures, a process combining forming and sintering is usually more suitable.

(1) First Determine the Material System and Target Density

Before manufacturing begins, the material system needs to be determined according to the counterweight's weight, installation space, mechanical properties, magnetic properties, and service environment. The common ones are tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron) and tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper). Tungsten (W, Tungsten) provides the main high-density characteristic, while nickel (Ni, Nickel) and iron (Fe, Iron) or copper (Cu, Copper) form the binder phase. Only after the target density is determined can the powder ratio, pressing parameters, and sintering process be further determined.

(2) Prepare and Formulate Tungsten Alloy Powder

Production first requires preparing tungsten powder and binder phase powder that meet



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particle size, purity, and composition requirements. The powder composition differs for different material systems. High-density tungsten alloys usually have a relatively high tungsten content, but the actual density is not determined only by tungsten content; it is also affected by binder phase ratio, powder particle size, compact density, sintering shrinkage, and final porosity. Therefore, it cannot simply be assumed that a certain tungsten content necessarily corresponds to a certain actual density.

(3) Powder Mixing

After weighing according to the designed formula, tungsten powder, nickel powder, iron powder, or copper powder need to be fully mixed so that the different powders are uniformly distributed. Mixing uniformity directly affects the subsequent sintered structure and final product performance. If mixing is insufficient, local composition differences may occur, thereby affecting density, dimensional stability, and mechanical properties. For mass production, the consistency of different batches of powder also needs to be controlled.

(4) Press Forming

The mixed powder enters the mold and is pressed to form a green compact close to the product shape. For example, cylindrical, disc-shaped, ring-shaped, and rectangular counterweights can be directly formed into basic contours through corresponding molds. Complex products can also be designed with forming structures with holes, steps, or other features, thereby reducing subsequent mechanical machining. However, shrinkage occurs during sintering, so the mold dimensions cannot simply be equal to the final product dimensions; compensation design needs to be carried out according to the material system and process data.

(5) Debinding or Pretreatment

Some manufacturing routes require debinding, pre-sintering, or other pretreatment before sintering, so that the forming auxiliary substances in the compact are removed and stable conditions are created for subsequent high-temperature sintering. The heating rate, atmosphere, and temperature control at this stage are all relatively important. If pretreatment is unreasonable, it may cause cracking, deformation, or internal defects in the compact.

(6) High-Temperature Liquid-Phase Sintering

This is a very critical step in the manufacturing process of tungsten alloy counterweights. During sintering, tungsten particles gradually form a dense skeleton structure, and the binder phase forms a liquid phase under high-temperature conditions and promotes the rearrangement, dissolution, and re-precipitation of tungsten particles, thereby gradually densifying the material. After sintering is completed, the density, microstructure, dimensional changes, and mechanical properties of the product are basically formed. Parameters such as sintering temperature, holding time, heating and cooling rates, and



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furnace atmosphere must be controlled according to the specific material system and product structure.

(7) Sintering Shrinkage Needs to Be Calculated in Advance

The pressed green compact is usually larger than the final product dimensions because a certain degree of shrinkage occurs during sintering. For example, if the designed final outer diameter is 20 mm, the mold cannot simply be manufactured at 20 mm; dimensional compensation needs to be carried out according to the material formula and actual sintering shrinkage rate. This is also why mold design for tungsten alloy powder metallurgy products needs to be combined with material and actual sintering data, and the mold cannot be directly machined only according to the final two-dimensional drawing dimensions.

(8) Mechanical Machining After Sintering

After sintering is completed, the product is usually already close to the final shape, but critical dimensions may still need further processing. Common operations include turning, milling, drilling, tapping, grinding, and finishing. For cylindrical counterweights, the outer diameter, end faces, and center hole can be mainly machined; for complex counterweights, multiple holes, grooves, steps, and mounting surfaces may need to be machined. Because tungsten alloy has relatively high density and a special structural organization, mechanical machining parameters, tool materials, cutting speed, and cooling methods need to be selected according to the specific material grade.

(9) Complex Structures May Use a Combination of Sintering and Finishing

Not all dimensions must be directly formed by the mold. In actual production, a method of near-net forming plus subsequent finishing is often used: first use the mold to form the approximate contour, and then obtain the final dimensions through mechanical machining. This can achieve a balance among mold cost, material utilization, and machining accuracy. For small-batch complex products, CNC machining directly from tungsten alloy sintered blanks is also possible to avoid manufacturing special molds.

(10) Surface Treatment According to Application

If the product has special requirements for appearance, corrosion resistance, or surface performance, corresponding surface treatment can be carried out after machining is completed. If there are no special requirements, tungsten alloy counterweights can usually be delivered directly in the specified machined condition. Surface treatment is not a necessary process for all counterweights; whether to use it should be determined according to the actual working environment and assembly requirements.

(11) Dimension and Weight Inspection

After machining is completed, the product needs final inspection. Basic items usually



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include external dimensions, hole diameter, thickness, weight, and appearance; precision products may also need to be tested for coaxiality, circular runout, flatness, position tolerance, and surface roughness Ra (Arithmetic Average Roughness). Weight inspection is especially important because the core function of a counterweight is to provide accurate mass.

(12) High-Speed Rotating Counterweights Also Require Dynamic Balancing Testing

If the product is installed in a high-speed rotating system, testing weight alone is not enough. For example, for two counterweights of exactly the same weight, if the center of gravity of one product deviates from the rotating axis while the mass distribution of the other product is more uniform, there will be a difference in actual operating condition. The centrifugal force of a rotating system can be expressed as $F=m\omega^2r$, where F is centrifugal force, m is mass, ω is angular velocity, and r is eccentric distance. Therefore, applications such as high-speed rotors, engines, and motors usually also require dynamic balancing testing according to design requirements.

(13) Process Quality Control Is Also Required in Mass Production

Mass production of tungsten alloy counterweights cannot rely only on testing final products; the entire production process also needs to be controlled. Attention usually needs to be paid to key parameters such as powder composition, powder mixing uniformity, compact density, sintering temperature, sintering shrinkage, post-sintering density, machining dimensions, and final weight. If the sintering shrinkage of a certain batch changes, even if the subsequent machining dimensions can still be adjusted to a qualified range, it may cause changes in material utilization and machining allowance, so batch process stability is very important.

(14) Different Batch Sizes Are Suitable for Different Manufacturing Methods

For small batches of dozens or hundreds of pieces, if the structure is complex, direct machining from sintered blanks can be considered to reduce investment in special molds. For medium batches, simple mold forming can be used, followed by finishing of critical dimensions. For large batches of regular products, it is more suitable to make full use of powder metallurgy forming, improve material utilization and production efficiency through special molds, and then concentrate mechanical machining on critical dimensions. Therefore, there is no single fixed manufacturing method for the same tungsten alloy counterweight; the best process depends on product structure, quantity, precision, and cost objectives.

(15) CTIA GROUP Can Provide a Complete Manufacturing Process

CTIA GROUP can match processes for powder formulation, press forming, sintering, mechanical machining, and quality inspection according to the target density, material system, product structure, and procurement quantity of tungsten alloy counterweights,



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and determine the corresponding manufacturing plan according to the final weight, dimensional tolerances, and application environment. Overall, the manufacturing core of tungsten alloy counterweights can be summarized as: material formula determines basic performance, powder mixing ensures uniform composition, press forming determines the basic contour, high-temperature liquid-phase sintering achieves densification, mechanical machining obtains final dimensions, and inspection ensures weight and precision.

For simple large-batch counterweights, powder metallurgy forming plus sintering has obvious scale advantages; for small batches or complex structures, more reliance can be placed on mechanical machining of sintered blanks. The final choice of process should simultaneously consider density, weight, structure, precision, quantity, material utilization, and comprehensive cost.



Q34 Why Are Tungsten Alloy Counterweights Usually Manufactured by Powder Metallurgy?

Tungsten alloy counterweights usually adopt powder metallurgy (PM, Powder Metallurgy) mainly because tungsten (W, Tungsten) has a very high melting point, making traditional melting and casting forming difficult, while powder metallurgy can bypass the difficulty of directly melting large amounts of tungsten. Through powder mixing, press forming, and high-temperature sintering, it obtains high-density tungsten alloy blanks, which are then combined with mechanical machining to obtain the final counterweight. For counterweight parts with high density, small volume, and mass production, this process has relatively



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good adaptability in terms of material utilization, forming efficiency, density control, and product consistency.

(1) Tungsten Has a Very High Melting Point, Making Traditional Melting Difficult

The melting point of pure tungsten is about 3422 °C, far higher than that of ordinary steel materials. Therefore, if tungsten were directly melted and poured according to the ordinary metal casting approach, there would be very high requirements for equipment, furnace bodies, crucibles, protective atmospheres, and process control. Tungsten alloy counterweights usually do not directly melt large amounts of tungsten completely; instead, tungsten powder is used as the main high-density phase, and a dense material is formed through a binder phase and the sintering process. This is also one of the fundamental reasons why powder metallurgy has become an important manufacturing route for tungsten alloys.

(2) Tungsten Powder Can Be Directly Used to Manufacture High-Density Materials

The core performance required by tungsten alloy counterweights is high density. Through powder metallurgy, a high proportion of tungsten powder can be precisely proportioned with binder phase materials such as nickel (Ni, Nickel), iron (Fe, Iron), or copper (Cu, Copper), and then formed into a high-density alloy through pressing and sintering. Common material systems include tungsten-nickel-iron (W-Ni-Fe, Tungsten-Nickel-Iron) and tungsten-nickel-copper (W-Ni-Cu, Tungsten-Nickel-Copper). The material ratio, compact density, and sintering process jointly determine the actual density of the final product.

(3) It Is Easy to Manufacture Counterweight Blanks Close to the Final Shape

Common shapes of tungsten alloy counterweights include cylinders, discs, rings, rectangular blocks, and special-shaped structures with holes, grooves, and steps. Through pressing molds, a geometric shape close to the final product can be formed before sintering, so that after sintering only a small amount of mechanical machining is needed for key dimensions. For example, for a simple cylindrical counterweight, the approximate contour of the outer circle and end faces can be obtained directly by die pressing, without the need to cut it entirely from a larger piece of tungsten alloy material.

(4) It Can Reduce the Amount of Mechanical Removal of Expensive Material

The material value of tungsten alloy is relatively high. If a counterweight were manufactured entirely by mechanical machining, a relatively large sintered blank would need to be prepared first, and then a large amount of material would be removed by turning, milling, and other methods. This method not only wastes material but also increases processing time and tool consumption. Powder metallurgy, however, can make the blank close to the final dimensions through near-net shape (Near-Net Shape) forming, reducing material removal from the source. For large-batch counterweights, this advantage is especially obvious.



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(5) It Is Suitable for Mass Production

Another important advantage of powder metallurgy is that repeated forming is easy to achieve. Once the mold is determined, a large number of green compacts can be continuously produced according to the same pressing parameters, and then batch products can be obtained through a stable sintering process. If one set of molds is used to produce thousands or even tens of thousands of counterweights, fixed costs such as mold manufacturing and equipment debugging can be spread over more products, thereby reducing unit manufacturing cost. This is also why powder metallurgy is particularly suitable for large-batch tungsten alloy counterweights.

(6) It Is Helpful for Controlling Product Density

Tungsten alloy counterweights are often designed according to different density grades such as 17.0, 17.5, 18.0, and 18.5 g/cm³. For a given mass, the counterweight volume satisfies $V=m/\rho$, where V is volume, m is mass, and ρ is density. For example, the theoretical volume of a 1 kg, 18.0 g/cm³ tungsten alloy is about 55.56 cm³. The powder formula, pressing density, sintering process, and final porosity all affect the actual density. Therefore, through a stable powder metallurgy process, density and batch consistency can be controlled relatively systematically.

(7) It Can Balance High Density and a Certain Degree of Toughness

Although pure tungsten has a density of about 19.25 g/cm³, the material itself is relatively hard and brittle, and there are certain difficulties in processing and manufacturing complex structures. By adding binder phases such as nickel, iron, or copper, tungsten alloy can improve the toughness, processing adaptability, and overall mechanical properties of the material while maintaining high density. Therefore, counterweights do not necessarily need to pursue the highest density of pure tungsten; instead, the material system can be adjusted through powder metallurgy to balance density, strength, toughness, magnetic properties, and processing performance.

(8) Complex Structures Can Adopt a Combination of Forming and Finishing

Powder metallurgy does not mean that the product is completely free from processing after pressing is completed. In actual production, a combined process of press forming, sintering, and precision mechanical machining is often used. Most of the external shape is obtained through the mold, while the center hole, threads, mounting surfaces, precision outer diameter, and other key dimensions are processed after sintering. This method can take into account both production efficiency and dimensional accuracy.

(9) It Can Reduce the Comprehensive Cost of Large-Batch Products

For large-batch tungsten alloy counterweights, the comprehensive cost can be understood as: total cost $\approx$ material cost + forming cost + sintering cost + mechanical machining cost + mold and tooling cost + inspection cost. Powder metallurgy requires investment in molds



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and process development costs in the early stage, but as the production quantity increases, the mold and process costs can be spread over a large number of products. At the same time, the reduction in mechanical machining after forming also helps reduce unit product cost. Therefore, the advantages of powder metallurgy are especially suitable for medium- and large-batch tungsten alloy counterweights.

(10) It Is Helpful for Maintaining Batch Consistency

Counterweight products not only require high density but also often require consistent weight. If they are used in multiple identical devices or installed in batches, mass differences between individual pieces will directly affect assembly and debugging efficiency. Stable powder formulas, pressing parameters, and sintering processes can reduce material and dimensional fluctuations between different batches. For high-speed rotating counterweights, parameters such as center of mass, coaxiality, and circular runout also need to be further controlled.

(11) Why Is It Not Necessary for All Tungsten Alloy Counterweights to Adopt Powder Metallurgy?

Although powder metallurgy is suitable for a large number of tungsten alloy counterweights, not all products must adopt this process. If there are only a few pieces or dozens of samples and the structure is very complex, specially making a pressing mold may not be economical. In this case, already sintered tungsten alloy blanks can be used for CNC machining. If the product quantity is very small, direct machining may have lower material utilization, but it can save dedicated mold development costs and part of the process preparation time. Therefore, the manufacturing process can usually be selected according to product quantity: small-batch complex parts can consider direct machining from sintered blanks, medium batches can adopt simple molds plus subsequent finishing, and large-batch regular parts are more suitable for powder metallurgy near-net shape forming.

(12) Process Matching by CTIA GROUP

CTIA GROUP can evaluate combined solutions for powder preparation, die pressing, sintering, and subsequent mechanical machining according to the material system, target density, structural dimensions, procurement quantity, and precision requirements of tungsten alloy counterweights. For regular counterweights with relatively large batches, near-net shape forming can reduce subsequent material removal; for small batches or complex structures, cost and process comparisons can be carried out in combination with sintered blank machining solutions.

The fundamental reason why tungsten alloy counterweights adopt powder metallurgy is that it can well adapt to the characteristics of tungsten materials, namely high melting point, high density, and high value. It does not require melting large amounts of tungsten in the traditional casting manner; instead, it achieves material densification through powder



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proportioning, pressing, and sintering, and then obtains final dimensions through finishing. Therefore, for tungsten alloy counterweights with high density, limited volume, regular structure, and relatively large demand, powder metallurgy can usually achieve a good balance among material utilization, forming efficiency, density control, dimensional consistency, and batch cost; for small quantities of complex products, mold cost and mechanical machining cost should be compared together before determining the manufacturing route.





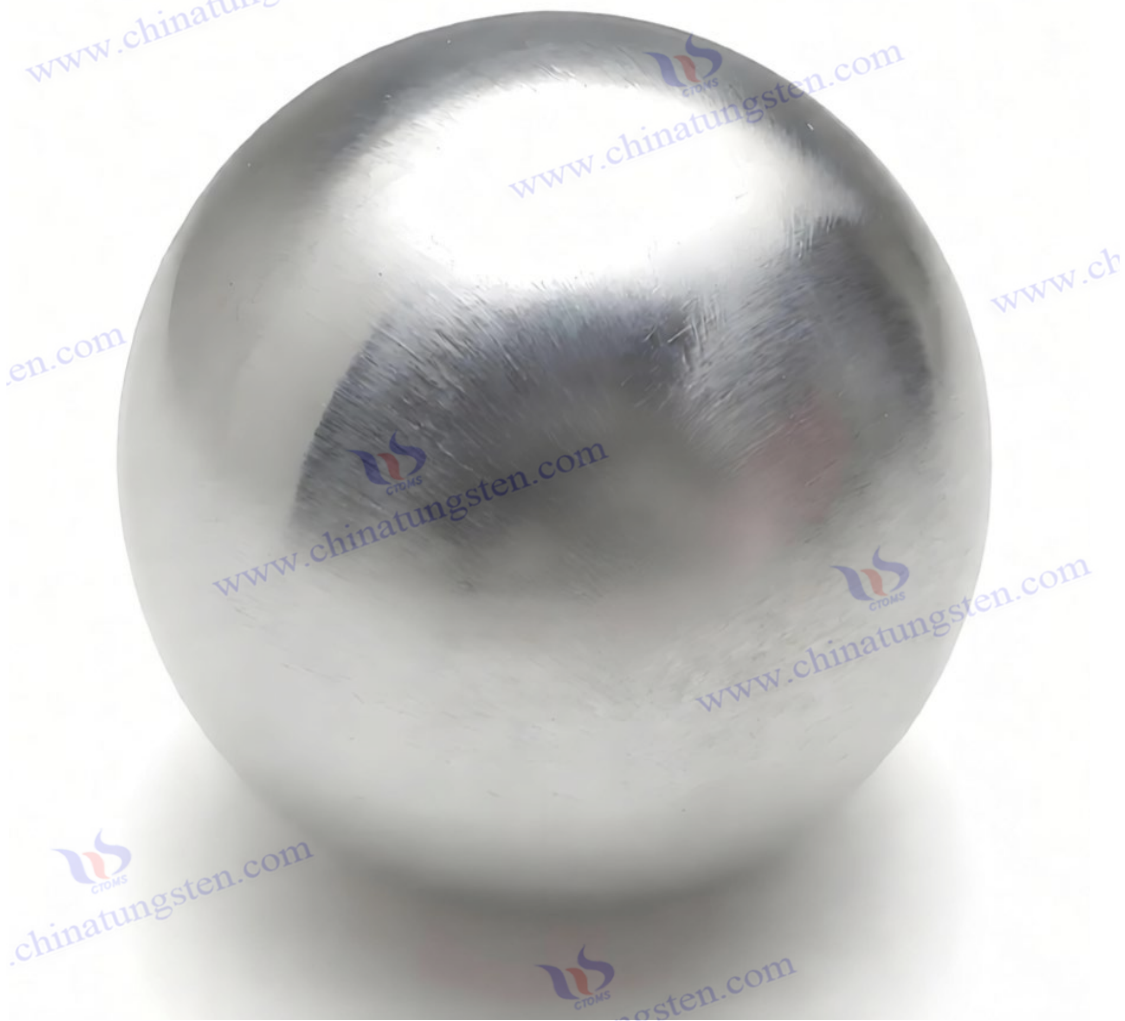
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Q35 Can Tungsten Alloy Counterweights Be Turned?

Tungsten alloy counterweights can be turned, and turning is one of the commonly used mechanical machining methods for tungsten alloy counterweights after sintering. It is especially suitable for counterweight parts such as cylinders, discs, rings, shaft sleeves, and stepped structures. However, compared with ordinary steel, tungsten alloy has higher density, relatively high hardness, and high tungsten particle content. During turning, the requirements for tool material, tool geometry parameters, cutting parameters, clamping method, and cooling conditions are higher.

(1) Which Tungsten Alloy Counterweights Are Suitable for Turning?

Turning is mainly suitable for products with rotational symmetry features, such as cylindrical counterweights, disc counterweights, ring counterweights, counterweights with center holes, stepped shaft-shaped counterweights, and products whose outer diameters and inner holes need finishing. For example, a cylindrical tungsten alloy counterweight with



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an outer diameter of 20 mm and a thickness of 10 mm can have its outer diameter and end faces machined by turning; if there is a mounting hole in the middle, inner hole machining can also be further carried out. For rectangular blocks, complex curved surfaces, or structures with a large number of non-circular holes and grooves, it is usually necessary to combine milling, drilling, or other processing methods.

(2) Why Is Turning Tungsten Alloy More Difficult Than Steel?

Tungsten alloy usually contains a relatively high proportion of tungsten (W, Tungsten). Tungsten itself has relatively high hardness, and the sintered material has a special two-phase structure. During turning, the tool needs to continuously cut high-hardness tungsten particles and is also affected by the binder phase structure. Therefore, problems such as tool wear, cutting edge chipping, deterioration of surface roughness, and gradual dimensional drift are likely to occur. This is also why ordinary carbon steel turning parameters cannot simply be copied.

(3) Tool Material Needs to Be Selected According to the Tungsten Alloy Grade

Tungsten alloy turning usually requires tools with relatively good wear resistance, and the selection should be based on the specific material density, tungsten content, sintering state, and machining allowance. In actual processing, cemented carbide tools, coated tools, or other tool systems suitable for high-wear-resistant materials may be used. For high-density, high-tungsten-content materials, tool selection is especially important. The specific tool cannot be determined only by the product name; rather, trial cutting verification should be carried out in combination with the actual material grade and the material properties provided by the supplier.

(4) Cutting Parameters Cannot Simply Copy Those for Ordinary Steel

When turning tungsten alloy, cutting speed, feed rate, cutting depth, tool geometry angle, and cooling method need to be comprehensively considered. Generally, blindly pursuing excessively high cutting speed should be avoided, because excessively high cutting speed may accelerate tool wear and cutting edge temperature rise. During processing, parameters can be gradually optimized according to the material and tool condition. For batch production, it is more important to find a parameter combination that can stably maintain dimensions and tool life, rather than simply pursuing the highest cutting efficiency of a certain operation.

(5) Rough Machining and Finish Machining Should Be Treated Differently

If the sintered blank has a relatively large machining allowance, rough turning can be carried out first to quickly remove excess material, and then finish turning can be carried out. Rough machining mainly focuses on material removal efficiency and tool load-bearing capacity; finish machining focuses more on dimensional tolerances, roundness, coaxiality, surface roughness, and final weight. For high-precision counterweights, it is not



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recommended to obtain all final dimensions directly through one turning pass.

(6) Turning Can Control Counterweight Weight

The weight of a tungsten alloy counterweight can be controlled jointly by dimensions and density. The basic relationship is $m=\rho V$, where m is mass, ρ is material density, and V is volume. Therefore, when turning the outer diameter, thickness, or other structural dimensions, the product mass is actually also changed. For example, for an 18.0 g/cm³ tungsten alloy, if 0.01 cm³ of material is removed during processing, the corresponding mass change is about 0.18 g. For ordinary counterweights with relatively wide weight tolerances, this change may not be obvious; but for high-precision small counterweights, machining allowance and final weighing control need to be combined.

(7) The Coaxiality of the Center Hole and Outer Diameter Is Very Important

If the counterweight needs to be installed on a rotating shaft, it is not enough just to turn the outer diameter to the specified size. The coaxiality, circular runout, and perpendicular relationship among the center hole, outer diameter, and end face will all affect the final installation state. For example, if there is eccentricity between the center hole and the outer diameter, even if the total weight of the counterweight fully meets the requirements, additional unbalance may still be generated after installation in a high-speed rotating system. Therefore, high-precision rotating counterweights usually need to be turned under a unified datum, with special fixtures and final inspection.

(8) Is Grinding Required After Turning?

Not necessarily. If turning can already meet the dimensional tolerances and surface roughness specified in the drawing, it can be directly used as the final machining operation. If stricter outer diameter, roundness, coaxiality, or surface roughness is required, grinding or other finishing processes may need to be further adopted. Whether grinding is specifically required should be determined according to the engineering drawing requirements, rather than because the tungsten alloy material itself must be ground.

(9) Cooling and Chip Removal Are Also Very Important

When turning tungsten alloy, the temperature of the cutting area needs to be controlled, and chips need to be discharged in time. Reasonable cooling and lubrication can help stabilize the cutting state, reduce tool temperature rise, and reduce secondary scratching of the machined surface by chips. At the same time, the machine tool, fixture, and tool area should be kept clean to avoid tungsten alloy chips affecting precision positioning and subsequent clamping.

(10) The Clamping Method Will Affect Final Accuracy

Tungsten alloy has high density, and products of the same volume are significantly heavier than steel, so workpiece mass and clamping stability need to be considered during



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clamping. For thin-walled ring parts or thin disc-shaped counterweights, excessive clamping force may cause local deformation; for high-precision cylindrical parts, repeated clamping may also cause datum offset. Therefore, in batch production, stable special fixtures usually need to be designed to reduce dimensional and coaxiality fluctuations caused by repeated clamping.

(11) Sintered Blanks and Finishing Dimensions Need to Be Coordinated

If a tungsten alloy counterweight is manufactured by powder metallurgy (PM, Powder Metallurgy), after sintering it is usually already close to the final shape, but a certain machining allowance will still be retained. Turning processing needs to reasonably arrange the allowance according to the sintering dimensional deviation. If the sintering allowance is too small, it may not be possible to completely eliminate dimensional deviations; if the allowance is too large, it will increase material removal, processing time, and tool consumption. Therefore, mold dimensions, sintering shrinkage, and subsequent turning allowance should be designed as a whole.

(12) Tool Life Can Be Optimized in Batch Production

For thousands or even tens of thousands of tungsten alloy counterweights, tool life will directly affect unit cost. Production efficiency can be improved by unifying material grades, stabilizing the sintered structure, reducing unnecessary machining allowance, optimizing cutting parameters, and reasonably arranging tool replacement cycles. For products with high repeatability, tool life records can also be established based on actual processing data, and preventive replacement can be carried out before the specified wear level is reached, avoiding batch dimensional out-of-tolerance caused by sudden tool failure.

(13) Turning Does Not Mean That Only Simple Products Can Be Machined

For relatively complex tungsten alloy counterweights, turning can be used as the main operation, combined with drilling, milling, tapping, and other processes. For example, a cylindrical counterweight can first have its outer diameter and end faces turned, then a center hole drilled, and finally thread machining carried out; if there is a positioning groove on the outer diameter, a milling operation can also be added. Therefore, the actual manufacturing route is usually a combination of turning and other mechanical machining processes, rather than relying solely on turning to complete the entire product.

(14) CTIA GROUP Can Determine the Turning Plan According to the Structure

CTIA GROUP can evaluate processing operations such as rough turning, finish turning, and grinding according to the material system, target density, sintering state, product dimensions, and precision requirements of tungsten alloy counterweights, and determine reasonable machining allowances and inspection plans in combination with center holes, outer diameters, coaxiality, and weight tolerances.



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(15) In What Cases Is Turning Particularly Advantageous?

If the counterweight has an obvious rotational symmetry structure and there are many outer diameter, inner hole, end face, or step dimensions, turning usually has relatively good processing efficiency. If the product quantity is small, directly turning sintered blanks can also reduce investment in special molds; if the product quantity is very large, powder metallurgy near-net shaping can first be used to reduce blank machining volume, and then turning can be used to complete key dimensions.

Tungsten alloy counterweights can absolutely be turned, and cylindrical, disc, ring, and shaft sleeve type counterweights are especially suitable for turning. The real difficulty is not whether they can be turned, but how to achieve stable tool life, dimensional accuracy, surface quality, and weight control under the conditions of high material density, high hardness, and special sintered structure. For ordinary-sized counterweights, a reasonable turning process can meet the requirements; for high-precision rotating counterweights, the overall process design should further combine clamping datum, coaxiality, circular runout, weight tolerance, and dynamic balance.



Q36 Can Tungsten Alloy Counterweights Be Milled and Ground?

Yes. Tungsten alloy counterweights can not only be milled and ground, but for counterweight parts with complex mounting structures, high-precision dimensions, precision holes and grooves, and relatively high surface quality requirements, milling and grinding are often important subsequent processing operations. However, tungsten alloy is a high-density, high-hardness material, especially high-tungsten-content grades. During



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mechanical machining, the requirements for tools, grinding wheels, machine tool rigidity, and cooling conditions are significantly higher than those for ordinary steel.

(1) Tungsten Alloy Counterweights Can Be Milled

Milling is mainly used to machine planes, steps, grooves, areas around hole positions, mounting notches, and complex external shapes. For block-shaped, plate-shaped, special-shaped, or mounting-structure counterweights, CNC milling machines or machining centers can be used for processing. Common milling contents include external contour processing, plane processing, positioning groove processing, bolt mounting groove processing, weight-reduction groove processing, and special-shaped curved surface processing. For counterweights that need to precisely fit with other components, milling can also be used to establish datum surfaces and mounting positioning surfaces. The biggest characteristic of tungsten alloy milling is relatively obvious tool wear. The tungsten (W, Tungsten) hard phase has relatively high hardness and wear resistance, and will produce a strong abrasive effect on the cutting edge. If equipment rigidity is insufficient, tool selection is unreasonable, or cutting parameters are too aggressive, problems such as accelerated tool wear, edge chipping, vibration, and gradual dimensional deviation may occur.

(2) Tungsten Alloy Counterweights Can Also Be Ground

Grinding is especially suitable for machining areas with high requirements for dimensional accuracy, geometric accuracy, and surface roughness. For example, outer diameters, inner holes, end faces, and precision fitting surfaces can all be further finished by grinding after turning or milling. The main difference between grinding and milling lies in the different material removal methods. Milling mainly relies on the cutting edge of the tool to remove more material, while grinding uses abrasive grains of the grinding wheel for micro cutting and grinding, so it is more suitable for finishing. For tungsten alloy counterweights that are already close to final dimensions, grinding can be used to control final dimensions and surface quality. For high-tungsten-content tungsten alloys, the abrasive type, grain size, bond, dressing method, and cooling conditions of the grinding wheel all need to be determined according to the specific material. It cannot simply be assumed that a certain type of grinding wheel is suitable for all tungsten alloy grades.

(3) Why Does Tungsten Alloy Usually Adopt Milling First and Then Grinding?

If the final dimensional requirements of the counterweight are relatively high, grinding is usually not directly relied upon to complete all material removal. Instead, the process concept of rough machining, semi-finish machining, and finish machining is adopted. For example, a sintered tungsten alloy counterweight first has a relatively large machining allowance removed by milling, while datum surfaces and basic contours are machined; then finish milling is carried out to control dimensions close to the final requirements; for key mounting surfaces or fitting surfaces, grinding is then used to remove a small amount of



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allowance, thereby obtaining better dimensional accuracy and surface quality. This process can reduce the burden on the grinding wheel, improve overall processing efficiency, and at the same time reduce the thermal effects and dimensional control difficulty caused by excessive grinding.

(4) What Processing Factors Need to Be Considered for Milling and Grinding?

When machining tungsten alloy counterweights, material system, tungsten content, density, hardness, sintering state, workpiece dimensions, and final precision requirements need to be comprehensively considered. Common materials include W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). Although both belong to tungsten-based high-density alloys, their specific processing performance is still affected by tungsten content, binder phase ratio, and sintered structure. During milling, the focus is on tool wear resistance, spindle and fixture rigidity, cutting parameters, chip removal, and cooling; during grinding, the focus is on grinding wheel selection, grinding wheel dressing, grinding allowance, feed method, cooling, and workpiece temperature rise. For counterweights with thin walls, slender shapes, or hole-and-groove structures, it is also necessary to avoid final dimensional deviations caused by clamping deformation or processing vibration.

(5) How Are Surface Roughness and Dimensional Accuracy Controlled?

If only ordinary structural dimensions are required, reasonable milling or turning can meet the requirements; if the mounting surface needs lower surface roughness or higher flatness and parallelism, a grinding operation can be added. For precision counterweights, it is not enough to specify only a surface roughness Ra (Arithmetic Average Roughness) value; dimensional tolerances, flatness, perpendicularity, coaxiality, circular runout, and other requirements must also be clearly specified at the same time. For example, between the mounting hole and outer diameter of a rotating counterweight, if coaxiality is insufficient, even if the outer diameter and hole diameter are individually qualified when measured, mass eccentricity may still occur after assembly.

(6) What Is the Relationship Between Milling and Grinding and Counterweight Performance?

The final performance of a tungsten alloy counterweight is not determined only by material density, but is also related to the mass distribution after machining. For static counterweights, the target mass and center-of-gravity position need to be ensured; for high-speed rotating counterweights, the mounting datum, mass eccentricity, circular runout, and dynamic balance also need to be controlled. The centrifugal force in a rotating system can be expressed as $F=m\omega^2r$, where m is mass, ω is angular velocity, and r is mass eccentricity. Even if the total mass of the counterweight fully meets the requirements, if the eccentricity caused by machining is relatively large, obvious vibration may still be generated during high-speed operation. Therefore, for parts such as rotor counterweights



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and balance rings, the precision control after milling and grinding and the final dynamic balancing test usually need to be considered together.

(7) Process Selection Also Differs for Different Production Batches

For small batches or the sample stage, sintered blanks can be directly milled, turned, and ground, and process adjustment is relatively flexible; for medium-batch production, powder metallurgy near-net shaping can be used, followed by milling and grinding of key positions; for large-batch production, material removal is usually reduced as much as possible through mold forming, and mechanical machining is concentrated only on mounting surfaces, hole positions, datum surfaces, and high-precision areas.

For tungsten alloy counterweight customization, CTIA GROUP can carry out combined design of milling, turning, grinding, and other operations according to material grade, target density, structural complexity, batch size, and dimensional and surface quality requirements, so that preliminary forming and subsequent finishing match each other.

Tungsten alloy counterweights can absolutely be milled and ground. Milling is more suitable for external shapes, planes, grooves, and complex structure processing, while grinding is more suitable for high-precision dimensions, fitting surfaces, and lower surface roughness processing. For high-density tungsten alloys, a reasonable process usually does not rely solely on one processing method, but adopts a combination of powder metallurgy near-net shaping, milling or turning rough and finish machining, grinding finishing, and final dimension and quality inspection.





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Q37 Can the Holes in Tungsten Alloy Counterweight Parts Be Formed During Rolling and Also Be Drilled?

Yes, but it is necessary to distinguish between two processes: forming during rolling and subsequent drilling. Holes, through holes, mounting holes, and positioning holes in tungsten alloy counterweight parts can be obtained by forming processes according to the part structure, material state, hole diameter accuracy, batch size, and hole position requirements, or they can be obtained by drilling on blanks after sintering or rolling. For common high-density tungsten alloy counterweights, subsequent mechanical drilling is usually more flexible, while directly forming hole structures during the forming stage is more suitable for specific structures and batch production.

(1) Can Holes Be Formed During Rolling?

From the perspective of process principles, tungsten alloy can be processed into plates, strips, or specific cross-section materials by plastic forming methods such as rolling, but it cannot be simply understood that ordinary rolling can freely form precise mounting holes like stamping. Rolling mainly causes plastic deformation of the material through roll pressure, thereby changing thickness, cross-section, and structure; if through holes or specific hole profiles need to be formed during the forming stage, special rolling tools, pre-formed hole structures, or other forming processes are usually required. For high-density tungsten alloy counterweights, if the hole position, hole diameter, and shape requirements are relatively high, directly relying on rolling to form the final hole dimensions is often not as easy to control as subsequent mechanical machining. In particular, when there are strict position tolerance requirements between the hole and the outer diameter or mounting datum, precise positioning and machining are usually required in the subsequent processing stage.

(2) Can Tungsten Alloy Counterweights Be Drilled?

Yes, and drilling is one of the relatively common mechanical machining methods for tungsten alloy counterweights. Sintered tungsten alloy blanks can be processed into through holes, blind holes, threaded pilot holes, positioning holes, and mounting holes by equipment such as drilling machines and CNC machining centers. For example, if a cylindrical tungsten alloy counterweight requires a central through hole, the outer diameter can first be turned, and then the center hole can be drilled; if the hole diameter accuracy is relatively high, processes such as reaming, honing, and hole grinding can be further used for finishing. For block-shaped counterweights with multiple mounting holes, a CNC (Computer Numerical Control) machining center can be used to complete multiple hole positions in one clamping, thereby improving the positional accuracy between holes.

(3) Why Is Drilling Tungsten Alloy More Difficult Than Ordinary Steel?

The main reason is that the hard tungsten (W, Tungsten) phase in tungsten alloy has



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relatively high hardness and wear resistance. Taking common W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) as examples, the material contains a relatively high proportion of tungsten phase, and obvious tool wear is likely to occur during drilling. If the drill bit is not properly selected, the cutting parameters are unreasonable, or the machine tool rigidity is insufficient, problems such as drill bit wear, cutting edge chipping, hole diameter enlargement, rough hole walls, and hole position deviation may occur. Therefore, when drilling, it is necessary to select appropriate drilling tools according to the specific material grade and sintering state, and maintain stable clamping and cooling conditions.

(4) Can Already-Sintered Tungsten Alloy Be Drilled Directly?

Yes, and this is a relatively common route in actual production. A typical process can use powder metallurgy (PM, Powder Metallurgy) press forming and sintering to obtain a blank close to the final size, and then complete precision machining through operations such as turning, milling, drilling, and grinding. If the hole structure is relatively simple, the hole position can be reserved during the pressing stage, and only a small amount of trimming is performed after sintering; if the hole diameter is small, the position accuracy is high, or it is a complex special-shaped structure, a certain machining allowance is usually retained, and drilling or other precision machining is completed after sintering. The advantage of this method is that it can simultaneously use the forming process to reduce material removal and use mechanical machining to ensure the final hole dimensions and positional accuracy.

(5) Can Holes Be Made Directly During the Pressing or Forming Stage?

For tungsten alloy counterweights manufactured by powder metallurgy, the mold can pre-form holes, stepped holes, or partial internal structures during the pressing stage through structures such as core rods. For regular large-batch counterweights, this method can reduce material loss and processing time caused by subsequent drilling. However, formed holes are not necessarily equal to final precision holes. Dimensional shrinkage occurs during the sintering of tungsten alloy, so the sintering shrinkage rate must be considered during mold design. If relatively high hole diameter accuracy, roundness, coaxiality, or position accuracy is ultimately required, finishing after sintering is usually still required. It can be simply understood as: the forming stage is responsible for getting as close to the final structure as possible, and mechanical machining is responsible for bringing key dimensions and precision to the final requirements.

(6) Is Hole Position Accuracy More Important Than the Hole Diameter Itself?

For counterweight parts, both are important, but the specific priority depends on the application. If the hole is only an ordinary mounting hole, hole diameter tolerance may be the main control item; if the counterweight is installed on a rotating shaft, rotor, or high-speed motion mechanism, then the relationship among hole position, coaxiality, and mounting datum is often more critical. For example, if the mounting hole of a rotating



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counterweight is eccentric relative to the outer diameter, even if the hole diameter fully meets the requirements, it may still cause mass distribution deviation after installation. The centrifugal force in a rotating system can be expressed as $F=m\omega^2r$, where m is mass, ω is angular velocity, and r is the mass eccentricity distance. Therefore, for high-speed rotating counterweights, it is necessary to simultaneously control hole diameter, hole position, coaxiality, circular runout, and final dynamic balance.

(7) How Should Rolling Forming and Drilling Be Selected?

If the product is plate-shaped, strip-shaped, or long-dimension material, rolling can be used to obtain the basic material shape and dimensions; if high-precision mounting holes need to be formed in the material, methods such as drilling, milling, reaming, honing, or hole grinding are usually used in the subsequent processing stage. If the product is a regular large-batch tungsten alloy counterweight, a more common approach is to pre-form the hole structure through powder metallurgy pressing and sintering, and then finish the key holes; if it is a small-batch, special-shaped counterweight or a customized part with complex hole positions, the sintered blank can be directly used, and drilling and other mechanical machining can be completed through a CNC (Computer Numerical Control) machining center.

For tungsten alloy counterweight parts, CTIA GROUP can carry out combined design of processes such as forming pre-formed holes and post-sintering drilling according to the material system, hole diameter, hole depth, hole position accuracy, product batch, and final quality requirements. The holes in tungsten alloy counterweight parts can be pre-formed during the forming process or drilled on the blank after sintering, but the applicable scenarios of the two are different. For high-precision holes, it is usually not recommended to rely solely on rolling or pressing to directly obtain the final dimensions; instead, forming reservation, sintering shrinkage control, and subsequent processes such as drilling, reaming, and hole grinding should be used to ensure final precision. For rotating counterweights, hole position accuracy should further be considered together with coaxiality, circular runout, and dynamic balancing requirements.



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Q38 Can Tungsten Alloy Counterweights Be Tapped?

Yes. Tungsten alloy counterweights can be tapped, and internal threads can also be machined by turning threads, thread milling, and other methods, thereby meeting structural requirements such as bolt fixing, screw connection, positioning installation, and detachable counterweights. However, compared with ordinary steel, tungsten alloy has high density, high hardness, and strong wear resistance. During tapping, the requirements for taps, pilot hole dimensions, processing equipment rigidity, and cutting parameters are higher.

(1) Why Can Tungsten Alloy Be Tapped?

Common tungsten alloy counterweights usually use material systems such as W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper). Although the proportion of tungsten (W, Tungsten) is relatively high, the binder phases such as nickel (Ni, Nickel), iron (Fe, Iron), or copper (Cu, Copper) mean that the material is not pure tungsten, so it can be machined after appropriate process treatment. The basic process of tapping is to first machine a pilot hole that meets the requirements, and then use a tap to cut the thread profile. For counterweight parts with relatively high precision requirements, thread milling or thread turning can also be used to obtain better dimensional and positional control.

(2) What Is the Biggest Difficulty During Tapping?



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The main problem is tool wear and edge chipping. The tungsten hard phase in high-tungsten-content materials has an obvious abrasive effect on taps, and thread machining itself is a process that is relatively prone to chip jamming and local stress concentration. If the pilot hole is too small, the cutting load on the tap will increase significantly; if the pilot hole is too large, the thread profile will be incomplete and the effective engagement depth will be insufficient. During processing, situations such as increased tap torque, rough thread surface, thread profile damage, and even tap breakage may also occur. Therefore, tungsten alloy tapping cannot be directly processed simply according to ordinary carbon steel parameters; the process should be adjusted according to the specific material grade, tungsten content, thread specification, and processing depth.

(3) Pilot Hole Size Is Very Important

Before tapping, a suitable pilot hole size must first be determined. Taking ordinary metric threads as an example, the commonly used empirical relationship can be approximately expressed as pilot hole diameter $\approx$ nominal thread diameter - pitch, but actual production cannot rely only on this approximate formula. The final size also needs to be determined according to thread standards, material, tap type, and the required thread engagement rate. For example, M6 $\times$ 1 (Metric Thread, nominal diameter 6 mm, pitch 1 mm) usually uses a pilot hole of about 5 mm, but for difficult-to-machine materials such as tungsten alloy, the actual pilot hole size should be confirmed in combination with the target thread class, tap manufacturer recommendations, and the specific material state. For blind holes, hole depth, effective thread depth, and the ineffective tooth length at the front end of the tap must also be additionally considered to avoid insufficient actual effective thread length.

(4) In What Cases Is Direct Tapping Suitable?

For mounting holes with medium diameter, regular structure, and moderate thread depth, sintered tungsten alloy counterweights can be directly tapped. Typical applications include counterweight block mounting holes, equipment fixing holes, adjusting screw holes, and connecting holes for detachable counterweights. If the thread is relatively small and deep, or the material density and tungsten content are relatively high, more caution is required. For particularly small threads, the tap itself is small in size and has limited torsion resistance, and the cutting resistance and material abrasiveness of tungsten alloy may further increase the risk of tap breakage.

(5) Thread Milling Is Sometimes More Flexible Than Traditional Tapping

For tungsten alloy counterweights produced on CNC machining centers, thread milling is also a solution worth considering. Thread milling uses a rotating tool to gradually form threads along a helical path. Compared with cutting the entire thread in one pass, it has relatively good process flexibility on certain complex or high-value parts. One of its advantages is that after tool wear occurs, it is easier to adjust through processing



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parameters and tool compensation, and the processing process has strong independent control capability for individual holes. For high-precision, multi-specification threads or structures not suitable for ordinary taps, thread milling can be considered.

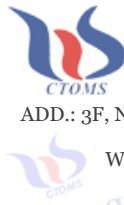
(6) What Else Needs to Be Checked After Thread Machining Is Completed?

It is not enough to check only whether the bolt can be screwed in. For precision tungsten alloy counterweights, it is also necessary to check thread go/no-go gauging, effective thread depth, hole diameter, thread position, and the positional relationship with the mounting datum according to drawing requirements. If the counterweight is used in high-speed rotating components, the positional accuracy of the threaded hole relative to the rotation axis should also be controlled. This is because if the threaded hole has obvious eccentricity, installing bolts or other connecting parts may change the overall mass distribution. For rotating counterweights, the final evaluation should also combine mass, center of gravity, coaxiality, circular runout, and dynamic balance.

(7) How Should the Manufacturing Process Be Reasonably Arranged?

For tungsten alloy counterweights manufactured by powder metallurgy, mounting hole positions can be reserved during the pressing stage, and the pilot hole and thread can be machined after sintering; for relatively high thread accuracy requirements, a finishing operation for the hole can be appropriately added before tapping. A relatively typical route can be: powder metallurgy press forming → sintering → turning or milling of the datum surface → drilling the pilot hole → reaming or finishing if necessary → tapping → deburring → thread inspection → dimension and mass inspection. For large-batch products, hole positions can be directly preformed through the mold to reduce the amount of material removed by drilling; for small-batch or complex customized parts, CNC (Computer Numerical Control) machining of sintered blanks can be used, making it easier to adjust hole positions and thread dimensions.

CTIA GROUP can select tapping, thread milling, or other combined processing solutions according to the material system, thread specification, hole diameter, thread depth, precision grade, and production batch of tungsten alloy counterweights, and carry out process design in combination with subsequent thread inspection and counterweight quality control. In short, tungsten alloy counterweights can be tapped and can meet various threaded connection structures, but the processing difficulty is higher than that of ordinary steel. In actual production, pilot hole size, tap selection, machine tool rigidity, cooling and lubrication, thread depth, and tool wear control are all key factors. For high-precision or high-value counterweight parts, thread milling can also be adopted according to specific conditions, and after processing is completed, thread dimensions, positional accuracy, and overall mass distribution should be inspected.



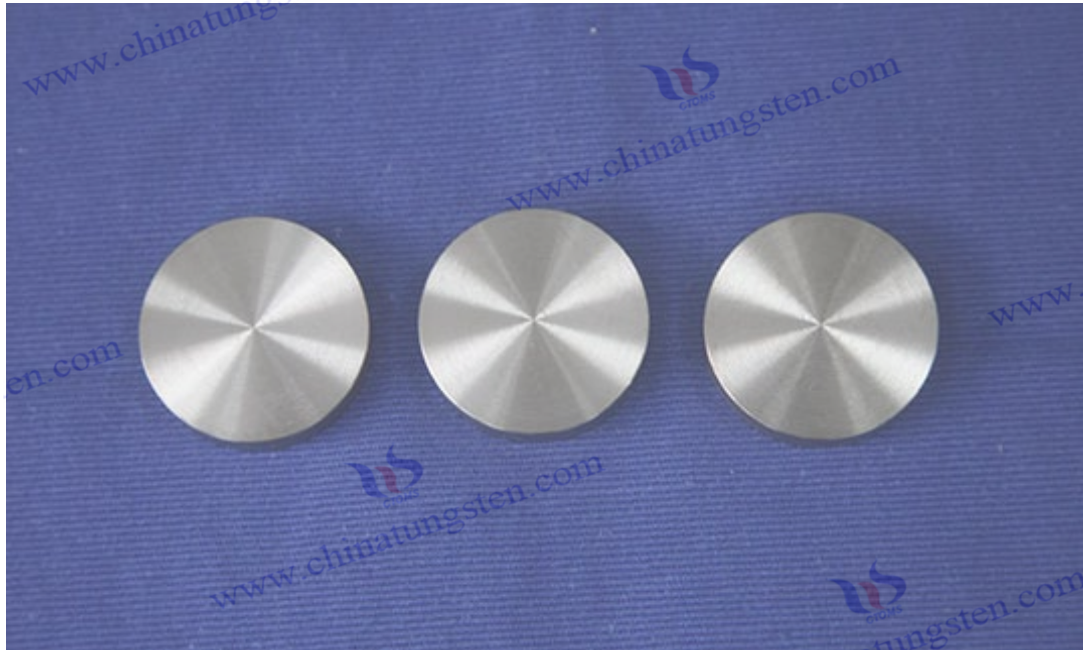
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Q39 Why Do Tungsten Alloy Counterweights Easily Wear Tools?

Tungsten alloy counterweights are relatively prone to tool wear during mechanical processing such as turning, milling, drilling, and tapping. The core reason is that the material contains a relatively high proportion of tungsten (W, Tungsten) hard phase. Tungsten itself has very high hardness, strength, and wear resistance. Tungsten alloy also usually adopts a composite structure formed by tungsten particles and binder phases such as nickel (Ni, Nickel), iron (Fe, Iron), or copper (Cu, Copper). Therefore, during processing, the tool is continuously subjected to abrasion by hard particles and relatively large mechanical loads.

(1) Strong Abrasive Effect Brought by High Tungsten Content

The tungsten content of common high-density tungsten alloys can reach about 90%–97%, with a large amount of tungsten phase distributed in the binder phase. When the cutting tool contacts the material, it is not cutting a uniform, soft metal, but continuously cutting and squeezing a large amount of high-hardness tungsten phase. This processing condition easily causes abrasive wear of the tool edge. As cutting time increases, the edge gradually becomes blunt, cutting force increases, and eventually dimensional accuracy may decrease, surface roughness may deteriorate, or even edge chipping may occur.

(2) The Hardness and Wear Resistance of Tungsten Alloy Are Themselves Its Advantages

The reason why tungsten alloy counterweights can provide relatively large mass in a relatively small volume is related to the high density of tungsten and the material system; at the same time, their relatively good wear resistance is also an important reason why



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many engineering applications choose tungsten alloy. However, the wear resistance of a material in a service environment and its machinability during tool processing are two different concepts. The more wear-resistant a material is, the more difficult it is not necessarily to machine. The fact that tungsten alloy is not easily worn during use precisely means that the processing tool needs to withstand a higher wear load when cutting it. Therefore, the suitability of tungsten alloy as a wear-resistant, high-density counterweight material and whether it is easy to machine are not the same evaluation dimension.

(3) Tungsten Alloy Is a Multi-Phase Structure, Which Also Increases Tool Impact

Taking W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) as examples, the material is usually composed of a tungsten-rich phase and a binder phase. During cutting, the tool continuously experiences different structural regions. If the internal structure of the material is uneven, the tungsten particle size is relatively large, or the local hard phase distribution changes, the cutting load on the tool may fluctuate. For milling, interrupted cutting, and hole machining, this load variation is especially likely to cause micro-chipping of the edge.

(4) Tool Wear Will Further Affect Counterweight Dimensions

Tool wear does not only mean shortened tool life; it also directly affects the final dimensions of tungsten alloy counterweights. For example, during outer diameter turning, gradual tool wear will cause the actual machined dimensions to change; when milling groove width, tool wear may cause the groove dimensions to deviate from drawing requirements; when drilling, drill wear may cause hole diameter changes, deterioration of hole wall quality, or affect hole positional accuracy. For precision counterweights, these dimensional changes may ultimately also affect mass distribution and center-of-gravity position. Therefore, a tool wear monitoring and dimensional compensation mechanism needs to be established during processing, rather than only performing a final inspection after processing is completed.

(5) Excessive Cutting Speed Will Aggravate Tool Wear

When machining tungsten alloy, higher cutting speed does not mean higher efficiency. Excessive cutting speed will increase the temperature and friction in the cutting area while accelerating tool wear. Actual parameters need to be determined according to the tungsten alloy grade, tungsten content, hardness, tool material, and tool geometry. For different materials and tools, the suitable cutting speed, feed rate, and cutting depth may differ significantly. Therefore, the recommended parameters provided by material suppliers and tool manufacturers should usually be used as a starting basis, and then optimized through trial cutting.

(6) Tool Material and Geometric Parameters Are Very Critical

When machining tungsten alloy, the tool solution for ordinary steel cannot simply be



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copied. In actual production, tool systems such as cemented carbide (Cemented Carbide), PCD (Polycrystalline Diamond), or CBN (Cubic Boron Nitride) can be selected according to the operation and material state. At the same time, the tool edge condition, rake angle, relief angle, nose radius, groove type, and tool coating will all affect actual processing performance. For high-tungsten-content materials, more attention is usually paid to edge strength, wear resistance, and processing stability, rather than simply pursuing extremely high cutting efficiency.

(7) Machine Tool Rigidity and Clamping Also Affect Tool Life

Tungsten alloy has very high density, and cutting force during processing may be relatively large. If the workpiece is not firmly clamped, the tool holder overhang is too long, or the machine tool rigidity is insufficient, vibration is likely to occur. Vibration causes the tool to bear periodic impact, especially in milling, interrupted cutting, and thin-wall structure processing, and may cause micro-chipping or even sudden breakage of the tool. Therefore, when machining tungsten alloy counterweights, it is necessary to shorten the tool overhang as much as possible, improve workpiece clamping rigidity, and ensure that the machine tool spindle and tool system have sufficient stability.

(8) Cooling and Chip Removal Cannot Be Ignored Either

Reasonable cooling can help control the temperature of the cutting area and carry away chips in time. If chips remain in the processing area, they may cause secondary friction and repeated cutting, further accelerating tool wear. For drilling, deep grooves, and deep hole machining, chip removal is especially important. The specific cooling method to be used should be determined in combination with tool material, machine tool conditions, processing depth, and tungsten alloy grade, and the cooling solution for ordinary steel cannot simply be applied.

(9) How to Reduce Tool Wear?

A relatively effective approach is to optimize simultaneously from four aspects: material, tool, equipment, and process: select tungsten alloy blanks with uniform structure, select wear-resistant tools according to W (Tungsten) content, maintain sufficient rigidity of the machine tool and workpiece, adopt reasonable cutting parameters and cooling methods, and establish a tool life management and dimensional compensation system. For batch production, powder metallurgy near-net shaping can also be used to reduce mechanical machining allowance. The less material that needs to be removed, the shorter the actual cutting time of the tool is usually, which also helps reduce tool consumption and processing cost per unit product. In the processing of tungsten alloy counterweights, CTIA GROUP can match turning, milling, drilling, tapping, and grinding operations according to material systems such as W-Ni-Fe and W-Ni-Cu, as well as part structure, machining allowance, and precision requirements, and formulate corresponding processing plans for tool wear and dimensional stability.



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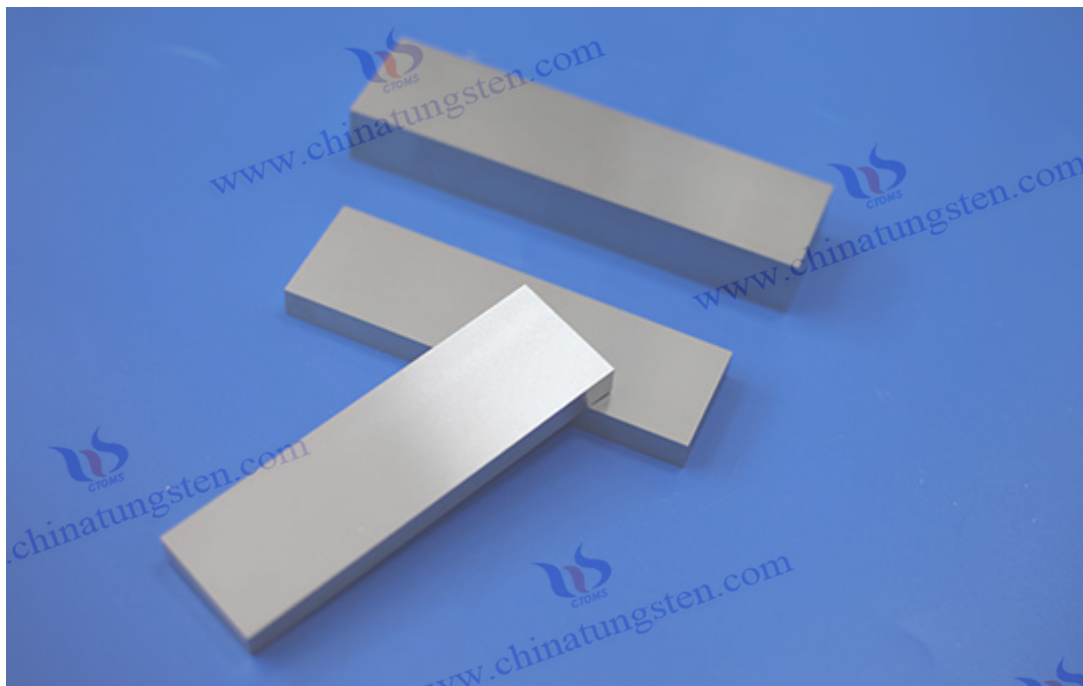
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Tungsten alloy counterweights easily wear tools not because the material simply has high density, but mainly because of the high hardness, strong wear resistance, and multi-phase structural characteristics brought by the high proportion of tungsten hard phase. If unreasonable tool selection, excessive cutting speed, insufficient clamping rigidity, or insufficient cooling and chip removal are superimposed during processing, wear will be further aggravated. Therefore, the focus of processing tungsten alloy counterweights is not simply increasing cutting speed, but achieving a balance among processing efficiency, tool life, and dimensional accuracy through suitable tools, stable equipment, reasonable parameters, and near-net shaping processes.



Q40 How Are Dimensional Tolerances Controlled in the Machining of Tungsten Alloy Counterweights?

When machining tungsten alloy counterweights, dimensional tolerance control usually requires simultaneous control across multiple stages, including material, sintering, machining datum, tools, cutting parameters, measurement compensation, and final inspection. Especially for tungsten alloy counterweights manufactured by powder metallurgy (PM, Powder Metallurgy), shrinkage occurs during sintering, and subsequent turning, milling, drilling, and grinding also produce dimensional changes. Therefore, tolerances cannot be controlled only by relying on the final machining operation; rather, a full-process dimensional control system from forming to finishing should be established.



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(1) First Control the Sintered Blank Dimensions

Tungsten alloy counterweights are often formed by powder metallurgy pressing and sintering. The green compact dimensions during pressing are not equal to the final product dimensions, and obvious volume shrinkage occurs during sintering. Therefore, mold dimensions must be compensated according to the material formula, pressing density, and actual sintering shrinkage rate. If sintering shrinkage control is unstable, even if subsequent CNC (Computer Numerical Control) machining accuracy is very high, machining allowance fluctuations will increase. Therefore, in mass production, it is necessary to focus on controlling powder particle size, mixing uniformity, pressing density, sintering temperature, sintering time, and furnace process consistency.

(2) Establish a Stable Machining Datum

When machining precision tungsten alloy counterweights, a unified machining datum needs to be clearly established. For example, a cylindrical counterweight can use the central axis and end face as the main datum, while a block-shaped counterweight can establish a coordinate system based on the datum bottom surface, side surface, and end face. If different positioning datums are used for each operation, even if each dimension is individually measured and qualified, problems such as hole position offset, insufficient coaxiality, and incorrect positional relationships between planes may still occur. Therefore, for multi-operation counterweight parts, reclamping should be minimized as much as possible, and turning, milling, drilling, and grinding should share a stable datum system.

(3) Rough Machining and Finish Machining Should Be Separated

For counterweight parts with relatively high dimensional requirements, it is not advisable to machine to the final size in one pass. Usually, rough machining can be carried out first to remove the main allowance, then semi-finish machining, and finally finish turning, finish milling, or grinding to reach the final dimensions. This can reduce the impact of cutting force, heat, and clamping stress generated by rough machining on the final dimensions. Especially for thin-walled, slender, or structurally complex tungsten alloy counterweights, after rough machining, appropriate stabilization followed by finish machining usually makes dimensional control more reliable.

(4) Tool Wear Must Be Included in Tolerance Control

The high proportion of hard tungsten (W, Tungsten) phase in tungsten alloy causes obvious tool wear. The actual cutting dimensions when a tool first starts machining and after it has been used for a period of time may differ. If compensation is not carried out, the first piece may be qualified while subsequent batch products gradually go out of tolerance. For example, during outer diameter turning, tool wear compensation can be established by regularly measuring outer diameter changes; when milling grooves and drilling holes, tool diameter and edge condition also need to be monitored. For mass production, tool change cycles can be set according to actual tool life, rather than waiting until the machined



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dimensions are already out of tolerance before replacing the tool.

(5) Cutting Parameters Need to Remain Stable

Changes in cutting speed, feed rate, and cutting depth will all affect cutting force, temperature, and tool wear, thereby affecting final dimensions. Tungsten alloy cannot simply be produced according to the machining parameters for ordinary steel. Actual parameters should be trial-cut and optimized according to specific material systems such as W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper), tungsten content, hardness, and tool type. After batch production, mature process parameters should be fixed as much as possible to avoid dimensional fluctuations caused by arbitrary adjustment by operators.

(6) Grinding Can Be Used to Control High-Precision Dimensions

If the critical dimensions of the counterweight have relatively high requirements, turning or milling alone may not be sufficient. A small grinding allowance can be left on the critical surfaces, and finishing can finally be carried out by grinding. For example, for shaft holes, outer diameters, precision mounting surfaces, and other parts, turning or milling can be used to complete most of the material removal, and then grinding can be used to control the final dimensions, roundness, and surface roughness. For surfaces requiring lower Ra (Arithmetic Average Roughness), grinding also makes it easier to meet the corresponding requirements.

(7) Measurement Should Run Through the Entire Machining Process

Dimensional tolerance control cannot rely only on final inspection. A more reasonable approach is to establish first-piece inspection, in-process inspection, and final inspection. After the first piece is machined, key dimensions and datum relationships need to be confirmed; during batch machining, key dimensions such as outer diameter, inner diameter, length, hole diameter, and groove width are regularly sampled and inspected, and tool compensation is adjusted according to the measurement results; the final product undergoes complete dimensional inspection. For high-precision counterweights, geometric tolerances such as roundness, flatness, perpendicularity, coaxiality, position tolerance, and circular runout can also be inspected according to drawing requirements.

(8) Mass Tolerance and Dimensional Tolerance Need to Be Controlled Simultaneously

Tungsten alloy counterweights have a special requirement compared with ordinary mechanical parts: in addition to dimensions, the final mass must also be controlled. Counterweight mass can be expressed as $m=\rho V$, where m is mass, ρ is actual material density, and V is actual material volume. If all dimensions are qualified but the actual material density fluctuates, the final weight may still deviate. Therefore, high-precision counterweights usually need to simultaneously control material density, part volume, and individual piece mass. For the same batch of products, attention should also be paid to



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density consistency, avoiding compensating for abnormal material density simply by modifying external dimensions.

(9) Rotating Counterweights Also Need to Control Geometric Tolerances and Mass Distribution

If a tungsten alloy counterweight is installed on a rotor, crankshaft, flywheel, or other high-speed rotating component, controlling only length, diameter, and hole diameter is not enough. The centrifugal force in a rotating system can be expressed as $F=m\omega^2r$, where m is mass, ω is angular velocity, and r is mass eccentricity. Therefore, focus should be placed on controlling the positional relationship between the mounting hole and the rotating axis, coaxiality, circular runout, and the actual center-of-gravity position of the counterweight. For such products, dynamic balancing testing is usually also required after machining, and slight weight removal, correction, or remachining is carried out according to the test results.

(10) Different Batches Adopt Different Tolerance Control Strategies

Small-batch tungsten alloy counterweights can rely more on CNC machining and piece-by-piece inspection, achieving dimensional control through precision turning, milling, and grinding; medium-batch products can use powder metallurgy near-net shaping and then control key dimensions through mechanical machining; large-batch products need to focus on establishing stable databases for mold dimensions, sintering shrinkage, machining allowance, and tool life. For batch products, SPC (Statistical Process Control) can also be used to monitor the average value and fluctuation trend of key dimensions, and tool compensation or process adjustment can be carried out before dimensions approach the tolerance boundary, rather than dealing with the problem after the product is already out of tolerance.

In the customization of tungsten alloy counterweights, CTIA GROUP can match processes for powder metallurgy forming, sintering shrinkage control, CNC machining, grinding, and final dimensional and quality inspection according to material grade, target density, product structure, and dimensional tolerance requirements, and establish corresponding process control plans for key dimensions.

The dimensional tolerance control of tungsten alloy counterweights is a full-process issue, which can be summarized as: stabilizing materials and the sintering process, reasonably designing forming allowance, establishing a unified machining datum, separating rough and finish machining, controlling tool wear, stabilizing cutting parameters, using grinding for finishing when necessary, and then carrying out closed-loop control through in-process measurement and final inspection. For ordinary counterweights, controlling the main dimensions and weight is sufficient; for high-precision and high-speed rotating counterweights, further control of coaxiality, circular runout, hole position accuracy, mass



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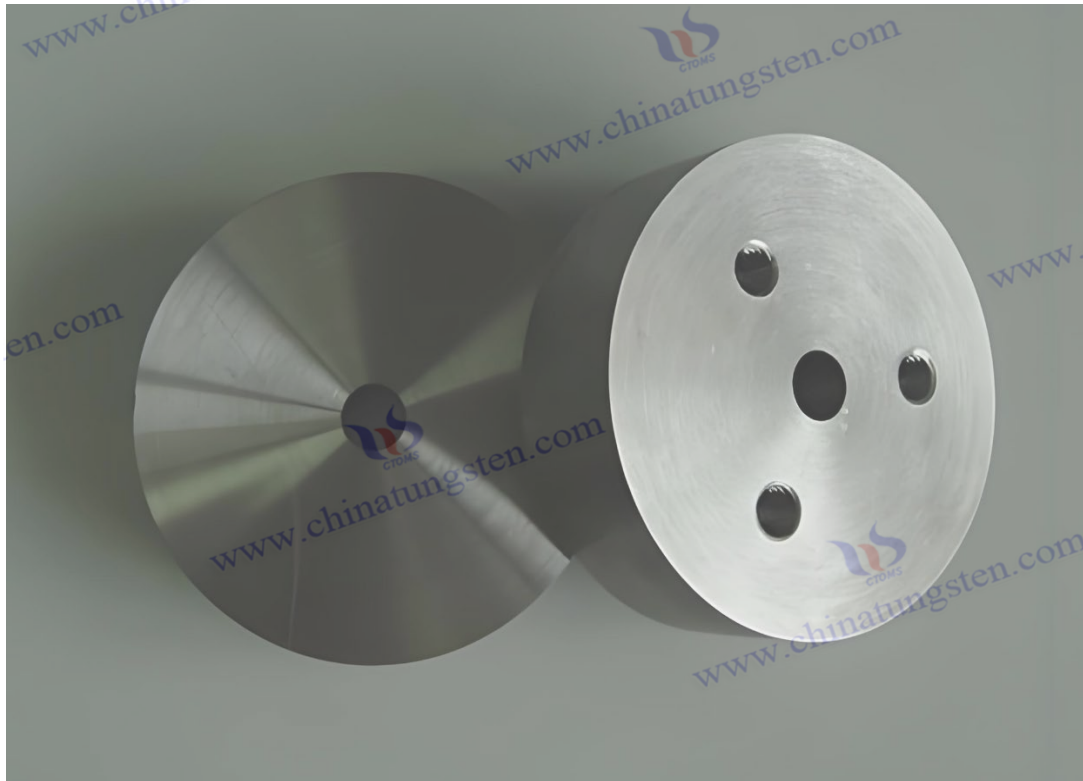
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tolerance, and dynamic balance is also required.



PART VI. What Tungsten Alloy Counterweights Are Used in the Automotive, Aviation, and Rotating Machinery Fields?

Tungsten alloy counterweights in the automotive, aviation, and rotating machinery fields mainly revolve around mass balancing, center-of-gravity adjustment, inertia control, and high-density counterweights within limited space. Although the application objects of the three fields are different, their common feature is that mass needs to be accurately added at a specific position, and tungsten alloy can achieve small-volume counterweights by utilizing relatively high density.

Automotive Field

Tungsten alloy counterweights in automobiles are mainly used in components with relatively high requirements for mass distribution and rotational balance. Engine crankshaft counterweights are a relatively typical application. When the crankshaft rotates at high speed, the rotational and reciprocating inertial loads generated by the crank mechanism need to be balanced through reasonable mass distribution. Tungsten alloy has high density and can concentrate a relatively large mass in positions where crankshaft space is limited. For a 1 kg tungsten alloy with a density of 18.0 g/cm³, its theoretical volume is about 55.56 cm³, while steel with a density of 7.85 g/cm³ requires about 127.39 cm³. Drive shafts, half shafts, and other rotating components may also use local high-density counterweights,



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with the counterweight mass and installation angle determined through dynamic balancing tests. The unbalance force of a rotating component can be approximately expressed as $F=m\omega^2r$, where m is the unbalanced mass, ω is the angular velocity, and r is the eccentric radius. As the rotational speed increases, the effect of mass distribution errors increases significantly. Special counterweights in automobile wheel hubs, wheels, and suspension systems may also use tungsten alloy, especially for high-performance vehicles and racing cars with limited installation space, the need for relatively large local mass, or special requirements for mass layout. Racing cars may also use high-density counterweights to adjust front-rear and left-right mass distribution as well as local center-of-gravity position. In addition, in equipment such as automotive millimeter-wave radar, cameras, LiDAR (Light Detection and Ranging), and gimbal-type sensors, high-density counterweights can also be used to adjust the inertia and center of gravity of small motion mechanisms.

Aviation Field

The requirements for counterweights in the aviation field are more stringent. Main applications include control surface mass balancing, trim counterweights, rotor and propeller balancing, and inertial system counterweights. Aircraft control surfaces such as elevators, ailerons, and rudders may be provided with mass balance counterweights. Their main purpose is to adjust the mass center and inertial characteristics of the control surface so that they meet aeroelastic and flutter (Flutter) design requirements. Tungsten alloy can provide a relatively large mass within the limited space inside a control surface, so it is suitable for placement at specific positions such as near the leading edge or hinge. Aircraft trim systems may also use high-density tungsten alloy counterweights. When mass needs to be added at a specific position to adjust the aircraft center of gravity (CG, Center of Gravity), high-density material can reduce the counterweight volume. The mass moment can be expressed as $M=mr$, where m is the counterweight mass and r is the distance from the counterweight center of mass to the reference axis. Therefore, the counterweight position is just as important as the counterweight mass. Propellers, rotors, and other high-speed rotating aviation components place even more emphasis on dynamic balancing. After measuring the unbalance amount and phase angle with dynamic balancing equipment, tungsten alloy counterweights can be installed on the specified correction plane, or correction can be carried out by material removal according to the design. Unmanned aerial vehicles also have similar applications, including fuselage center-of-gravity adjustment, gimbal counterweights, rotor system balancing, and mission payload counterweights. For small drones, the volume advantage brought by high density is especially obvious.

Rotating Machinery Field

Rotating machinery is one of the fields most directly related to dynamic balancing in the application of tungsten alloy counterweights. Typical equipment includes motors, generators, industrial fans, compressors, pumps, centrifuges, high-speed main shafts, and some precision rotors. When motor and generator rotors rotate at high speed, if the mass



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distribution relative to the rotating shaft is uneven, periodic vibration will be generated. Through dynamic balancing testing, the angle and correction plane where the unbalance is located can be determined, and then tungsten alloy counterweights can be used for local weight addition. For slender rotors, two correction planes usually need to be considered. Single-plane counterweights are mainly suitable for relatively simple balancing problems, while two-plane counterweights can simultaneously correct static unbalance and couple unbalance. Finally, it is necessary to confirm through another dynamic balancing test whether the residual unbalance meets the specified requirements. Fan, pump, and compressor impellers may also require local counterweights. Especially when the impeller size is restricted and the counterweight installation space is narrow, tungsten alloy can provide a relatively large mass correction through a smaller volume. High-speed main shafts and precision centrifuge mechanisms have relatively high requirements for counterweight mass, installation angle, coaxiality, runout, and counterweight fixing reliability. For high-speed rotating parts, the counterweight is not simply as heavy as possible; rather, the mass and position need to be accurately determined according to the test results.

Why All Three Fields Value Tungsten Alloy

The most direct reason is density. The density of common high-density tungsten alloys is about 17–18.5 g/cm³, significantly higher than that of ordinary steel. Under the same mass condition, the higher the density, the smaller the required volume, allowing the counterweight to be arranged in a concentrated manner within limited space. The second advantage is freedom of mass layout. What a counterweight truly affects is mass distribution, not simply total mass. For parameters such as center of mass, mass moment, and moment of inertia, the position of the counterweight is very important. The moment of inertia can be expressed as $I = \sum m_i r_i^2$. Therefore, placing mass farther from the rotating shaft usually has a more obvious effect on inertia. The third advantage is that it can be customized according to different structures. Tungsten alloy can be machined into block-shaped, cylindrical, disc-shaped, ring-shaped, arc-shaped, screw-type, and various special-shaped counterweights, and can meet different structural requirements through powder metallurgy (PM, Powder Metallurgy) and subsequent processes such as turning, milling, drilling, tapping, and grinding.

CTIA GROUP can customize tungsten alloy counterweights for automotive rotating components, aviation control surfaces and rotor counterweights, industrial rotors, and high-speed machinery balancing parts according to target mass, density, installation space, counterweight position, and precision requirements. Overall, the automotive field places more emphasis on the mass balancing of engines and transmission systems as well as vehicle mass layout, the aviation field pays more attention to control surface mass balancing, center of gravity, and high-speed rotating component balancing, while rotating machinery focuses on rotor dynamic balancing and high-speed operation vibration control. All three jointly utilize the characteristics of high density and small volume of tungsten alloy



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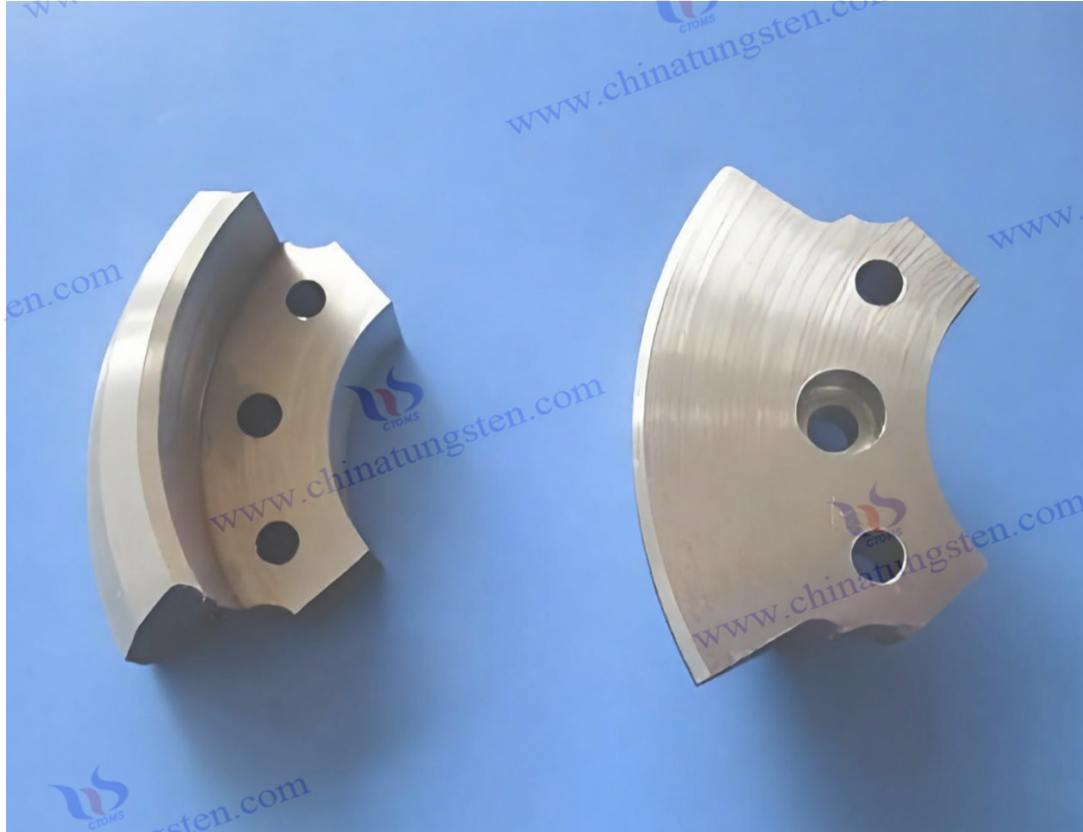
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to achieve local mass concentration and precise balancing that are difficult to accomplish with traditional low-density materials.



Q41 Why Do Automobiles Use Tungsten Alloy Counterweights?

The core reason automobiles use tungsten alloy counterweights is that tungsten (W, Tungsten) alloy has very high density, can obtain relatively large counterweight mass within limited installation space, and at the same time has relatively good strength, wear resistance, and dimensional stability. For parts such as engines, transmission systems, wheels, suspensions, and racing cars that are relatively sensitive to mass distribution and spatial dimensions, tungsten alloy can provide high mass density that ordinary steel counterweights find difficult to achieve.

(1) The Most Direct Advantage Is Small Volume and Large Mass per Unit Volume

The density of common high-density tungsten alloy counterweights is about 17–18.5 g/cm³, while the density of ordinary steel is about 7.85 g/cm³. When a 1 kg counterweight is required in each case, the volume of a tungsten alloy with a density of 18.0 g/cm³ is about 55.56 cm³, while that of steel is about 127.39 cm³. The volume required by tungsten alloy is reduced by about 56%. For automobiles, this is very important because the installation space inside the engine compartment, wheel hubs, suspension, and transmission mechanisms is usually limited. If a steel counterweight requires a relatively large size,



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tungsten alloy can significantly reduce the part volume while maintaining the same mass.

(2) It Makes Mass Distribution Design More Convenient

Many automobile systems not only need to add a certain mass but also need to place the mass at a specific position. For example, crankshafts need rotational mass balancing, drive shafts need dynamic balancing, wheels need mass compensation, and suspension systems may also need to arrange additional mass within limited space. Tungsten alloy counterweights can, by reducing volume, concentrate the required mass in a designated area. For rotating parts, mass distribution is especially important because centrifugal force can be expressed as $F=m\omega^2r$, where m is mass, ω is angular velocity, and r is the distance of the mass relative to the axis of rotation. Therefore, the position, mass, and eccentricity of the counterweight need to be designed in combination with the entire rotating system.

(3) It Can Be Used for Crankshaft Counterweights in Automobile Engines

During high-speed rotation, an engine crankshaft needs to form a reasonable mass balance with moving parts such as pistons and connecting rods. If the original structure is limited by space, rotational speed, or lightweight design, traditional counterweights may require relatively large dimensions. Because tungsten alloy has high density, it can provide relatively large mass within a relatively small space, so it can be used in crankshaft counterweight designs for some high-performance engines and racing engines. By reasonably arranging the counterweight mass, it can help adjust the mass distribution and inertia characteristics of the rotating system.

(4) Transmission Systems May Also Use Tungsten Alloy Counterweights

Drive shafts, propeller shafts, flywheels, and other high-speed rotating parts may have mass non-uniformity, geometric eccentricity, or mass distribution deviation after manufacturing and assembly, and need to be corrected by counterweights for balancing. For transmission parts with limited installation space, tungsten alloy counterweights can use relatively small block-shaped, ring-shaped, or special-shaped structures, fixed at designated positions by bolts, welding, press fitting, or other methods. In this way, the space occupied by the counterweight itself on surrounding parts can be reduced.

(5) Wheels and Suspension Systems Also Have Space Advantages

When automobile wheels require dynamic balancing, traditional methods usually use counterweight blocks of relatively small volume. If there is a further requirement to reduce counterweight volume and increase mass per unit volume, tungsten alloy has certain advantages. In suspension systems, counterweights may also be used to adjust mass distribution, improve the inertia characteristics of moving parts, or meet specific structural design requirements. Especially for racing cars and high-performance vehicles, because the structural space is compact, they are more sensitive to the size and installation position of counterweights.



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(6) Racing Cars Place More Emphasis on the High-Density Characteristics of Tungsten Alloy Counterweights

A typical reason racing cars use tungsten alloy counterweights is the need to adjust vehicle mass distribution within very limited space. In racing car design, counterweights are not simply added weight; they also involve front-to-rear axle mass distribution, left-to-right mass distribution, and the overall vehicle center-of-gravity position. Tungsten alloy can concentrate relatively large mass within a relatively small volume, making it easier for engineers to arrange the counterweight at a designated position while reducing spatial interference of the counterweight with other mechanical structures and aerodynamic components. For example, when a certain mass needs to be added and kept as close as possible to the bottom of the vehicle, high-density tungsten alloy can be arranged using thin blocks, strip blocks, or customized special-shaped parts, thereby balancing mass, dimensions, and installation space.

(7) Tungsten Alloy Also Has Relatively Good Wear Resistance and Dimensional Stability

Automotive counterweights work under long-term vibration, impact, and temperature changes, so the material cannot be considered only in terms of density; mechanical strength, wear resistance, and long-term dimensional stability also need to be considered. Tungsten alloy is usually composed of a hard tungsten phase and binder phases such as nickel (Ni, Nickel), iron (Fe, Iron), or copper (Cu, Copper). Common W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) materials can be selected according to specific applications. However, specific mechanical properties, magnetic properties, and processing performance need to be based on the actual material grade and manufacturing process, and cannot be judged solely by density.

(8) Not All Automotive Counterweights Require Tungsten Alloy

The advantages of tungsten alloy are mainly reflected in high density and small volume. If a certain part of an automobile has sufficient space and there are no strict restrictions on counterweight dimensions, then materials such as steel and cast iron may already be able to meet the requirements, and the use of tungsten alloy may not necessarily have an economic advantage. Therefore, the selection of automotive counterweight materials usually requires comprehensive consideration of target mass, installation space, center-of-gravity position, rotational speed, dynamic balancing requirements, material cost, processing cost, and batch size, rather than simply pursuing the highest density. In the customization of tungsten alloy counterweights for automobiles and racing cars, CTIA GROUP can match material systems such as W-Ni-Fe and W-Ni-Cu according to the target mass, installation space, structural dimensions, and precision requirements of different applications such as crankshafts, transmission systems, wheels, and suspensions, and combine turning, milling, drilling, grinding, and dynamic balancing testing for counterweight part design and manufacturing.



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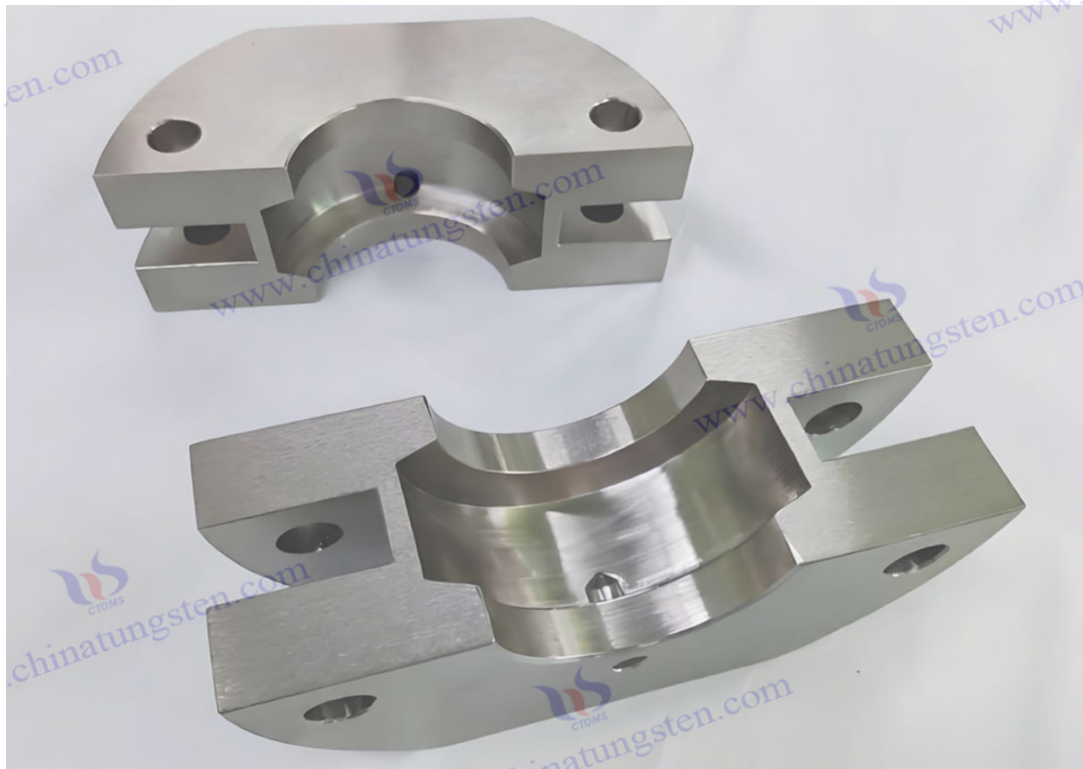
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The core value of automobiles using tungsten alloy counterweights can be summarized as the small volume and flexible mass distribution design brought by high density. For applications such as crankshafts, drive shafts, wheels, suspensions, and racing cars with compact space and relatively high mass distribution requirements, this material advantage is especially obvious; for ordinary automotive counterweights with sufficient space and cost sensitivity, whether tungsten alloy is worth using needs to be judged according to actual structural requirements.



Q42 What Is the Function of a Tungsten Alloy Crankshaft Counterweight?

Tungsten alloy crankshaft counterweights are mainly used to adjust the mass distribution and rotational inertia of an engine crankshaft, helping the crankshaft system achieve a more reasonable state of balance. Because tungsten (W, Tungsten) alloy has very high density, when a relatively large counterweight mass needs to be added but installation space is limited, a smaller tungsten alloy counterweight can be used to achieve the target mass. Therefore, it has application value in high-performance engines, racing engines, and some crankshaft designs with limited space.

(1) Compensating for the Mass Distribution in the Crankshaft System

When an engine operates, the pistons and connecting rods produce reciprocating motion, while the crankshaft itself rotates at high speed. Because the mass, geometric position, and motion trajectory of each moving part are different, it is difficult for the crankshaft system



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to naturally achieve ideal mass balance. The basic function of a crankshaft counterweight is to compensate for the unbalanced mass in the crank mechanism by adding mass at specific positions, making the mass distribution of the rotating system more reasonable. For tungsten alloy, its main advantage is that it can provide a relatively large mass within a relatively small volume. For example, for a tungsten alloy with a density of 18.0 g/cm³, 1 kg of material requires only about 55.56 cm³; if steel with a density of about 7.85 g/cm³ is used, about 127.39 cm³ is required. For structures with limited space around the crankshaft, this volume difference is relatively obvious.

(2) Helping Reduce the Unbalance of the Crankshaft Rotating System

When the crankshaft rotates at high speed, if there is a deviation in mass distribution, periodic centrifugal force will be generated. Its basic relationship can be expressed as $F = m\omega^2 r$, where m is the unbalanced mass, ω is the angular velocity, and r is the distance of that mass relative to the axis of rotation. As engine speed increases, ω affects centrifugal force in a squared relationship, so even a relatively small mass deviation may produce relatively obvious vibration at high speed. Reasonably designing crankshaft counterweights can adjust the magnitude and position of the unbalanced mass, making the mass distribution during crankshaft rotation closer to the design target.

(3) Enabling a Relatively Large Counterweight Mass to Be Added Within Limited Space

This is an important feature that distinguishes tungsten alloy crankshaft counterweights from ordinary steel counterweights. Suppose 500 g of counterweight mass needs to be added. The volume of tungsten alloy with a density of 18.0 g/cm³ is about 27.78 cm³, while that of steel is about 63.69 cm³. The mass is the same, but the space occupied by tungsten alloy is obviously smaller. Therefore, if bearings, cylinder blocks, oil pans, connecting rods, or other structural restrictions near the crankshaft make it impossible to install a relatively large steel counterweight, high-density tungsten alloy can be used to obtain the required mass within limited space.

(4) Adjusting the Rotational Inertia of the Crankshaft

Crankshaft counterweights not only affect total mass but also affect rotational inertia. Mass farther from the axis of rotation contributes more obviously to rotational inertia, which can be expressed as $I = \sum m_i r_i^2$, where I is rotational inertia, m_i is the mass of each mass unit, and r_i is its distance from the axis of rotation. Therefore, when designing a crankshaft counterweight, it is not enough to look only at how many grams the counterweight has; the position where the counterweight is installed must also be considered. Tungsten alloy has high density and can obtain relatively large mass at relatively small geometric dimensions, allowing engineers to adjust the mass and spatial position of the counterweight more flexibly to a certain extent. However, the specific change in inertia must be calculated in combination with the complete crankshaft assembly and cannot be judged only by material density.



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(5) Helping Control Engine Vibration

Whether the crankshaft counterweight is reasonable or not will affect the vibration level of the engine rotating system. If the crankshaft mass distribution is unreasonable, relatively large rotational unbalance force may be generated and transmitted through the crankshaft, bearings, and engine block. By reasonably configuring crankshaft counterweights, periodic excitation caused by mass unbalance can be reduced, thereby improving the vibration state during engine operation. However, it is necessary to distinguish rotational unbalance from reciprocating inertia force. Crankshaft counterweights mainly solve the mass distribution problem of the rotating system, and it cannot simply be considered that adding counterweights can eliminate all engine vibration. Actual engine balancing also involves multiple factors such as piston mass, connecting rod mass, crank radius, cylinder arrangement, firing order, and balance shafts.

(6) The Demand for Tungsten Alloy Counterweights Is More Obvious in Racing Engines

In racing engines, engine speeds are usually relatively high, and the crankshaft structure must simultaneously take into account strength, stiffness, mass, and spatial layout. If ordinary steel counterweights are used to achieve the target mass, larger geometric dimensions may be required. Tungsten alloy can use its high-density characteristics to reduce counterweight volume, making it easier to arrange the counterweight near the crank. For crankshafts that have already undergone lightweight design, this high-mass-density material can provide relatively large design freedom. However, the racing crankshaft ultimately still needs to be designed as a whole according to engine speed, crankshaft structure, connecting rod and piston mass, and the target balancing scheme, and the weight of the tungsten alloy counterweight alone cannot be used as the basis for judgment.

(7) A Tungsten Alloy Counterweight Does Not Mean That Heavier Is Better

What a crankshaft counterweight needs to achieve is a reasonable state of balance, not as much mass as possible. If the counterweight is too large, it may increase the total mass and rotational inertia of the crankshaft and change the original dynamic characteristics of the engine. Therefore, actual design requires calculation of the target balance mass, counterweight radius, counterweight position, and overall crankshaft mass distribution. The advantage of tungsten alloy lies mainly in high density, not in allowing unlimited increase of counterweight mass. For example, when 1 kg of counterweight is required in each case, a density of 17.5 g/cm³ requires about 57.14 cm³, 18.0 g/cm³ requires about 55.56 cm³, and 18.5 g/cm³ requires about 54.05 cm³. Increased density mainly brings volume reduction and does not mean that the crankshaft needs to add more counterweight mass.

(8) How Are Tungsten Alloy Crankshaft Counterweights Manufactured and Installed?

Crankshaft counterweights can adopt block-shaped, arc-shaped, sector-shaped, or other customized structures according to the structure. Common tungsten alloy materials include



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W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper), and mounting holes, positioning surfaces, threaded holes, or other connecting structures are then machined according to the crankshaft installation method. The manufacturing process can usually use powder metallurgy (PM, Powder Metallurgy) forming and sintering, followed by mechanical machining such as turning, milling, drilling, and grinding to obtain final dimensions. For small batches or complex structures, sintered blanks can also be subjected to CNC (Computer Numerical Control) precision machining. The installation method depends on the crankshaft structure and can use mechanical fixing, press fitting, or other connection methods verified by engineering. In a high-speed rotating environment, the reliability of the counterweight connection is especially important. CTIA GROUP can select a suitable tungsten alloy material system according to the target balance mass of the crankshaft, counterweight installation space, crankshaft speed, counterweight radius, and mass tolerance, and carry out counterweight structure design, mechanical machining, and quality inspection.

(9) Final Balancing Testing Is Required

After tungsten alloy crankshaft counterweights are machined, whether they are qualified cannot be judged only by weighing. For engine crankshafts, static or dynamic balancing testing needs to be carried out in combination with the entire crankshaft assembly, and minor weight removal or adjustment should be carried out according to the test results. During testing, attention usually needs to be paid to counterweight mass, center-of-mass position, mounting hole position, coaxiality, circular runout, and final unbalance amount. Especially for high-speed engines, a tiny mass eccentricity, after being amplified by ω^2 , may also form relatively large dynamic excitation. Therefore, the key to whether a tungsten alloy crankshaft counterweight truly functions is not simply the use of high-density material, but the combination of high-density material with accurate mass calculation, reasonable counterweight position, reliable structural connection, and final dynamic balancing testing.

The main function of a tungsten alloy crankshaft counterweight is to provide the required counterweight mass within limited space through high-density material, thereby adjusting the mass distribution, rotational inertia, and dynamic balance state of the crankshaft system, and helping control the unbalance excitation generated by high-speed rotation. It is especially suitable for engines and racing crankshafts with limited space, high rotational speed, and relatively high requirements for mass distribution, but actual design should still be based on the dynamic calculation and balancing test results of the entire crankshaft assembly.



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Q43 Why Do Racing Cars Use Tungsten Alloy Counterweights?

Racing cars use tungsten alloy counterweights mainly to take advantage of the high density and small volume of tungsten (W, Tungsten) alloy to precisely add or adjust mass within limited installation space, and further control the vehicle's mass distribution, center-of-gravity position, and the balance state of rotating components. Compared with ordinary steel counterweights, tungsten alloy is not simply used to increase weight, but to obtain greater design freedom among space, mass, and layout.

(1) High Density Can Significantly Reduce Counterweight Volume

The density of common high-density tungsten alloy counterweights is about 17–18.5 g/cm³, while that of steel is about 7.85 g/cm³. Calculated with 18.0 g/cm³ tungsten alloy, a 1 kg counterweight requires only about 55.56 cm³; steel requires about 127.39 cm³, so the theoretical volume of tungsten alloy is reduced by about 56%. The internal space of a racing car is very limited, especially in the engine compartment, suspension, transmission system, and lower body area. When tungsten alloy is used for a counterweight of the same mass, smaller structural dimensions can be used, making it easier to install at the designated position.

(2) Facilitating Precise Adjustment of Racing Car Mass Distribution

Racing car tuning focuses not only on the total vehicle mass but also on front and rear axle



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loads, left and right side mass distribution, and center-of-gravity position. Counterweights can be installed at specific positions to change the vehicle's mass distribution. The high density of tungsten alloy means that a relatively large mass can be concentrated in a very small volume. For example, when 500 g of mass needs to be added, 18.0 g/cm³ tungsten alloy requires only about 27.78 cm³. Engineers can arrange the corresponding mass within limited space according to the chassis structure, without having to use larger steel counterweights.

(3) Beneficial to Center-of-Gravity Position Design

The vehicle's center-of-gravity height is affected by the mass and installation position of each component. Different counterweight placement positions have different effects on the vehicle's overall center of gravity. If mass needs to be added in a specific area, tungsten alloy can be concentrated at the target position through a smaller volume. For example, arranging a counterweight at a lower position on the chassis can add the specified mass without occupying a large amount of space. However, tungsten alloy itself does not automatically lower the vehicle's center of gravity; the final effect depends on the actual installation position of the counterweight and the mass distribution.

(4) Rotational Balancing in the Engine and Transmission System Is Also Very Important

Racing engines usually operate at relatively high speeds, and the crankshaft, flywheel, drive shaft, clutch, and other rotating components require precise mass balancing. The centrifugal force in a rotating system can be expressed as $F=m\omega^2r$, where m is the unbalanced mass, ω is the angular velocity, and r is the mass eccentricity distance. The higher the rotational speed, the more obvious the effect of mass eccentricity on vibration. Tungsten alloy can be used for counterweights on specific rotating components, providing the target mass through a smaller volume, thereby helping designers adjust the rotating mass distribution. However, the actual balancing effect depends on mass and position, not on material density itself.

(5) It Can Be Used for Racing Engine Crankshaft Counterweights

Crankshaft counterweights need to provide sufficient mass within the limited crank space. After using high-density tungsten alloy, the target counterweight mass can be achieved within a smaller space. For example, at the same mass, the volume of a tungsten alloy counterweight is obviously smaller than that of a steel counterweight, which can reduce the possibility of spatial interference with surrounding structures such as connecting rods, cylinder blocks, and oil pans. For high-speed engines, design also needs to be carried out in combination with crankshaft strength, stiffness, rotational inertia, and the overall balancing scheme; it is not simply a matter of replacing a steel counterweight with tungsten alloy.

(6) It Can Be Used for Other Precision Counterweights in Racing Cars

In addition to the crankshaft, tungsten alloy may also be used for transmission system



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counterweights, wheel and hub-related counterweights, suspension system mass adjustment, and other structures requiring local mass addition. For high-speed rotating components, it is usually necessary to simultaneously control counterweight mass, installation position, coaxiality, circular runout, and final dynamic balance; for non-rotating structures, more attention is paid to mass, center of gravity, and installation reliability.

(7) The Mechanical Properties of Tungsten Alloy Are Also Suitable for Harsh Working Environments

Racing cars are exposed to high vibration, high impact, and temperature changes for long periods. In addition to high density, counterweights also need sufficient mechanical strength and structural stability. Common materials include tungsten-based heavy alloys such as W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). Different material systems differ in mechanical properties, magnetic response, and processing performance, so selection needs to be made according to the specific application.

(8) Tungsten Alloy Is Not the Only Choice for Racing Car Counterweights

If installation space is sufficient, materials such as steel and cast iron can also be used for counterweights. The value of tungsten alloy lies mainly in the space advantage brought by high density and the ability to finely arrange mass positions. At the same time, the material and processing costs of tungsten alloy are usually higher than those of ordinary steel. Therefore, if there is no obvious space limitation at a counterweight position, there is no need to use tungsten alloy merely for the sake of pursuing higher density. The selection of racing car counterweight materials usually requires comprehensive consideration of target mass, installation space, center-of-gravity position, rotational speed, balancing requirements, structural strength, processing cost, and reliability.

CTIA GROUP can select tungsten alloy material systems such as W-Ni-Fe and W-Ni-Cu according to the target mass, installation space, and precision requirements of racing car crankshafts, transmission systems, suspensions, and other counterweight positions, and complete the manufacturing of customized counterweight parts in combination with turning, milling, drilling, grinding, and dynamic balancing testing. The core reason racing cars use tungsten alloy counterweights can be summarized as the small volume and relatively high degree of mass placement freedom brought by high density. It can help racing cars achieve precise mass adjustment within limited space and is used for the balancing design of rotating components such as crankshafts and transmission systems. What truly determines the counterweight effect is still mass, position, center of gravity, and mass distribution, rather than simply pursuing higher material density.



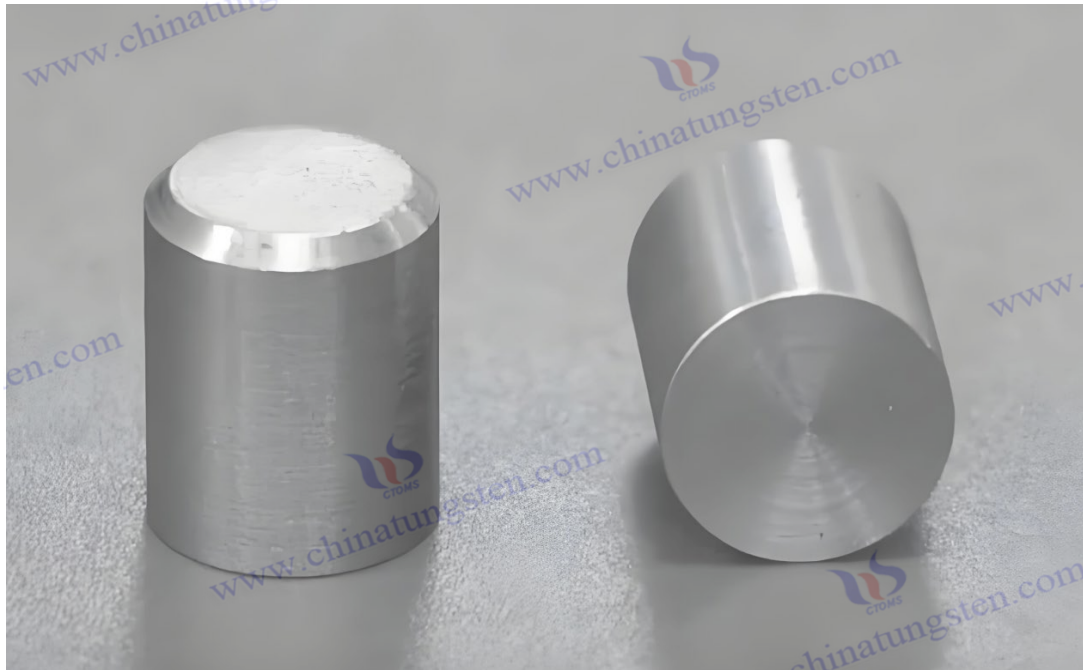
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44 Why Do Aircraft Use Tungsten Alloy Counterweights?

The core reason aircraft use tungsten alloy counterweights is not simply to increase aircraft weight, but rather, under conditions where aircraft have strict requirements for mass distribution, center of gravity (CG, Center of Gravity) position, rotational balance, and structural space, to utilize the high-density characteristics of tungsten alloy to obtain the required mass within a smaller volume. Common high-density tungsten alloy counterweights in the aviation field have a density of about 17–18.5 g/cm³, and some material systems can also reach higher or lower specific ranges. Calculated at 18.0 g/cm³, the volume of a 1 kg tungsten alloy counterweight is about 55.56 cm³, while that of steel of the same mass is about 127.39 cm³, a volume reduction of about 56.4%.

Control Surface Mass Balancing Is an Important Application

Aircraft control surfaces such as elevators, ailerons, and rudders operate in high-speed airflow. If the mass distribution of a control surface is unreasonable, it will increase the load at the hinge and may increase the risk of flutter. Therefore, some control surfaces are equipped with mass balance weights so that the center of mass of the control surface is at the position required by the design relative to the hinge axis. The advantage of tungsten alloy is that it can provide relatively large mass with a relatively small size. For example, when 1 kg of mass needs to be installed, if an 18.0 g/cm³ tungsten alloy is used, only about 55.56 cm³ of material volume is needed. This is very valuable for structures with limited internal space such as wings, tail surfaces, and control surfaces. The counterweight can be arranged at design positions such as near the hinge axis or the leading edge of the control



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surface, while minimizing the impact on the aerodynamic shape and internal structural space. The function here is to reduce and control flutter-related risks, rather than relying on the counterweight alone to eliminate flutter; the actual effect also depends on control surface structural stiffness, hinge characteristics, aerodynamic characteristics, and overall aircraft design.

Used for Aircraft Center-of-Gravity and Trim Adjustment

The center-of-gravity position of an aircraft directly affects longitudinal stability, handling characteristics, and flight trim. During aircraft design and modification, it is sometimes necessary to add or adjust a certain mass at a specific position. Such counterweights are usually called trim counterweights or ballast counterweights. The value of tungsten alloy in such applications is highly concentrated mass. For example, when hundreds of grams to several kilograms of mass need to be arranged in a limited structural bay, the use of high-density material can reduce the space occupied by the counterweight, making it easier to install the counterweight at the design position. However, tungsten alloy itself will not automatically lower the aircraft center of gravity or improve the trim effect; what truly determines the effect is the mass of the counterweight and its installation position. For a position at distance r from the reference point, the mass moment generated by the counterweight can be expressed as $M=mr$, where m is the counterweight mass. Therefore, the same mass installed at different positions may produce completely different trim effects.

Used for Balancing Propellers, Rotors, and High-Speed Rotating Components

Propellers, rotors, drive shafts, and some high-speed rotating components on aircraft all need to control mass distribution. If a rotating component has eccentric mass, periodic centrifugal force will be generated during high-speed rotation. Its basic relationship can be expressed as $F=m\omega^2r$, where F is centrifugal force, m is unbalanced mass, ω is angular velocity, and r is the distance by which the mass deviates from the rotating shaft. Because centrifugal force is proportional to the square of angular velocity, high-speed rotating components may also be very sensitive to tiny mass deviations. Therefore, tungsten alloy counterweights can be used for local mass correction at specific positions, achieving relatively large mass adjustment within limited space while reducing counterweight size. Such applications do not simply pursue the heavier the counterweight the better; rather, the required mass is determined according to parameters such as the residual unbalance of the rotating component, counterweight installation radius, and allowable residual unbalance.

High Density Is Conducive to the Miniaturization of Aviation Structures

Aviation structures are usually simultaneously constrained by weight, space, aerodynamic shape, and structural layout. For ordinary steel counterweights, if a relatively large mass is required, a larger volume may be needed; tungsten alloy can achieve the same mass within



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a smaller space. For example:

Material Reference Density Volume Required for 1 kg

Steel About 7.85 g/cm³ About 127.39 cm³

Tungsten alloy 18.0 g/cm³ About 55.56 cm³

Pure tungsten About 19.25 g/cm³ About 51.95 cm³

The main advantage of tungsten alloy compared with steel is not reducing the mass of an individual counterweight part, but allowing the same counterweight mass to occupy a smaller space. This is especially important for control surface leading edges, rotor assemblies, narrow installation cavities, and other space-limited positions.

Tungsten Alloy Can Also Provide Good Structural Adaptability

Aviation counterweights are not necessarily simple rectangular blocks. According to different installation positions, they can be designed as cylinders, discs, rings, arc-shaped parts, thin plates, special-shaped blocks, perforated counterweights, and threaded mounting structures. Common tungsten alloy systems include W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). Both use W (Tungsten) as the main high-density phase and form a binder phase through Ni (Nickel) and Fe (Iron) or Cu (Copper). The specific material selection needs to be determined in combination with density, strength, toughness, magnetic properties, processing performance, and service environment.

Aviation Counterweights Have Relatively High Requirements for Machining Accuracy

The truly difficult part of aircraft counterweights is often not only making the material into a specified weight, but simultaneously ensuring the accuracy of dimensions, mass, and installation position. For control surface counterweights, attention needs to be paid to mounting hole positions, counterweight mass, center-of-gravity position, and the geometric relationship with the hinge axis; for rotating components, coaxiality, circular runout, mass distribution, and dynamic balance also need to be controlled. Tungsten alloy usually uses powder metallurgy (PM, Powder Metallurgy) processes to manufacture blanks, and then performs finishing such as turning, milling, drilling, tapping, and grinding according to final requirements. Because tungsten alloy has a relatively high content of hard tungsten phase, tool wear during processing is usually more obvious than with ordinary steel. Therefore, batch manufacturing of aviation counterweights requires control of tool life, machining datum, dimensional compensation, and in-process inspection.

For customized counterweights in the aviation field, tungsten alloy manufacturers such as CTIA GROUP can carry out targeted design and processing of density, mass, dimensions, mounting holes, center-of-gravity position, and tolerance requirements according to different uses such as control surface counterweights, trim counterweights, and rotor balance counterweights. The core logic of aircraft using tungsten alloy counterweights can be summarized as follows: at positions where a specific mass must be configured, use high



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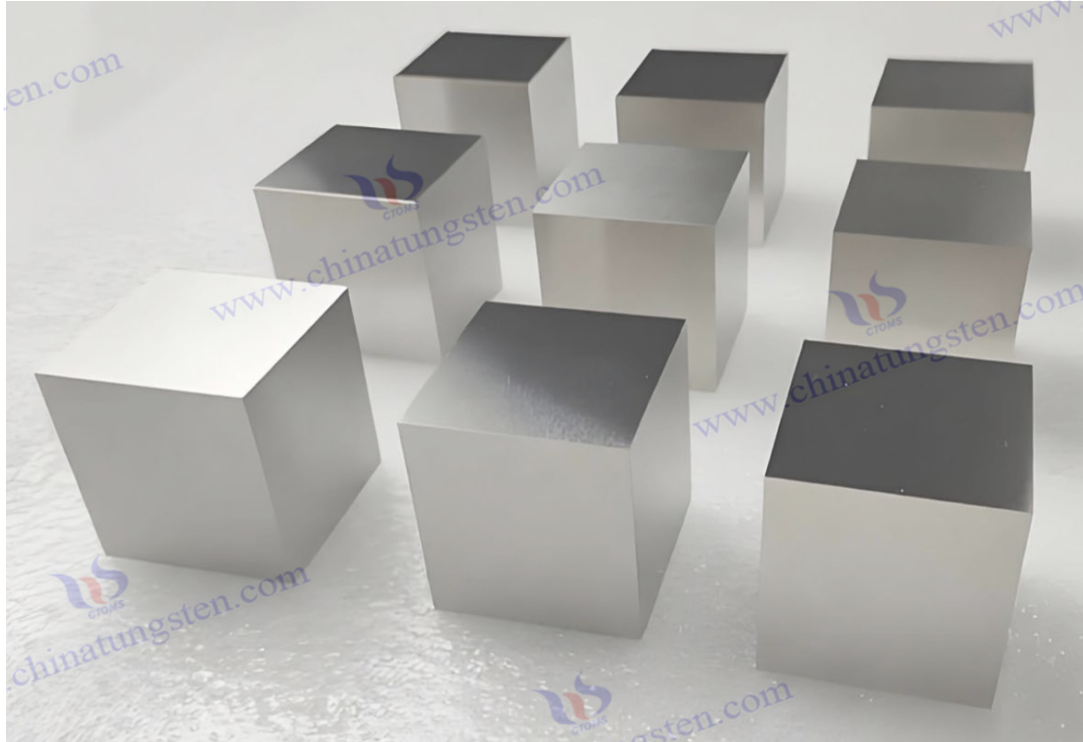
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density to achieve mass concentration in a small volume, and then control aircraft control surface balance, rotating component balance, and center-of-gravity and trim requirements through precise mass distribution and installation position. It is especially suitable for aviation components with limited space, strict mass position requirements, and the need for precise local counterweights, but it does not mean that all aircraft counterweights must use tungsten alloy; if space is sufficient and cost is sensitive, other materials such as steel may also meet design requirements.



Q45 Why Do Aircraft Control Surfaces Need Tungsten Alloy Counterweights?

The reason aircraft control surfaces use tungsten alloy counterweights is not to increase aircraft weight, but rather to arrange precise mass on the control surface so that its mass distribution meets aerodynamic stability, control load, and flutter control requirements. Typical control surfaces include elevators, ailerons, rudders, and some other movable aerodynamic surfaces. In these components, counterweights usually form part of the mass balance design.

The Most Important Function Is to Control Surface Mass Balance

Aircraft control surfaces are installed on wing or tail structures through hinges and move at high speed under airflow. If the center-of-gravity position and mass distribution of a control surface do not match the design requirements, the control surface may generate relatively large inertial loads and aerodynamic coupling effects during flight. The basic idea of a mass balance counterweight is to arrange part of the mass near the hinge axis or forward of the



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hinge axis, so that the center of mass of the control surface moves to the position specified by the design. For the mass moment generated by a certain counterweight, it can be expressed as $M=mr$, where M is the mass moment, m is the counterweight mass, and r is the distance from the counterweight center of mass to the reference axis. The same mass placed at different positions produces different mass moments. Therefore, aircraft control surface counterweights do not simply pursue greater mass, but require mass, position, and geometric dimensions to simultaneously meet the design requirements.

Helping Reduce the Risk of Flutter in Control Surfaces

Flutter is a self-excited vibration phenomenon formed by the mutual coupling of aerodynamics, structure, and inertia. For high-speed aircraft, control surfaces are among the important components susceptible to aeroelastic effects. If the mass distribution of a control surface is unreasonable, its inertial effects may couple with aerodynamic forces, structural elasticity, and hinge motion, thereby increasing flutter risk. Mass balance counterweights can change the center of mass and inertial characteristics of the control surface so that it meets the mass balance conditions specified by the design, thereby reducing related flutter risks. The counterweight here is only part of the overall flutter design and cannot be understood as meaning that installing a tungsten alloy counterweight alone can solve the flutter problem. Factors such as control surface stiffness, hinge clearance, aerodynamic layout, structural modes, and flight speed range are equally important.

Why High-Density Tungsten Alloy Is Particularly Suitable

The internal space of aircraft control surfaces is usually relatively limited, while mass balancing may require a certain mass to be concentrated at a position relatively far from the hinge axis. If a low-density material is used, a larger volume is required to obtain the same mass. Taking an 18.0 g/cm³ tungsten alloy as an example, the volume of a 1 kg counterweight is about 55.56 cm³; if steel with a density of about 7.85 g/cm³ is used, the same 1 kg requires about 127.39 cm³. Therefore, under the same mass requirement, the volume of a tungsten alloy counterweight can be reduced by about 56.4%. This makes tungsten alloy particularly suitable for installation in control surface leading edges, narrow cavities, or local structural spaces. After the counterweight size is reduced, it is also easier to coordinate with the internal structure, skin, and aerodynamic shape of the control surface.

Small Volume Also Helps Maintain the Aerodynamic Shape of the Control Surface

The external shape of a control surface usually cannot undergo obvious aerodynamic shape changes due to the installation of a counterweight. If the counterweight volume is too large, it may increase structural design difficulty and may even affect the internal spatial layout of the control surface. Tungsten alloy can concentrate relatively large mass within a relatively small volume, so it can be designed into cylindrical, block, plate, arc, perforated,



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or other special-shaped structures and embedded inside the control surface. For some control surfaces with limited leading-edge space, high-density materials especially have structural layout advantages.

Counterweight Mass and Installation Position Need to Be Precisely Controlled Simultaneously

Control surface mass balancing is not simply controlling the weight of the counterweight part. Suppose a certain mass moment needs to be generated. If the counterweight mass is m and the installation position is at distance r from the hinge axis, then $M=mr$. In other words, the mass of the counterweight and the installation distance together determine the final effect.

In actual manufacturing, it is usually necessary to control counterweight mass tolerance, external dimensions, mounting hole position, mounting datum, center-of-gravity position, and the geometric relationship with the hinge axis. If the control surface is a high-speed moving component, the mass distribution and motion state after assembly also need to be further checked. Therefore, a control surface counterweight that appears to weigh only a few hundred grams or even a few dozen grams may have manufacturing accuracy requirements far higher than those of an ordinary mechanical counterweight.

A Tungsten Alloy Counterweight Is Not Better the Heavier It Is

What an aircraft control surface needs is the mass balance specified by the design, not maximization of counterweight mass. If the counterweight is too light, it may not achieve the specified mass moment; if the counterweight is too heavy, it will increase structural loads and the overall mass of the aircraft and may change the inertial parameters of the control surface.

Therefore, actual design usually requires comprehensive calculation of control surface mass, center-of-gravity position, moment of inertia, hinge position, and aerodynamic loads, rather than selecting a counterweight solely according to material density. For rotating components, rotational inertia $I=\sum m_i r_i^2$ is also involved, where m_i represents the mass of each mass unit and r_i represents its distance to the rotating shaft. This shows that the position of the mass relative to the reference axis is equally important.

Manufacturing Usually Uses High-Density Blanks Plus Finishing

Tungsten alloy control surface counterweights can usually be formed into near-net-shape blanks by powder metallurgy (PM, Powder Metallurgy), and then subjected to finishing such as turning, milling, drilling, tapping, and grinding. For counterweights with simple structures, die pressing can reduce subsequent material removal; for complex special-shaped parts, a suitable sintered blank can first be obtained, and then the final dimensions can be obtained through mechanical machining. During the processing stage, key control is required over dimensional tolerances, hole position accuracy, surface quality, and the actual mass of the counterweight. For aviation applications, material batch



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traceability, dimensional inspection, quality inspection, and related technical document management are also required according to specific project requirements.

CTIA GROUP can, for aircraft control surface mass balance counterweights, match tungsten alloy density, mass, dimensions, mounting holes, center-of-gravity position, and tolerances according to design requirements, and combine powder metallurgy and precision mechanical machining to meet the manufacturing needs of customized counterweight parts. Therefore, the use of tungsten alloy counterweights in aircraft control surfaces can be understood as a precise mass balancing solution under space-limited conditions: through the high-density characteristics of tungsten alloy, obtaining the specified mass within a smaller volume, and then accurately arranging this mass at the design position to meet control surface mass balance, inertial characteristics, and flutter design requirements.



Q46 Why Do Drones Use Tungsten Alloy Counterweights?

Drones use tungsten alloy counterweights mainly to achieve precise mass distribution and center-of-gravity control within the limited body space of the drone. The drone's fuselage, arms, gimbal, battery, flight controller, camera, and propulsion system usually all need to be arranged as compactly as possible. Therefore, when a certain mass needs to be added or adjusted, high-density tungsten alloy can use a smaller volume to achieve a relatively large counterweight mass. For an 18.0 g/cm³ tungsten alloy, the theoretical volume of 1 kg of material is about 55.56 cm³, while steel with a density of about 7.85 g/cm³ requires about 127.39 cm³. At the same mass, the volume of tungsten alloy can be reduced by about 56.4%. For small drones and highly integrated aerial platforms, this volume advantage is relatively obvious.

Used to Adjust the Drone Center of Gravity

The center-of-gravity (CG, Center of Gravity) position of a drone directly affects flight attitude, control response, and stability. After the positions of components such as



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batteries, cameras, gimbals, and communication equipment change, the center of gravity of the entire aircraft will also change accordingly. At this time, tungsten alloy counterweights can be used for local mass compensation. For example, when a counterweight is installed at distance r from the reference position, the mass moment it generates can be expressed as $M=mr$, where m is the counterweight mass. By changing the counterweight mass or installation position, the mass distribution of the drone in the front-rear and left-right directions can be adjusted. For multi-rotor drones, if there is a difference in load between the left and right sides, counterweights can also be used to assist in correcting the lateral mass distribution, so that the flight control system does not need to counteract the structural mass offset through relatively large attitude control inputs over the long term.

Gimbal and Camera Systems Especially Need Precise Counterweights

Drones often carry electro-optical pods, cameras, surveying and mapping equipment, infrared equipment, or other mission payloads. These devices may be installed at the front, bottom, or on the gimbal of the body, thereby changing the center of gravity and local inertia of the entire aircraft. In gimbal systems, the function of counterweights is not only to adjust the overall center of gravity, but may also be used to balance the mass distribution among the lens, sensor, and motor. High-density tungsten alloy can provide the required mass without significantly increasing structural volume, making it easier to achieve a compact layout inside the gimbal. For gimbals requiring rapid attitude response, the counterweight position also affects rotational inertia. Rotational inertia can be expressed as $I=\sum m_i r_i^2$, where m_i is the mass unit and r_i is the distance from that mass unit to the rotating shaft. Therefore, where the counterweight is installed is just as important as how heavy the counterweight itself is.

Can Be Used for Balancing Rotors and Rotating Components

The motors, propellers, and some high-speed rotating components in drone propulsion systems are very sensitive to mass distribution. If a rotating component has eccentric mass, centrifugal force will be generated during high-speed rotation. Its basic relationship is $F=m\omega^2 r$, where F is centrifugal force, m is unbalanced mass, ω is angular velocity, and r is the distance by which the mass deviates from the rotating shaft. Because centrifugal force is related to the square of rotational speed, the higher the rotational speed, the more sensitive it is to tiny mass unbalance. Therefore, in specific rotating components, high-density counterweights can be used for local mass correction, making the counterweight size as small as possible while satisfying the specified mass adjustment amount. Such applications need to determine the counterweight mass and position according to actual dynamic balancing test results, and cannot simply be understood as meaning that the heavier the tungsten alloy installed, the better.



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Small Drones Particularly Value the Volume Advantage

For large aircraft, counterweight space is sometimes relatively ample; for small drones, internal space is often very tight. Batteries, ESCs, flight controllers, GPS (Global Positioning System), communication modules, and mission payloads already occupy a large amount of space, so counterweight parts are usually expected to be miniaturized. For example, when 100 g of mass needs to be configured, an 18.0 g/cm³ tungsten alloy requires only about 5.56 cm³. If 7.85 g/cm³ steel is used, about 12.74 cm³ is required. For a very small body, this difference may directly affect the structural layout.

For Drones, Counterweights Are Not Simply About Adding Weight

Drones themselves are highly sensitive to payload weight. Every additional 1 g of counterweight may increase the continuous thrust demand and energy consumption of the motors. Therefore, using tungsten alloy is not to make the drone heavier, but, when the design has already determined that a certain mass needs to be added, to make this part of the mass as concentrated, compact, and accurate as possible. For example, if a drone needs to add 100 g of counterweight to balance a front-mounted camera, the design goal is usually to achieve this 100 g in as small a space as possible, rather than increasing it to 150 g or 200 g. Material selection ultimately also needs to comprehensively consider counterweight mass, installation position, space, cost, and flight time.

Tungsten Alloy Is Suitable for Making Different Forms of Drone Counterweights

According to the drone structure, tungsten alloy can be machined into forms such as cylinders, discs, blocks, rings, thin plates, arcs, and perforated counterweights. For the interior of the fuselage, small block-shaped or cylindrical counterweights can be used; for the gimbal, ring-shaped or arc-shaped counterweights can be designed; for rotating components, structures such as local mounting blocks and balance rings may be used. Common material systems include W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). W-Ni-Fe usually has a relatively obvious magnetic response, while W-Ni-Cu usually has a lower magnetic response. The specific choice also needs to be determined according to the sensors, motors, magnetic compass, and structural environment on the drone.

Counterweight Accuracy Directly Affects Actual Drone Performance

Drone counterweights cannot be judged only by nominal weight. During actual manufacturing, attention also needs to be paid to mass tolerance, dimensional tolerance, mounting hole position, center-of-gravity position, and mass distribution after assembly. If it is a gimbal counterweight, the relationship between the rotating shaft and the counterweight center of mass also needs to be considered; if it is a rotor- or motor-related component, coaxiality, runout, and dynamic balance need to be considered; if it is an entire-aircraft counterweight, the effect on the center-of-gravity coordinates of the entire aircraft after installation needs to be considered. In the manufacturing process, powder



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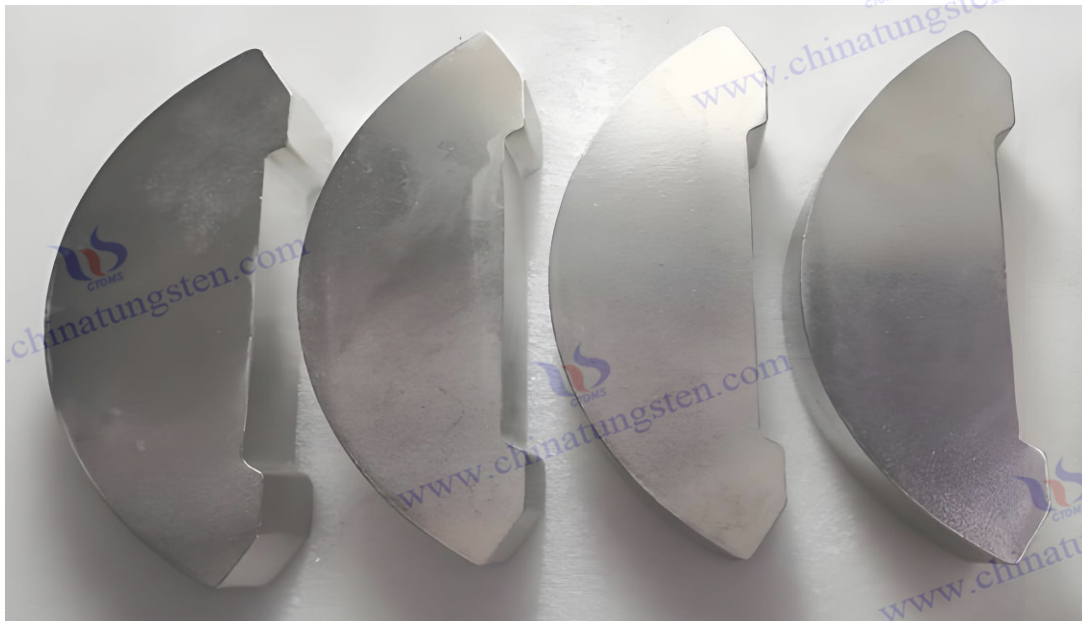
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metallurgy (PM, Powder Metallurgy) can usually be used to obtain high-density tungsten alloy blanks, and then final dimensions can be obtained through processes such as turning, milling, drilling, tapping, or grinding. For drone counterweights with relatively large batches, near-net shaping can reduce subsequent processing and improve material utilization. CTIA GROUP can customize material density, mass, external dimensions, installation method, and tolerances according to different uses such as drone fuselage counterweights, gimbal counterweights, rotor balance counterweights, and mission payload counterweights.

The main value of drones using tungsten alloy counterweights can be summarized as follows: when it has already been determined that a certain mass needs to be configured, use a smaller volume to achieve precise mass distribution, while controlling the center of gravity of the entire aircraft, gimbal inertia, and mass balance of rotating components. Especially for drone systems with miniaturization, high integration, high rotational speed, and high-precision attitude control, the space utilization advantage of high-density tungsten alloy is more obvious.



Q47 How Are Tungsten Alloy Counterweights Used in Industrial Rotors?

The core use of tungsten alloy counterweights in industrial rotors is to add precise mass at specific angular and radial positions to correct the unbalance caused by uneven rotor mass distribution, thereby reducing vibration, bearing load, and noise during high-speed rotation. Common applications include motor rotors, generator rotors, compressor rotors, pump impellers, fans, centrifuges, high-speed main shafts, and other high-speed rotating components.

First Determine the Unbalance Position Through Dynamic Balancing Testing



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After an industrial rotor is installed, the residual unbalance of the rotor needs to be measured using dynamic balancing equipment. The testing system usually provides the unbalance amount and the corresponding angular position, and then determines where mass should be added or where material should be removed according to the results. For a counterweight concentrated at a certain radius r , the mass moment it generates can be approximately expressed as $M=mr$, where m is the counterweight mass and r is the distance from the counterweight center of mass to the rotating shaft. If the rotor speed is relatively high, the centrifugal force generated by the unbalanced mass can be expressed as $F=m\omega^2r$, where ω is the angular velocity. Therefore, even if the counterweight mass is not large, as long as the rotational speed is very high, it may still produce an obvious dynamic effect.

Tungsten Alloy Is Particularly Suitable for Rotors with Limited Space

Industrial rotors usually have dimensional limitations, especially in equipment such as high-speed motors, aviation motors, centrifuges, and precision main shafts. If the counterweight is too large in volume, it may conflict spatially with the rotor body, bearings, housing, or other moving parts. The high density of tungsten alloy can provide relatively large mass within a relatively small volume. For example, when an 18.0 g/cm^3 tungsten alloy is used to make a 1 kg counterweight, the theoretical volume is about 55.56 cm^3 ; steel of the same mass requires about 127.39 cm^3 . Therefore, at the same counterweight mass, tungsten alloy can significantly reduce the space occupied by the counterweight. This is especially valuable in situations where the available installation space on the rotor is very limited.

Unbalance Can Be Corrected by Adding Local Mass

Industrial rotor dynamic balancing usually has two basic approaches: weight removal and weight addition. Weight removal is removing material from a position with excess mass, while weight addition is installing a counterweight at a position with insufficient mass. Tungsten alloy is mainly suitable for weight addition correction. For example, if there is insufficient mass at a certain angle of the rotor, a small tungsten alloy block, cylindrical pin, screw-type counterweight, arc-shaped counterweight, or ring-shaped counterweight can be installed at that position to change the rotor mass distribution by adding local mass. For rotors that have already been machined and where damage to the main material is not desired, the weight addition solution is especially practical.

Counterweight Position Is More Important Than Counterweight Weight Alone

For the same 100 g counterweight, when installed at a distance of 10 mm and 100 mm from the rotating shaft, the mass moments generated are $1 \text{ g}\cdot\text{m}$ and $10 \text{ g}\cdot\text{m}$ respectively, a difference of 10 times. Therefore, industrial rotor counterweight design usually needs to simultaneously determine three key parameters: mass, angle, and radius. In actual production, the position tolerance of the counterweight mounting holes, the dimensional



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tolerance of the counterweight itself, the installation clearance, and the actual center-of-gravity position after assembly must also be considered. If the rotor belongs to high-speed precision equipment, controlling only the weight of the counterweight part cannot guarantee final balancing accuracy.

For High-Speed Rotors, Tungsten Alloy Counterweights Can Reduce Local Structural Dimensions

In some designs, counterweights need to be installed on the outer edge, end, or specific balance grooves of the rotor. After using high-density tungsten alloy, a smaller counterweight volume can be used to obtain the same mass, thereby reducing the impact on rotor outer diameter, balance groove dimensions, and surrounding space. For example, when an 18.0 g/cm³ tungsten alloy is used, a 100 g counterweight requires only about 5.56 cm³. If 7.85 g/cm³ steel is used, about 12.74 cm³ is required. For rotor structures with millimeter-level space limitations, this volume difference may directly affect the counterweight solution.

Can Be Used for Single-Plane and Two-Plane Dynamic Balancing

For slender rotors, correction in only one plane may not simultaneously solve static unbalance and couple unbalance. Therefore, high-speed industrial rotors often use two-plane or even multi-plane balancing. For example, if a rotor is equipped with tungsten alloy counterweights in two correction planes, A and B, different types of unbalance can be corrected by simultaneously adjusting the mass and angle of the two planes. The actual counterweight mass needs to be calculated from dynamic balancing test data and rotor geometric parameters, rather than being directly determined by experience.

Tungsten Alloy Counterweights Need Reliable Fixing

When an industrial rotor operates at high speed, the centrifugal load borne by the counterweight may be very large, so the counterweight fixing method is a key link in the design. Common methods include screw fixing, press fitting, dovetail groove or dedicated balance groove installation, pin fixing, and mechanical locking structures matched with the rotor structure. The specific method depends on rotational speed, counterweight mass, installation radius, rotor material, and equipment safety requirements. For high-speed rotating components, ordinary adhesives cannot be relied upon alone to bear the main centrifugal load, and adhesive-type counterweights especially cannot be directly used without strength and reliability verification.

Material and Machining Accuracy Are Equally Important

Industrial rotor counterweights often use tungsten alloy systems such as W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper). Material selection needs to be determined in combination with density, mechanical properties, magnetic response, processing performance, and working environment. Tungsten alloy counterweights can



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usually be formed into blanks by powder metallurgy (PM, Powder Metallurgy), and then processed by turning, milling, drilling, tapping, or grinding. For precision rotor counterweights, key control is required over counterweight mass, dimensions, hole positions, center of gravity, and coaxiality and runout after assembly. CTIA GROUP can customize tungsten alloy counterweight parts with different densities, shapes, masses, and mounting structures according to the actual balancing requirements of rotors such as industrial motors, fans, compressors, pumps, centrifuges, and high-speed main shafts.

The Dynamic Balance State After Assembly Must Be Verified

The fact that a tungsten alloy counterweight is machined to qualification does not mean that the rotor will definitely meet balancing requirements after assembly. Finally, the counterweight should be installed on the actual rotor and dynamic balancing testing should be carried out again to check the residual unbalance, correction angle, and balance state of two or more correction planes. For high-speed rotors, factors such as bearings, couplings, shaft deflection, assembly eccentricity, and changes caused by thermal operation also need to be comprehensively considered. If necessary, balancing verification at different rotational speeds is required.

Therefore, the complete logic of using tungsten alloy counterweights in industrial rotors can be summarized as follows: first determine the unbalance amount and angle through dynamic balancing testing, then determine the counterweight mass, radius, and installation angle according to the mass moment relationship, use the high density of tungsten alloy to achieve small-volume weight addition, and finally verify the effect through reliable mechanical fixing and re-testing of dynamic balance. Its true value is not simply increasing rotor weight, but achieving high-precision, controllable local mass correction within limited space.





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Q48 How Is Dynamic Balancing Testing Performed for Tungsten Alloy Counterweights?

Whether a tungsten alloy counterweight itself needs dynamic balancing testing depends on what component it is ultimately applied to. For static counterweight blocks used alone, the focus is usually on checking mass, dimensions, and center-of-gravity position; for tungsten alloy counterweights installed on motor rotors, industrial rotors, main shafts, fans, pumps, centrifuges, or other high-speed rotating assemblies, dynamic balancing (Dynamic Balancing) testing is usually required for the assembled rotating assembly. The basic goal of dynamic balancing is to detect whether the mass distribution of the rotating body is reasonable relative to the axis of rotation, and to control the residual unbalance within the specified range by adding or removing a certain amount of mass.

First Clarify the Balancing Requirements of the Rotor

Before testing, parameters such as the mass of the rotor, operating speed, rotation diameter, allowable residual unbalance, number of correction planes, and balancing grade need to be determined. For low-speed, short, and thick rotating parts, static balancing is sometimes sufficient; for slender rotors, high-speed main shafts, motor rotors, compressor rotors, etc., two-plane dynamic balancing is usually required. The difference between dynamic balancing and static balancing is that dynamic balancing not only focuses on whether the overall center of gravity deviates from the axis of rotation, but also needs to consider the mass distribution at different axial positions.

Install the Rotor on the Dynamic Balancing Machine

During actual testing, the rotor equipped with the tungsten alloy counterweight is installed on a dynamic balancing machine, and vibration signals during rotation are obtained through the support system, drive system, and sensors. The equipment usually measures the vibration amplitude and phase of the rotor, determines the angular position of the unbalanced mass through the phase information, and then calculates how much mass needs to be added or removed. During testing, the installation state must be as consistent as possible with the actual use state, because assembly eccentricity among the shaft, coupling, impeller, counterweight, and other parts will all affect the final result.

Bring the Rotor to the Specified Test Speed

Start the equipment so that the rotor reaches the specified test speed. During rotation, the unbalanced mass will generate periodic centrifugal force. Its basic relationship is $F=m\omega^2r$, where F is centrifugal force, m is unbalanced mass, ω is angular velocity, and r is the distance from the unbalanced mass to the rotating shaft. Because centrifugal force is proportional to the square of angular velocity, the higher the speed, the more obvious the effect produced by the same unbalanced mass. Therefore, high-speed rotors usually have stricter requirements for counterweight mass, installation angle, and installation radius. The test speed is not necessarily equal to the final operating speed of the equipment; the



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specific value should be determined according to the rotor structure, equipment capability, and the corresponding balancing process.

Measure the Unbalance Amount and Phase Angle

A dynamic balancing machine generally outputs two very important data: unbalance amount and unbalance angle. For example, the test result may indicate that a certain correction plane has a certain unbalance amount and requires a certain mass to be added at a certain angular position. Based on this result, engineers determine the actual mass and installation position of the tungsten alloy counterweight. If the counterweight installation radius has already been determined, conversion can be carried out using the mass moment relationship, that is, $m_1 r_1 = m_2 r_2$, where m_1 is the theoretically required correction mass, r_1 is the theoretical correction radius, and m_2 and r_2 are the actually adopted counterweight mass and installation radius. This means that by changing the counterweight installation radius, the required actual counterweight mass can be adjusted.

Install the Tungsten Alloy Counterweight for the First Correction

If the additive method is used for balancing correction, the tungsten alloy counterweight can be installed at the specified position according to the test results. For example, if the rotor needs to add 100 g of mass but the installation space is very limited, a small-volume counterweight made of high-density tungsten alloy can be used. If the tungsten alloy density is 18.0 g/cm³, the theoretical volume of a 100 g counterweight is about 5.56 cm³. This is where the value of tungsten alloy is reflected: it can provide relatively large correction mass within a relatively small space. The counterweight can be designed in the form of a screw type, cylindrical pin type, arc-shaped block, balance block, ring, or other form matching the rotor structure.

Rotate and Test Again and Perform Iterative Correction

After the first counterweight installation, it cannot be directly assumed that balancing has been completed. The dynamic balancing equipment usually needs to be restarted for a second test. If the residual unbalance still exceeds the specified value, the counterweight is further adjusted according to the new measurement results. The actual process may require one or more corrections until the specified residual unbalance is reached. For two-plane balancing, the counterweight mass and angle of the two correction planes need to be calculated separately so that both static unbalance and couple unbalance are controlled at the same time.

The Counterweight Itself Also Needs Mass Accuracy Control

Although dynamic balancing testing mainly targets the entire rotor, the mass accuracy of the tungsten alloy counterweight itself is equally important. Suppose the design requires installing a 100.00 g counterweight. If it is actually machined to 99.5 g or 100.5 g, the impact may not be significant in low-precision applications, but for high-speed precision rotors, this



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mass error may directly change the final unbalance state. Therefore, before formal assembly, it is usually necessary to check the actual mass, dimensions, mounting hole positions, and center-of-mass position of the counterweight. For high-precision products, a corresponding relationship between counterweight mass and dynamic balancing test results should also be established.

Focus on Checking Runout and Coaxiality After Installation

Dynamic balancing cannot completely replace geometric accuracy inspection. Even if the mass distribution of the rotor has been adjusted, if there are obvious shaft bending, installation eccentricity, coaxiality errors, or runout problems, operational vibration may still occur. Therefore, for precision rotors, it is usually necessary to comprehensively inspect dimensions, coaxiality, circular runout, face runout, counterweight installation position, and final dynamic balancing state. In particular, when the tungsten alloy counterweight is installed using threads, pin holes, or groove-type structures, the positioning accuracy of the mounting structure itself may also affect the final balancing result.

High-Speed Rotors Also Need to Consider Counterweight Fixation Safety

When a tungsten alloy counterweight is installed on a high-speed rotating component, the counterweight fixation structure must be able to withstand the centrifugal load generated during operation. For example, when a 100 g counterweight is installed at a radius of 50 mm and rotates at 10000 rpm (Revolutions Per Minute), its theoretical centrifugal force has already reached about 5.48 kN (Kilonewton). Therefore, the counterweight fixation method cannot consider only static weight. Actual design should also consider maximum speed, material strength, mounting structure, fatigue load, safety factor, and possible overspeed conditions. CTIA GROUP can customize the mass, density, dimensions, and mounting structure of tungsten alloy counterweights according to different applications such as industrial rotors, motor rotors, fans, pumps, and high-speed main shafts, and process them in accordance with mass inspection and dynamic balancing requirements.

A Complete Testing Process

In actual engineering, the dynamic balancing process of a tungsten alloy rotor counterweight can be summarized as: initial rotor inspection → install on dynamic balancing equipment → rotate under specified conditions → measure vibration amplitude and phase → calculate unbalance amount → determine counterweight mass and angle → install tungsten alloy counterweight → test again → continue correction if necessary → finally confirm residual unbalance.

The focus of final acceptance is not how heavy the tungsten alloy counterweight itself is, but whether, after installing the tungsten alloy counterweight, the entire rotating assembly meets the specified residual unbalance and operating requirements.



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For industrial rotors, the most critical relationship can be summarized as mass, radius, and angular velocity jointly determining the unbalance effect: $F=m\omega^2r$. Therefore, the main advantage of high-density tungsten alloy is that it can achieve relatively large mass correction within limited installation space, but the final balancing accuracy still depends on counterweight mass, installation angle, installation radius, geometric accuracy, and the actual mass distribution of the entire rotor.



VII. What Applications Do Tungsten Alloy Counterweights Have in

Consumer Electronics, Sports, and Civilian Fields?

The applications of tungsten alloy counterweights in consumer electronics, sports, and civilian fields all follow the same core logic: utilizing their high density, small volume, and controllable mass distribution to achieve counterweighting, balancing, inertia adjustment, and center-of-gravity adjustment within limited space. Unlike simply pursuing high density, these products pay more attention to the volume, mass accuracy, installation method, feel, vibration characteristics, and batch consistency of the counterweight part.

Consumer Electronics Field

In consumer electronic products, tungsten alloy counterweights are mainly used in micro mechanisms that require vibration, inertia, center-of-gravity, or feel adjustment.



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Mobile phone vibration motors are a relatively typical application. For an eccentric rotating mass structure, the counterweight rotates at high speed with the rotor and generates inertial force. Its basic relationship is $F=m\omega^2r$, where F is centrifugal force, m is moving mass, ω is angular velocity, and r is the distance from the counterweight center of mass to the rotating shaft. Tungsten alloy has high density and can obtain relatively large moving mass within the limited size of the motor, thereby facilitating the miniaturization of the vibration module.

In addition to mobile phones, smart watches, smart bracelets, portable massage devices, electric toothbrushes, and other micro vibration products may also use high-density tungsten alloy counterweights. For these products, the counterweight part is often only a few grams or even smaller, but mass tolerance, eccentric distance, and assembly position may still affect the final vibration feel.

In camera equipment and gimbals, tungsten alloy can also be used to adjust local center of gravity and rotational inertia. For example, the internal space of cameras, lenses, and stabilizers is limited, and a small-volume high-density counterweight can be used to change the overall center-of-gravity position, enabling the actuator to obtain a more reasonable mass distribution under a specific posture.

Game controllers, controllers, and some portable devices may change the grip feel and mass distribution through local counterweights. Here, more attention is paid to ergonomics and inertia characteristics rather than simply increasing weight.

For consumer electronics, tungsten alloy usually needs to be machined into very small cylinders, discs, arc-shaped blocks, rings, or special-shaped parts, with control of mass, dimensions, concentricity, and surface quality. W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper) are common material systems, and the specific choice also needs to be combined with magnetic properties, density, processing performance, and cost.

Sports Equipment Field

Sports equipment is a very typical civilian market for tungsten alloy counterweight applications. Its main function is to adjust the center of gravity and inertia characteristics of equipment by changing mass distribution.

Golf clubs are one of the most representative products. Tungsten alloy is usually arranged at the bottom, rear, toe, or periphery of the club head, changing the club head center-of-gravity position, center-of-gravity depth, and moment of inertia (MOI, Moment of Inertia) through concentrated mass. Rotational inertia can be expressed as $I=\sum m_i r_i^2$, where m_i is a mass unit and r_i is its distance to the axis of rotation. Because the density of tungsten alloy is much higher than that of steel, a relatively large local mass can be arranged without



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significantly enlarging the club head size.

For club design, for the same 20 g counterweight, if the installation position is different, its effect on the club head center of gravity and moment of inertia is also different. Therefore, what tungsten alloy truly provides is freedom in mass layout, not simply increasing club head weight.

In tennis, badminton, baseball, softball, and other swinging sports equipment, high-density counterweights can also be used to adjust the mass balance and swing inertia of the equipment. For example, rackets can change the balance point and swing feel through counterweights on the handle, frame, or specific areas; baseball bats and other equipment can also adjust swing characteristics through mass distribution. However, the counterweight design of different products varies greatly, and not all products use tungsten alloy.

Fishing equipment is also an important application scenario for tungsten alloy counterweights. Tungsten alloy fishing sinkers, replacement parts for tungsten alloy lead sinkers, and internal counterweights for soft lures can use high-density characteristics to obtain relatively large sinking mass within a relatively small volume. Compared with traditional lead sinkers, tungsten alloy can reduce volume at the same weight, so it has advantages in situations requiring miniaturized fishing rigs, improved penetration ability, or changed soft lure mass distribution.

In racing, model sports, and racing-type civilian equipment, tungsten alloy counterweights can also be used to adjust the local mass distribution of vehicles or models. For example, model racing cars can adjust the front-to-rear counterweight ratio, left-to-right mass distribution, and local center-of-gravity position through small high-density counterweights. For high-speed rotating components, tungsten alloy can also be used for local mass correction.

Civilian Machinery and Personal Equipment Field

In ordinary civilian machinery, tungsten alloy counterweights are mainly used in mechanisms that require precise mass adjustment or have limited space.

Precision machinery and small rotating mechanisms can use tungsten alloy counterweights for mass balancing. For example, high-speed motors, micro fans, centrifugal mechanisms, and small rotors can be corrected by installing small high-density counterweights when local mass deviation exists.

Mechanical clocks and watches are also one of the typical applications. High-density tungsten alloy can be used for micro counterweights and inertial mass adjustment, achieving relatively large mass changes within limited space. For precision mechanisms, the



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mass, center-of-mass position, and dimensional tolerances of the counterweight need to be controlled simultaneously.

Sports equipment and fitness equipment can also use tungsten alloy for local mass adjustment. For example, certain small training equipment, handheld sports devices, and precision motion components need to add a certain mass within limited space, and high-density counterweights can reduce volume occupation.

In photographic equipment, tungsten alloy can serve as balance counterweights inside cameras, lenses, stabilizers, and gimbals. Photographic equipment often needs to maintain a reasonable center-of-gravity position after installing different lenses or accessories while maintaining overall portability. In this case, using small-volume counterweights can reduce the impact on the equipment's external shape and internal space.

Civilian Automobiles and Modification Equipment

In the automotive and automotive modification fields, tungsten alloy counterweights are mainly used in scenarios with special mass layout and limited space. For example, some high-performance vehicles, racing cars, and modified vehicles can use high-density counterweights in engine rotating components, transmission components, wheels, suspensions, or other positions requiring local mass adjustment. For rotating components, the counterweight needs to be determined in combination with dynamic balancing results for installation mass and angle.

Racing cars especially emphasize mass distribution, because the position of the counterweight not only affects total mass but also affects the vehicle center of gravity and front-to-rear and left-to-right mass distribution. Tungsten alloy can provide relatively large mass within a relatively small volume, so it is suitable for local areas with limited installation space.

However, for ordinary civilian automobiles, steel, cast iron, and other conventional materials can usually already meet most counterweight needs. Tungsten alloy has a relatively high cost, and its advantages become more obvious only when there are clear requirements for volume, installation position, or mass concentration.

Why Tungsten Alloy Counterweights Can Cover So Many Civilian Products

From consumer electronics to golf clubs, and then to fishing equipment and precision machinery, these products appear very different, but their requirements for counterweight materials have common points: they need to obtain a determined mass within limited space and hope to accurately control mass distribution.

The function of tungsten alloy counterweights can be summarized into four basic forms: first, increasing local mass, such as golf club head counterweights; second, adjusting the



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center of gravity, such as photographic gimbals and sports equipment; third, changing inertia characteristics, such as rackets, clubs, and rotating mechanisms; fourth, correcting mass unbalance, such as micro rotors, motors, and racing equipment. Among these, high density is the most prominent material advantage of tungsten alloy. Assuming a tungsten alloy density of 18.0 g/cm^3 , the theoretical volume of a 100 g counterweight is about 5.56 cm^3 ; steel of the same mass requires about 12.74 cm^3 . Therefore, when the internal space of a product is tight, tungsten alloy can compress an originally larger counterweight into a smaller structure.

Different Applications Have Different Requirements for Tungsten Alloy Counterweights

Consumer electronics usually pay more attention to miniaturization, mass consistency, magnetic properties, vibration characteristics, and batch manufacturing capability; sports equipment pays more attention to center of gravity, moment of inertia, feel, and mass distribution; civilian machinery pays more attention to dimensional accuracy, installation reliability, durability, and dynamic balance. Therefore, materials cannot simply be selected according to the principle that the higher the tungsten content or density, the better. The material characteristics of W-Ni-Fe and W-Ni-Cu differ, and the mechanical, magnetic, and processing performance of different material systems at the same density may also differ.

Actual material selection should be comprehensively determined according to target mass, space limitations, installation method, operating speed, center-of-gravity requirements, and cost.

From the perspective of the industrial chain, CTIA GROUP can provide customized tungsten alloys with different densities, dimensions, shapes, and installation methods according to product structures for mobile phone vibration counterweights, golf club counterweights, fishing sinkers, photographic gimbal counterweights, micro rotor counterweights, and other civilian high-density counterweight parts.

In summary, the common value of tungsten alloy counterweights in consumer electronics, sports, and civilian fields is to use high density to achieve mass concentration in a small volume, and then change the center of gravity, inertia, vibration, or balance state of a product through precise mass and position control. With the miniaturization of consumer electronics, the refinement of sports equipment, and the high-performance development of civilian machinery, the application range of such small high-density counterweights will continue to extend toward micro actuators, smart devices, photographic equipment, sports equipment, and precision civilian equipment.



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Q49 Why Do Mobile Phones Use Tungsten Alloy Vibration Counterweights?

Mobile phones use tungsten alloy vibration counterweights mainly because high-density tungsten alloy can provide a relatively large inertial mass within a very limited internal space, enabling the vibration motor to produce a sufficient vibration effect in a smaller volume. This is especially true in smartphones, where internal space is highly integrated, and the battery, camera, motherboard, speaker, and heat dissipation structure already occupy a large amount of space. Therefore, vibration components are usually expected to be as miniaturized as possible while ensuring vibration feel.

Tungsten Alloy Can Provide Relatively Large Mass Within a Small Volume

The counterweight in a mobile phone vibration motor is essentially a moving mass. The larger the mass, the more obvious the inertial force generated under the same motion conditions usually is, while there is not much space inside a mobile phone to accommodate a large-volume counterweight. For example, for tungsten alloy with a density of 18.0 g/cm^3 , the volume of 1 g of material is about 0.0556 cm^3 , and the volume of 10 g of material is about 0.556 cm^3 . Compared with steel with a density of about 7.85 g/cm^3 , the same 10 g mass requires about 1.27 cm^3 . Tungsten alloy can significantly reduce counterweight volume. Therefore, tungsten alloy is particularly suitable for products such as mobile phones, where both thickness and internal space are strictly limited.

Counterweight Mass Determines the Inertial Effect of the Vibration System



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Common vibration actuators in mobile phones include eccentric rotating mass structures and linear vibration structures. For an eccentric rotating mass, the centrifugal force generated when the counterweight rotates can be expressed as $F=m\omega^2r$, where F is centrifugal force, m is moving mass, ω is angular velocity, and r is the distance from the counterweight center of mass to the rotating shaft. This shows that the vibration effect is related to mass m , rotational speed ω , and eccentric radius r . When motor dimensions and rotational speed are already limited by design, increasing counterweight density can obtain a relatively large moving mass within limited space. However, vibration intensity is not determined solely by counterweight weight; it is also related to motor output capability, eccentricity, rotational speed, installation stiffness, mobile phone structure, and control algorithm.

High Density Is Conducive to Miniaturization of Mobile Phone Vibration Modules

The internal space of a mobile phone usually has a highly three-dimensional layout, and the vibration motor may need to be arranged near the motherboard, battery, camera module, or middle frame. If the counterweight size is too large, it will not only occupy internal space but may also interfere with other components. Tungsten alloy can concentrate relatively large mass into a very small volume, thus helping vibration modules achieve thin and compact designs. For example, for the same 5 g counterweight, 18.0 g/cm³ tungsten alloy requires only about 0.278 cm³, while 7.85 g/cm³ steel requires about 0.637 cm³. For mobile phone structures with millimeter-level thickness restrictions, this difference is of practical significance.

The Mass Distribution of the Counterweight Also Affects the Vibration Effect

A mobile phone vibration counterweight is not simply a high-density metal block. The center-of-mass position, eccentric distance, shape, and installation direction of the counterweight all affect the motion state of the vibration system. For a rotating eccentric mass, in addition to mass m , the eccentric radius r is also very important. If the position of its center of mass relative to the rotating shaft is changed without increasing the counterweight mass, the generated centrifugal force will also change. For some structures, the moment of inertia $I=\sum m_i r_i^2$ also needs to be considered, where m_i is a mass unit and r_i is the distance from that mass unit to the rotating shaft. Therefore, counterweight design usually needs to consider density, mass, shape, and center of mass at the same time, rather than only looking at material density.

Tungsten Alloy Can Adapt to Complex Small Structures

The size of mobile phone vibration counterweights is usually relatively small, and they may need to precisely fit with the motor rotor, rotating shaft, or other structures. Therefore, the product shape is not necessarily a simple cylinder. Tungsten alloy can achieve small near-net-shape forming through powder metallurgy (PM, Powder Metallurgy), and then obtain the required hole positions, groove positions, outer diameter, and fitting dimensions



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through precision machining. According to different structures, they can be manufactured into discs, sectors, arcs, rings, and other special-shaped counterweights. For large-batch mobile phone components, near-net-shape forming can reduce the amount of mechanical machining, improve material utilization, and at the same time help maintain mass consistency between batches.

Mobile Phone Counterweights Have Relatively High Requirements for Mass Consistency

Mobile phone vibration components are usually produced in batches, so counterweight parts must not only meet the design dimensions of a single piece but also maintain relatively high batch consistency. If the mass difference among counterweights in the same batch is relatively large, it may cause differences in vibration feel among different mobile phones. Therefore, the manufacturing process needs to control powder raw materials, pressing density, sintering shrinkage, machining dimensions, and final mass. For high-precision vibration components, attention also needs to be paid to the center-of-mass position, circular runout, concentricity of the counterweight, and assembly accuracy with the rotor.

The Tungsten Alloy Material System Needs to Be Selected According to the Mobile Phone Structure

Mobile phone vibration counterweights can often use high-density tungsten alloy systems such as W-Ni-Fe (Tungsten-Nickel-Iron) and W-Ni-Cu (Tungsten-Nickel-Copper). If there are magnetic sensors, magnetic compasses, or other electronic components sensitive to the magnetic environment near the product, the magnetic response of the material needs to be considered. Because W-Ni-Fe contains Fe (Iron), it usually has a more obvious magnetic response than W-Ni-Cu, while W-Ni-Cu usually has a lower magnetic response, but the specific performance still depends on material composition and manufacturing process. Therefore, material selection for mobile phone vibration counterweights cannot be based only on density; magnetic properties, mechanical properties, processing performance, and cost also need to be comprehensively considered.

Why Not Use Pure Tungsten?

The density of pure tungsten (W, Tungsten) is about 19.25 g/cm³, which is higher than many tungsten alloys. Theoretically, it can further reduce counterweight volume, but pure tungsten has characteristics such as high hardness, relatively obvious brittleness, and relatively high processing difficulty. By adding binder phases such as Ni (Nickel), Fe (Iron), or Cu (Copper), tungsten alloy can improve toughness and processing adaptability while maintaining relatively high density. Therefore, in mobile phone vibration counterweights that require batch manufacturing, complex structures, and precision dimensional control, high-density tungsten alloy is often easier to meet comprehensive performance requirements.



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CTIA GROUP Can Be Used for Customization of Small Tungsten Alloy Vibration Counterweights

CTIA GROUP can customize tungsten alloy counterweights for small vibration components such as mobile phones, smart wearable devices, electric toothbrushes, and massage equipment according to counterweight mass, density, shape, eccentric distance, mounting holes, and dimensional tolerances, and can meet the manufacturing requirements of batch components through powder metallurgy and subsequent precision machining.

It can thus be seen that the core reason mobile phones use tungsten alloy vibration counterweights can be summarized as follows: to obtain sufficient moving mass within an extremely small internal space, to generate the required vibration through a reasonable eccentric structure and high-speed motion, while maintaining miniaturization and batch consistency of the vibration module. The main value of tungsten alloy lies in the volume advantage brought by high density, while the final vibration feel also depends on multiple factors such as counterweight mass, eccentric radius, rotational speed, vibration mechanism, and overall device structure.



Q50 Why Do Golf Clubs Use Tungsten Alloy Counterweights?

Golf clubs use tungsten alloy counterweights mainly to utilize the characteristics of high density and small volume of tungsten alloy, so that a certain mass can be concentrated and arranged at the bottom, rear, periphery, or specific positions of the club head without



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significantly increasing the volume of the club head, thereby adjusting the club's center-of-gravity position, center-of-gravity depth, moment of inertia (MOI, Moment of Inertia), and mass distribution at impact. Compared with ordinary steel, the biggest advantage of tungsten alloy is not making the entire club heavier, but achieving more flexible mass configuration within the limited space of the club head.

High Density Can Increase Counterweight Within a Small Volume

The density of tungsten alloy is usually much higher than that of steel. Taking an 18.0 g/cm³ tungsten alloy as an example, the volume required for a 10 g counterweight is about 0.556 cm³; if steel with a density of about 7.85 g/cm³ is used, the same 10 g mass requires about 1.27 cm³. Therefore, designers can concentrate a certain mass in a very small area without significantly enlarging the club head size. For golf clubs, this is very important because the shape, dimensions, and aerodynamic design of the club head all have certain limitations.

It Can Adjust the Center-of-Gravity Position of the Club

The impact characteristics of a golf club are closely related to the center-of-gravity position of the club head. By arranging tungsten alloy at different positions on the club head, the overall mass distribution can be changed. For example, arranging a relatively high-density counterweight at the bottom of the club head can move the overall center of gravity to a lower position; arranging the counterweight at the rear of the club head can change the center-of-gravity depth; and if the mass is arranged around the periphery of the club head, the distribution of mass relative to the impact face can be changed. Its basic relationship can be expressed by the center-of-mass formula: $r_{CG} = \frac{\sum m_i r_i}{\sum m_i}$, where r_{CG} is the system center-of-gravity position, m_i is each mass unit, and r_i is the position of the corresponding mass. Therefore, for tungsten alloy counterweights of the same weight, different installation positions will ultimately produce different effects.

It Can Increase the Moment of Inertia of the Club Head

During the impact process, a golf club cannot always make the ball hit exactly on the sweet spot. If the impact position deviates from the center of the club head, the club head will tend to rotate about its own center of gravity. At this time, the moment of inertia (MOI, Moment of Inertia) of the club head about the relevant axis of rotation will affect its ability to resist such rotation. The basic relationship can be expressed as $I = \sum m_i r_i^2$, where I is the moment of inertia, m_i is mass, and r_i is the distance from the mass unit to the axis of rotation. Tungsten alloy has high density, so mass can be concentrated around the periphery of the club head or at positions far from the axis of rotation, changing the mass distribution without increasing too much volume. However, this does not simply mean that the more tungsten alloy the better, because the total mass of the club head, center-of-gravity position, moment of inertia, and swing characteristics need to be coordinated as a whole.



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It Is Conducive to Controlling the Center-of-Gravity Depth of the Club Head

For certain club designs, designers hope to adjust the front-to-back position of the center of gravity relative to the impact face. High-density tungsten alloy can serve as a local mass adjustment material, allowing more mass to be concentrated at the rear of the club head. For example, when the internal space of the club head is limited, if a low-density material is used, a larger counterweight volume is required to achieve the same mass; with tungsten alloy, mass can be shifted rearward within a smaller structural space. This is also one of the reasons why tungsten alloy is often designed as a rear counterweight block, bottom counterweight block, or peripheral counterweight.

Bottom Counterweights Can Help Achieve a Low Center-of-Gravity Design

For some clubs, designers arrange tungsten alloy at the bottom of the club head to change the overall center of gravity of the club head by lowering the position of the center of mass. For example, if a club head originally has a relatively uniform mass distribution, adding a certain mass at the bottom will move the overall center of gravity downward. Its effect can be understood from the perspective of mass moment: the farther the counterweight is from the original center of gravity, the more obvious its effect on the overall center-of-gravity position usually is. Therefore, tungsten alloy counterweights can help designers achieve a low center-of-gravity structure without greatly changing the shape of the club head.

Counterweights Can Also Be Used to Adjust Swing Weight

The swing weight (Swing Weight) of a golf club is related to the club head, shaft, grip, and the mass distribution of each part. Adding a certain mass to the club head will change the overall mass distribution and swing weight parameters of the club. By using tungsten alloy counterweights of different masses, the mass balance of the club can be adjusted within a certain range, enabling clubs of different specifications to meet design requirements. However, swing weight is not equal to the actual weight of the entire club; it reflects the distribution state of the club mass relative to a specific reference point. Therefore, adding the same mass of counterweight will have different effects on swing weight if the installation position is different.

Why Not Use Steel Instead of Tungsten Alloy?

Steel is not incapable of being used for golf club counterweights; rather, tungsten alloy can provide higher mass density. For example, the density of 18.0 g/cm³ tungsten alloy is about 2.29 times that of ordinary steel. If the design requires a 20 g local counterweight, tungsten alloy requires only about 1.11 cm³, while steel requires about 2.55 cm³. When the club head is already close to the design volume limit, this difference is relatively valuable. Designers can use the saved space to optimize other structures, such as adjusting counterweight position, increasing cavities, or redesigning the club head mass distribution.



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Tungsten Alloy Counterweights Can Be Made into Various Structures

Tungsten alloy counterweights in golf clubs are not necessarily simple block structures. According to the club head design, they can be machined into cylindrical, disc-shaped, strip-shaped, arc-shaped, screw-type, embedded, or special-shaped counterweights. Some products use replaceable counterweight structures, adjusting the club head mass and mass distribution through counterweights of different mass specifications. For such structures, the mass tolerance, thread dimensions, installation depth, and positioning accuracy of the counterweight part will directly affect the consistency of the final product.

Tungsten Alloy Materials Also Need to Consider Processing and Performance

Golf club counterweights can usually use high-density tungsten alloys such as W-Ni-Fe (Tungsten-Nickel-Iron) or W-Ni-Cu (Tungsten-Nickel-Copper). The specific material selection needs to be determined in combination with target density, mechanical properties, processing method, and cost. Tungsten alloy usually obtains a blank through powder metallurgy (PM, Powder Metallurgy), and then performs turning, milling, drilling, tapping, or grinding according to the structure. For small golf club counterweights, the consistency of dimensions and weight is especially important because changes in counterweight mass will directly affect the final mass and mass distribution of the club head. CTIA GROUP can customize tungsten alloy counterweights for golf club bottom counterweights, rear counterweights, peripheral counterweights, and replaceable counterweight parts according to target mass, density, dimensions, mounting structure, and tolerances.

The Core Is Not That the Heavier the Tungsten Alloy the Better

The real purpose of golf clubs using tungsten alloy counterweights is to use high-density material for precise mass layout, rather than simply pursuing a higher club head weight. For example, when adding the same 20 g of mass, installing it at the bottom, rear, toe, or near the impact face of the club head will produce different changes in center of gravity and moment of inertia. Therefore, actual design needs to comprehensively consider the total mass of the club head, center-of-gravity height, center-of-gravity depth, moment of inertia, counterweight position, and the overall swing weight of the club.

In summary, the main value of tungsten alloy in golf clubs can be summarized as follows: high density makes the counterweight volume smaller, and designers can concentrate more mass at designated positions, thereby flexibly adjusting the club head center of gravity, center-of-gravity depth, moment of inertia, and mass distribution, while avoiding excessive occupation of the club head internal space by the counterweight part. This is also an important reason why tungsten alloy has become a local counterweight material for high-end golf clubs.



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