# Complete Guide to Molybdenum Wire EDM

中钨智造科技有限公司
CTIA GROUP LTD

**CTIA GROUP LTD**

Global Leader in Intelligent Manufacturing for Tungsten, Molybdenum, and Rare Earth Industries

# INTRODUCTION TO CTIA GROUP

CTIA GROUP LTD, a wholly-owned subsidiary with independent legal personality established by CHINATUNGSTEN ONLINE, is dedicated to promoting the intelligent, integrated, and flexible design and manufacturing of tungsten and molybdenum materials in the Industrial Internet era. CHINATUNGSTEN ONLINE, founded in 1997 with www.chinatungsten.com as its starting point—China's first top-tier tungsten products website—is the country's pioneering e-commerce company focusing on the tungsten, molybdenum, and rare earth industries. Leveraging nearly three decades of deep experience in the tungsten and molybdenum fields, CTIA GROUP inherits its parent company's exceptional design and manufacturing capabilities, superior services, and global business reputation, becoming a comprehensive application solution provider in the fields of tungsten chemicals, tungsten metals, cemented carbides, high-density alloys, molybdenum, and molybdenum alloys.

Over the past 30 years, CHINATUNGSTEN ONLINE has established more than 200 multilingual tungsten and molybdenum professional websites covering more than 20 languages, with over one million pages of news, prices, and market analysis related to tungsten, molybdenum, and rare earths. Since 2013, its WeChat official account "CHINATUNGSTEN ONLINE" has published over 40,000 pieces of information, serving nearly 100,000 followers and providing free information daily to hundreds of thousands of industry professionals worldwide. With cumulative visits to its website cluster and official account reaching billions of times, it has become a recognized global and authoritative information hub for the tungsten, molybdenum, and rare earth industries, providing 24/7 multilingual news, product performance, market prices, and market trend services.

Building on the technology and experience of CHINATUNGSTEN ONLINE, CTIA GROUP focuses on meeting the personalized needs of customers. Utilizing AI technology, it collaboratively designs and produces tungsten and molybdenum products with specific chemical compositions and physical properties (such as particle size, density, hardness, strength, dimensions, and tolerances) with customers. It offers full-process integrated services ranging from mold opening, trial production, to finishing, packaging, and logistics. Over the past 30 years, CHINATUNGSTEN ONLINE has provided R&D, design, and production services for over 500,000 types of tungsten and molybdenum products to more than 130,000 customers worldwide, laying the foundation for customized, flexible, and intelligent manufacturing. Relying on this foundation, CTIA GROUP further deepens the intelligent manufacturing and integrated innovation of tungsten and molybdenum materials in the Industrial Internet era.

Dr. Hanns and his team at CTIA GROUP, based on their more than 30 years of industry experience, have also written and publicly released knowledge, technology, tungsten price and market trend analysis related to tungsten, molybdenum, and rare earths, freely sharing it with the tungsten industry. Dr. Han, with over 30 years of experience since the 1990s in the e-commerce and international trade of tungsten and molybdenum products, as well as the design and manufacturing of cemented carbides and high-density alloys, is a renowned expert in tungsten and molybdenum products both domestically and internationally. Adhering to the principle of providing professional and high-quality information to the industry, CTIA GROUP's team continuously writes technical research papers, articles, and industry reports based on production practice and market customer needs, winning widespread praise in the industry. These achievements provide solid support for CTIA GROUP's technological innovation, product promotion, and industry exchanges, propelling it to become a leader in global tungsten and molybdenum product manufacturing and information services.

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**Molybdenum Wire EDM Introduction**

### 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

### 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

### 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

# Directory




TEL: 0086 592 512 9696

sales@chinatungsten.com

TEL: 0086 592 512 9696

sales@chinatungsten.com

# Chapter 1 Introduction

## 1.1 Definition and overview of molybdenum wire EDM

Molybdenum wire EDM is a fine wire made primarily from high-purity molybdenum (with Mo content typically ≥99.3%), and is widely used in Wire Electrical Discharge Machining (WEDM). Due to its high melting point (approximately 2623°C), excellent tensile strength (ranging from 700 to 1200 MPa, depending on the manufacturing process), good electrical conductivity, and high-temperature resistance, molybdenum wire has become a commonly used electrode material in wire-cut EDM. Its diameter generally ranges between 0.08 mm and 0.3 mm, with a tolerance controlled within ±0.001 mm to meet high-precision machining requirements. Surface treatments—such as graphite emulsion coating or alkaline-washed white molybdenum wire—further enhance its discharge performance and durability.

Molybdenum wire is primarily used in fast-wire, medium-speed wire, and some high-precision slow-wire EDM machines. Compared to copper wire, tungsten wire, or brass wire, molybdenum wire offers advantages such as cost-effectiveness, high wear resistance, and suitability for multiple cuts, making it especially dominant in Asian markets like China and Japan. According to the International Molybdenum Association (IMOA), molybdenum is considered a strategic metal, and its demand in industrial applications continues to grow. As a major branch of molybdenum products, the global annual consumption of molybdenum wire EDM is estimated to reach several thousand tons, particularly in the fields of mold manufacturing and precision parts processing.

The production of molybdenum wire involves powder metallurgy, rotary swaging, wire drawing, and surface treatment processes. These steps must ensure uniform wire diameter, smooth surface finish, and optimal mechanical properties to meet the demands of high-speed and high-precision cutting. To further enhance the performance of molybdenum wire, manufacturers are continually innovating, such as developing wires doped with rare earth elements (e.g., lanthanum, yttrium) to improve tensile strength and corrosion resistance.

## 1.2 Wire EDM Technical Background

Wire EDM (WEDM) is an unconventional processing technology that melts or vaporizes materials at high temperatures (about 8000-12000°C) by using a high-voltage pulse discharge between the electrode wire and the workpiece to achieve precise cutting. This technology originated in the 40s of the 20th century, when the former Soviet scientists Lazarenko and his wife first proposed the principle of electrical discharge machining (EDM). In the 1960s, Swiss and Japanese machine tool manufacturers, such as AgieCharmilles and Fanuc, developed CNC wire EDM machines, which led to the industrial adoption of WEDM.

There are three types of wire EDM technology: fast, medium and slow:

Fast wire: mainly molybdenum wire, high line speed (8-12 m/s), low cost, widely used in mold and part processing in China and other markets, cutting speed up to 100-150 mm²/min, but slightly lower accuracy (surface roughness Ra 2.5-3.2 μm).

Medium wire: Combining the advantages of fast wire and slow wire, molybdenum wire or galvanized wire is used, with higher precision and surface quality (Ra 1.0-1.6 μm) and a cutting speed of about 50-100 mm²/min, which has become rapidly popular in the Chinese market in recent years.

Slow wire: Brass or coated wire (e.g. galvanized copper wire) is usually used, with low wire speed (0.2-0.3 m/s) and extremely high accuracy (Ra 0.2-0.8 μm), which is commonly found in high-end manufacturing in Japan and Europe.

According to the International Association for Manufacturing Technology (AMT), the global wire EDM machine tool market will be worth about $3 billion in 2023 and is expected to grow at a compound annual growth rate (CAGR) of 4.5% by 2030, with China accounting for more than 40% of the global market share. Due to its high-cost performance and applicability, molybdenum wire has become the mainstream choice of fast wire and medium wire equipment, especially in the Asian mold manufacturing and hardware processing industries. The European and North American markets are more inclined to slow wire machines, using copper-based or composite wires, but molybdenum wire is still used in the processing of certain high-strength materials.

Advances in wire EDM technology have benefited from improvements in numerical control technology, pulse power supply and automation control. Modern wire EDM machines are equipped with high-frequency pulse power supplies (up to 1 MHz) and an intelligent tension control system to ensure stable operation of molybdenum wire under high loads and reduce the risk of wire breakage.

**1.3 The importance of molybdenum wire in EDM**

The importance of molybdenum wire in wire EDM stems from its unique physical and chemical properties, making it ideal for machining high-hardness, complex-shaped materials such as die steel, carbide, titanium alloys. Here are the key advantages of molybdenum wire in WEDM:

High melting point and thermal stability: The high melting point (2623°C) of molybdenum wire allows it to withstand the high temperature generated by discharge, avoid melting or deformation, and ensure stability during the cutting process. Compared with copper wire (melting point 1083°C), molybdenum wire is more durable under high-energy discharge.

Excellent tensile strength: The tensile strength of molybdenum wire (700-1200 MPa) is much higher than that of brass wire (about 400-600 MPa), making it suitable for high-tension operation and reducing the probability of wire breakage, especially when machining thick workpieces (>100 mm).

Cost-effective: The price of molybdenum wire is lower than that of tungsten wire (about 1/3-1/5), and it can be reused (molybdenum wire can be recycled hundreds of times in fast wire equipment), which significantly reduces processing costs. According to Chinese market data, the cost per meter of molybdenum wire is about 0.1-0.3 yuan, while tungsten wire is as high as 1-2 yuan.

Surface treatment adaptability: Molybdenum wire can optimize the surface performance through graphite emulsion coating or alkali washing treatment, enhance discharge efficiency and wear resistance, and adapt to a variety of working conditions of fast wire and medium wire.

Machining complex geometries: The high strength and fine wire diameters (down to 0.08 mm) of molybdenum wire enable the machining of microstructures and complex contours to meet the high precision needs of the aerospace, medical device and electronics industries.

Globally, the application of molybdenum wire in fast wire and medium wire equipment dominates, especially in China's mold manufacturing industry, where about 80% of wire EDM machine tools use molybdenum wire. According to the IMOA report, molybdenum wire performs well in the machining of die steels (e.g. Cr12MoV), cemented carbide and superalloys, with a cutting accuracy of ±0.005 mm and a surface roughness of Ra 1.0-2.5 μm. In contrast, brass wire, commonly used for slow wire, is more suitable for ultra-high-precision machining (Ra < 0.5 μm), but the cost and frequency of consumables replacement are higher.

Limitations of molybdenum wire include that the conductivity is slightly lower than that of copper-based wire (about 5.5 μΩ·cm for molybdenum and 1.7 μΩ·cm for brass), it may affect discharge efficiency, and it is not as fine as coated wire in extremely high-precision scenarios. However, modern molybdenum wire performance has been significantly improved by doping rare earth elements such as lanthanum or yttrium or optimizing discharge parameters, partially compensating for these shortcomings.

### 1.4 Significance of research and application

The research and application of molybdenum wire EDM is of great significance to the manufacturing industry, which is reflected in technological progress, industrial upgrading and economic benefits.

Driving high-precision manufacturing: Molybdenum wire EDM supports the processing of complex geometries and high-hardness materials, and is widely used in mold making (stamping molds, injection molds), aerospace (turbine blades, titanium alloy parts), medical devices (orthopedic implants), and electronics (semiconductor molds). Its high precision and stability meet the needs of modern manufacturing for micron-level tolerances. For example, the Japanese Fanuc wire cutting machine uses molybdenum wire processing with an accuracy of ±2 μm, which significantly improves the high-end manufacturing capacity.

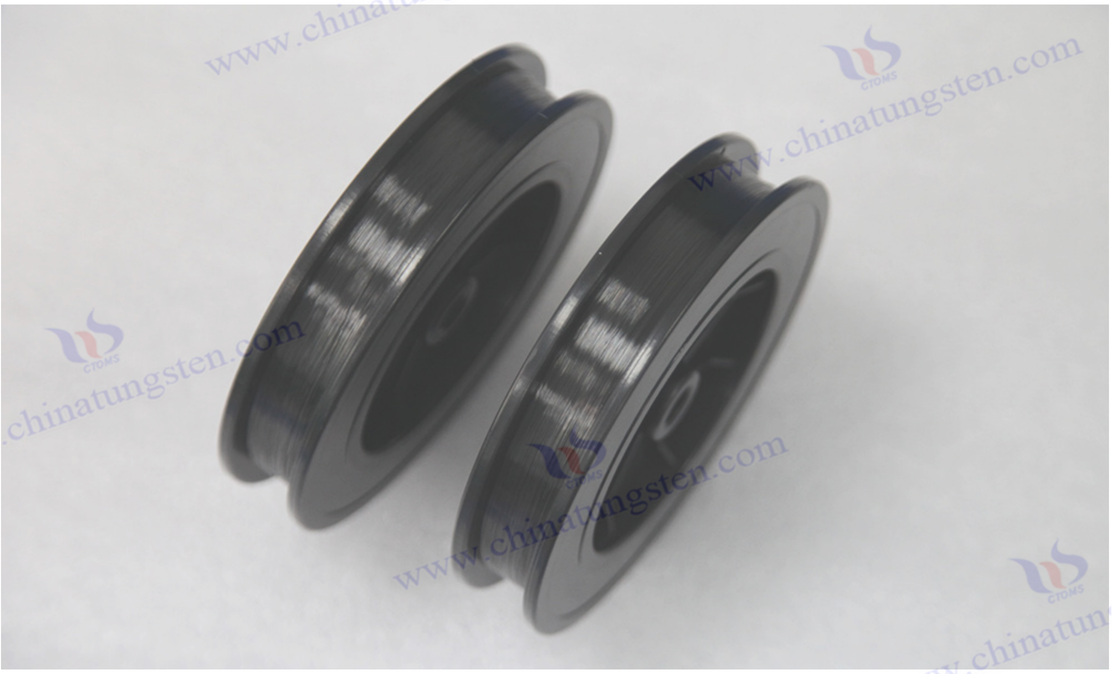
Reduced production costs: The high durability and recyclability of molybdenum wire reduces the cost of consumables for wire EDM processing, especially in fast wire machines, where a single molybdenum wire can cut thousands of square meters of workpiece area. The global mold manufacturing market is highly dependent on the cost advantage of molybdenum wire, especially in emerging markets such as China and India.

Promoting technological innovation: The research and development of molybdenum wire drives advances in materials science and manufacturing processes. For example, molybdenum wire doped with rare earth elements (such as La-Mo alloy wire) improves tensile strength and resistance to high-temperature oxidation, extending service life. In addition, intelligent tension control and adaptive discharge technology further optimize the processing efficiency of molybdenum wire.

Supporting green manufacturing: The high recycling rate of waste in molybdenum wire production (up to more than 90%) is in line with the global trend of green manufacturing. Compared with single-use copper-based wire, the recycling of molybdenum wire reduces the waste of resources.

Global Industry Impact: The research and application of molybdenum wire EDM has promoted the regionalization of the global manufacturing industry. As the world's largest molybdenum resource country (accounting for about 43% of the world's reserves), China's molybdenum wire industry has been exported to Southeast Asia, Africa and other places under the "Belt and Road" initiative, which has promoted regional industrial upgrading. Molybdenum wire research in Europe and North America focuses on high-performance doping and surface modification to provide technical support for high-end manufacturing.

In the future, the research directions of molybdenum wire EDM include a thinner wire diameter (<0.05 mm) to support micromachining, composite coating technology to improve discharge efficiency, and intelligent processing systems combined with artificial intelligence. The demand for high-precision, low-cost manufacturing in the global market will continue to drive the development of molybdenum wire technology, especially in the fields of new energy vehicles, 5G equipment and medical devices.



CTIA GROUP LTD molybdenum wire EDM

# Chapter 2 Characteristics of Molybdenum Wire EDM

## 2.1 Chemical properties of molybdenum wire EDM

### 2.1.1 Basic chemical properties of molybdenum element

Molybdenum (element symbol Mo, atomic number 42) is a silvery-white transition metal that belongs to the sixth period element and has stable chemical properties. The electronic configuration of molybdenum is [Kr] $4d^5\ 5s^1$, which exhibits high chemical inertness and does not react significantly with oxygen, acid or alkali at room temperature. Molybdenum oxidation states range from -2 to +6, most commonly +4 and +6, and molybdenum oxide ($MoO_3$) can be formed at high temperatures, but the surface of the molybdenum wire is generally stable in a typical wire-cut environment (water-based or oil-based working fluid).

Molybdenum's chemical stability makes it suitable for high-temperature discharge environments (up to 8000-12000°C) for wire-cut wire EDM (WEDM). According to the International Molybdenum Association (IMOA), molybdenum has little to no corrosion in weakly acidic or neutral working fluids (e.g., deionized water, pH 6-8) and is superior to copper-based wires (which are susceptible to corrosion in acidic environments). Molybdenum is also resistant to additives (e.g. emulsifiers, corrosion inhibitors) in common EDM fluids, ensuring long-term stability. Global manufacturers doped with trace amounts of rare earth elements (e.g., lanthanum, yttrium) to further enhance molybdenum's oxidation resistance and reduce chemical losses at high temperature discharges.

### 2.1.2 Purity requirements (Mo content≥ 99.3%)

The performance of molybdenum wire EDM is highly dependent on its purity, and industry standards typically require a molybdenum content of ≥99.3% to ensure excellent electrical conductivity, mechanical strength, and corrosion resistance. High purity molybdenum wire (Mo ≥99.95%) is more widely used in high-end medium wire walking and slow wire walking equipment, which can reduce the discharge instability caused by impurities. Common impurities include iron (Fe), nickel (Ni), carbon (C) and oxygen (O) and should be controlled in the following ranges (according to GB/T 4182-2017 and ASTM B387):

Fe：≤0.005%
Ni: ≤0.003%
C: ≤0.01%
O: ≤0.003%

Excessive impurities may lead to surface defects in the molybdenum wire, reduced discharge efficiency, or increased risk of wire breakage. For example, excess oxygen can form a brittle oxide layer that reduces tensile strength; Carbon impurities may cause local hardening and affect wire diameter uniformity. Some global companies use vacuum melting and multi-stage purification technology (such as hydrogen reduction) to produce high-purity molybdenum wire, with a Mo content of up to 99.97%, which significantly improves processing accuracy and stability. In the

Chinese market, some economical molybdenum wires have a Mo content of between 99.3-99.5%, which is suitable for fast wire equipment to meet the cost needs of mold manufacturing.

### 2.1.3 Corrosion resistance

Molybdenum wire EDM is exposed to water-based or oil-based working fluids in EDM, and its corrosion resistance directly affects the service life and processing quality. Molybdenum has excellent corrosion resistance to water, weak acids (e.g., sulfuric acid, hydrochloric acid dilute solution) and alkaline solutions at room temperature. According to the American Society of Corrosion Engineers (NACE) test, molybdenum has a corrosion rate of less than 0.01 mm/year in deionized water at pH 4-10, which is much better than brass wire (about 0.05-0.1 mm/year). Under high-temperature discharge conditions, a thin layer of oxide ($MoO_2$ or $MoO_3$) may form on the surface of the molybdenum wire, but the oxidation can be effectively anti-oxidized by graphite emulsion coating or alkali washing.

In practical applications, the corrosion resistance of molybdenum wire is affected by the composition of the working fluid, the discharge frequency and the processing environment. For example, the high-purity molybdenum wire used in the Japanese Fanuc wire cutting machine can run continuously for hundreds of hours without obvious corrosion in a working fluid containing corrosion inhibitors. European studies have shown that molybdenum wire doped with 0.5-1% lanthanum (La) has about 15% corrosion resistance in high temperature and high humidity environment, because rare earth elements reduce oxidation reactivity. The corrosion resistance is also closely related to the surface treatment, with black graphite emulsion-coated molybdenum wire being more stable in wet and electrolytic environments, while white molybdenum wire (alkali washed) is more suitable for high-precision processing but needs to avoid long-term exposure to corrosive environments.

## 2.2 Physical properties of molybdenum wire EDM

### 2.2.1 High melting point (about 2623°C)

The high melting point of molybdenum wire (2623°C±10°C) is its core advantage in WEDM, allowing it to withstand the high temperatures generated by discharge without melting or deforming. Compared to brass wires (melting point approx. 900-1000°C) or copper wires (1083°C), molybdenum wires maintain structural integrity under high-energy pulse discharges (current densities up to $10^6$ A/cm²). According to the Japanese Electromachining Society (JSPE), the surface loss rate of molybdenum wire in the transient environment of 8000-10000°C is only 0.001-0.002 mm³/h, which is much lower than that of brass wire 0.01-0.02 mm³/h.

The high melting point also supports the stability of molybdenum wire when machining high hardness materials such as carbide and titanium alloys. For example, when machining WC-Co cemented carbide (hardness HRC 60-70), molybdenum wire maintains a stable discharge gap (approx. 0.01-0.03 mm) to ensure cutting accuracy. Global manufacturers are optimizing the microstructure of molybdenum wire, such as fine grains, to further improve its thermal shock resistance and extend its service life.

### 2.2.2 Density and hardness

The density of molybdenum wire is 10.22 g/cm³, which is slightly higher than copper (8.96 g/cm³) but lower than tungsten (19.25 g/cm³), giving it a balance between weight and strength. Molybdenum has a hardness of about 5.5 on the Mohs scale and a Vickers hardness (HV) between 180-220 and is suitable for withstanding high tension (10-20 N) and mechanical wear in wire cutting. The combination of density and hardness allows the molybdenum wire to be cycled at high speeds (8-12 m/s) in fast wire walking equipment without being easy to break.

The high density ensures that the molybdenum wire has a low vibration amplitude under tension control, reducing the ripple error during processing. According to the Chinese National Standard (GB/T 3462-2017), the hardness of molybdenum wire should be uniform, and the grain size should be controlled at 5-10 μm to avoid local stress concentration.

### 2.2.3 Electrical and thermal conductivity

The conductivity of molybdenum wire is $1.8 \times 10^7$ S/m (resistivity is about 5.5 μΩ·cm), which is lower than that of copper ($5.9 \times 10^7$ S/m) but higher than that of tungsten ($1.1 \times 10^7$ S/m), providing moderate discharge efficiency in WEDM. Its thermal conductivity of 138 W/(m·K) is better than tungsten (173 W/(m·K)) but lower than copper (401 W/(m·K)), helping to dissipate heat quickly and reduce heat accumulation at the point of discharge.

Electrical conductivity has a direct impact on the frequency of discharge and the efficiency of energy transfer. According to the research of the Swiss GF processing program, the discharge stability of molybdenum wire is better than that of copper wire under the condition of pulse frequency of 50-200 kHz, especially when processing thick workpieces (>100 mm), the thermal conductivity of molybdenum wire can effectively reduce the risk of local overheating. Machine tool manufacturers around the world have further improved the discharge efficiency of molybdenum wire by optimizing the pulsed power supply (peak current 50-200 A) with cutting speeds of up to 150-200 mm²/min.

## 2.3 Mechanical characteristics of molybdenum wire EDM

### 2.3.1 Tensile strength

The Ultimate Tensile Strength (UTS) of molybdenum wire is typically between 700-1200 MPa, depending on the purity, doping process, and heat treatment conditions. The high tensile strength allows the molybdenum wire to withstand the high tension (10-20 N) in wire cutting equipment and avoid wire breakage. Compared to brass wire (UTS 400-600 MPa), molybdenum wire is more stable when machining high hardness materials or thick workpieces. According to ASTM B387, the tensile strength of molybdenum wire EDM needs to meet the following requirements:

Pure molybdenum wire: 700-900 MPa
Doped molybdenum wire (such as Mo-La): 900-1200 MPa

According to the R&D data of Chinese companies, the tensile strength of molybdenum wire doped with 0.5-1% lanthanum can reach 1100 MPa, and the wire breakage rate is reduced by about 20%. The tensile strength is also related to the wire diameter, and the strength of molybdenum wire with fine wire diameter (0.08-0.12 mm) is higher, but more stringent tension control is required. European studies have shown that optimizing the annealing process can keep the molybdenum wire low elongation at high tension and prolong the service life.

#### 2.3.2 Elongation (low elongation characteristics)

The elongation at break of molybdenum wire EDM is usually controlled at 1-3%, which is much lower than that of brass wire (10-20%). The low elongation ensures that the molybdenum wire remains rigid under high tension, reducing deformation and vibration during processing, thereby improving cutting accuracy. For example, when machining complex contours, such as mold tooth profiles, the low elongation keeps the discharge gap stable with an accuracy of ±0.005 mm.

Low elongation also presents challenges: molybdenum wires are sensitive to tension fluctuations, and too high tension can lead to wire breakage. The global wire EDM machine adopts an intelligent tension control system, which adjusts the tension in real time (error ± 0.1 N) through servo motors, making up for the limitations of low elongation of molybdenum wire.

#### 2.3.3 Curvature and wire diameter uniformity

Curvature refers to the degree to which a molybdenum wire retains its natural bend after being stretched, usually expressed in terms of curl radius per meter (ideal> 10 m). The low curl rate ensures smooth operation of the molybdenum wire between the guide wheel and the conductive block, reducing slippage or offset. The uniformity of wire diameter requires the diameter deviation to be controlled at ±0.001 mm to ensure the consistency of the discharge gap. Non-uniform wire diameter can lead to unstable discharge and affect surface roughness.

Global manufacturers control wire diameter uniformity with high-precision drawing dies, such as natural diamond dies. Curl control relies on annealing and wire drawing processes, and some intelligent manufacturers use vacuum annealing technology to reduce the curvature of molybdenum wire to less than 5 m, which is suitable for high-precision medium wire walking equipment.

### 2.4 Geometric properties of molybdenum wire EDM

#### 2.4.1 Wire diameter tolerances

The wire diameter of molybdenum wire EDM is usually 0.08-0.3 mm, and the tolerance is controlled at ±0.001 mm to ensure the accuracy of the discharge gap (generally 1.5-2 times of the wire diameter). According to GB/T 4182-2017, common wire diameters include 0.18 mm (fast wire standard), 0.12-0.15 mm (medium wire) and 0.08 mm (micro machining). For example, the discharge gap of 0.18 mm molybdenum wire is about 0.27-0.36 mm, and exceeding the tolerance may lead to gap fluctuations and reduce surface quality.

The world's high-precision wire drawing equipment uses laser calipers to monitor in real time to ensure that the tolerance is controlled at ±0.0005 mm. Tests conducted by Mitsubishi Electric have shown that molybdenum wire with a wire diameter tolerance of ±0.001 mm can achieve a cutting accuracy of ±3 μm, which is suitable for aerospace parts machining. The choice of wire diameter is also related to the thickness of the workpiece: 0.2-0.3 mm for thick workpieces (>100 mm) and

0.08-0.12 mm for thin workpieces or micromachining.

### 2.4.2 Surface smoothness and roundness

Surface Roughness is expressed as Ra value, and the Ra of molybdenum wire EDM is usually controlled at 0.1-0.3 μm to reduce arc concentration and surface wear during discharge. Roundness requires the cross-section of the molybdenum wire to be close to perfect roundness, with a deviation of < 0.001 mm to avoid uneven discharge. According to the ISO 1101 standard, excessive roundness errors can lead to streaks or burns on the machined surface.

Surface smoothness is achieved by multi-pass wire drawing and electropolishing. Roundness control relies on high-precision drawing dies and real-time inspection, and the world's leading manufacturers use X-ray microscopy to inspect cross-sections to ensure roundness errors are minimized.

## 2.5 Thermophysical properties of molybdenum wire EDM

### 2.5.1 High temperature stability

High temperature stability refers to the performance retention ability of molybdenum wire under high discharge temperature (8000-12000°C) and cyclic thermal stress. Molybdenum wire's high melting point and low coefficient of thermal expansion (approx. $5.0\times10^{-6}$ $K^{-1}$) make it less susceptible to softening or breaking at transient high temperatures. According to the American Society for Materials (ASM), the thermal fatigue performance of molybdenum wire below 1000°C is better than that of copper base wire, and the strength loss is <5% after 1 million cycles of discharge.

High-temperature stability is also related to grain structure. Molybdenum filaments with fine grains (5-10 μm) have higher resistance to thermal shock and are suitable for high-frequency pulse discharges (50-200 kHz). Chinese studies have shown that molybdenum wire doped with 0.5% yttrium reduces the oxidation rate by 30% at 1500°C, prolonging the service life in high-temperature environments. Machine tool manufacturers around the world have further enhanced the high-temperature stability of molybdenum wire by optimizing operating fluid cooling systems.

### 2.5.2 High temperature resistance

High temperature resistance refers to the oxidation and softening resistance of molybdenum wire at continuous high temperatures. Molybdenum wire is easy to form volatile $MoO_3$ at > 600°C in air, but in the water-based working solution of WEDM, the oxidation reaction is inhibited and the high temperature resistance is outstanding. According to JSPE's research, molybdenum wire can be continuously operated for up to 500 hours at 1000°C in deionized water with an oxygen content of < 10 ppm, and the thickness of the oxide layer on the surface is < 0.1 μm.

Molybdenum wire doped with rare earth elements (such as Mo-La, Mo-Y) has better high temperature resistance, and the initial oxidation temperature is increased to more than 800°C. The high temperature resistance makes molybdenum wire suitable for processing superalloys (such as Inconel 718, melting point about 1300°C), which is widely used in the aerospace field.

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**Molybdenum Wire EDM Introduction**

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### 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

### 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

### 2.6 Other characteristics of molybdenum wire EDM

#### 2.6.1 Surface treatment (black graphite emulsion coating and white molybdenum wire)

The surface treatment of molybdenum wire EDM is divided into two types: black graphite emulsion coating and white molybdenum wire:

Black Graphite Emulsion Coating: The surface of the molybdenum wire is coated with graphite emulsion (carbon-based lubricant) with a thickness of about 1-2 μm, which enhances wear resistance and conductivity, and reduces frictional heat during discharge. The graphite emulsion coating also protects the molybdenum wire from the working fluid and prolongs the life (about 20-30% more). In the Chinese market, 90% of fast walking molybdenum wire is processed in this way, which is low-cost and suitable for high-strength processing.

White molybdenum wire: Oxides and impurities on the surface are removed by alkali washing or electrolytic polishing, and the Ra value can reach 0.1 μm. White molybdenum wire is suitable for medium wire running equipment, reducing discharge residue and improving surface quality (Ra 0.8-1.2 μm). Most of the high-end molybdenum wires in Europe and Japan are white molybdenum wires, which are suitable for precision mold processing.

The choice of surface treatment depends on the processing needs. Black molybdenum wire is more suitable for high-speed cutting of fast wire (speed 150 mm²/min), while white molybdenum wire performs well in high-precision machining (accuracy ± 2 μm). Global manufacturers are optimizing coating formulations, such as adding carbon nanoparticles, to further improve discharge efficiency and durability.

#### 2.6.2 Abrasion resistance and durability

The wear resistance of molybdenum wire refers to its ability to resist the wear of guide wheels, conductive blocks and discharge. Molybdenum's high hardness (HV 180-220) and graphite emulsion coating make it more resistant to wear than brass wire (about 1/2 of brass).

Durability is also related to the rate of filament. The wear resistance and fatigue resistance of doped molybdenum wire (such as Mo-La) are improved, and the wire breakage rate is reduced to 0.1-0.5 times/hour (pure molybdenum wire is about 0.5-1 time/hour). Global studies have shown that optimizing tension control and coolant flow rates can further extend the life of molybdenum wires.

### 2.7 MSDS of Molybdenum Wire EDM from CTIA GROUP LTD

The following is a summary of the Material Safety Data Sheet (MSDS) based on CTIA GROUP LTD, which complies with international chemical safety standards (such as OSHA and GHS). MSDS provides chemical, physical and safety information on molybdenum wire to ensure safety during production, transportation and use.

Product dentification
Product name: Molybdenum Wire EDM
CAS No.: 7439-98-7 (Molybdenum)

Chemical name: molybdenum (Mo), purity≥99.3%, may contain trace amounts of lanthanum (La) or yttrium (Y)
Uses: Wire wire for wire EDM processing

Hazard identification
Physical hazards: solid molybdenum wire has no risk of explosion or flammability; Fine molybdenum dust can cause dust explosions (minimum ignition energy > 100 mJ).
Health hazards: Long-term inhalation of molybdenum dust may irritate the respiratory tract, and it is recommended to wear a protective mask (NIOSH N95). There is no obvious danger from skin contact.
Environmental hazards: Molybdenum is a low-toxicity metal, and waste materials need to be treated as hazardous waste to avoid polluting water bodies.

Composition and composition information
Molybdenum (Mo): ≥99.3%
Impurities: Fe≤0.005%, Ni≤0.003%, C≤0.01%, O≤0.003%
Doped elements: La or Y≤1% (if applicable)
Surface coating: graphite emulsion (carbon-based, non-hazardous substance)

First aid measures
Inhalation: Move the person to a ventilated place and seek immediate medical attention if breathing is difficult.
Skin contact: Wash with soapy water without special treatment.
Eye contact: Rinse with plenty of water for 15 minutes, and if irritation persists, consult a doctor.
Accidental ingestion: Unexpected situation, seek medical attention immediately and provide MSDS.

Fire protection measures
Fire extinguishing medium: dry powder or carbon dioxide fire extinguisher, water is prohibited.
Special hazards: $MoO_3$ vapor may be released at high temperatures, and positive pressure respirators need to be worn.

Emergency treatment of leaks
Method: Collect scattered molybdenum filaments or dust, seal them in hazardous waste containers to avoid dust.
Protective gear: Wear protective gloves, dust masks, and goggles.

Handling & Storage
Precautions for operation: to avoid molybdenum dust, the operation area should be well ventilated. The processing equipment should be equipped with a dust collection system.
Storage conditions: Store in a dry and ventilated environment (temperature < 40°C, humidity <60%), away from strong acids, strong alkalis and oxidants.

Exposure control and personal protection

Engineering control: Use local exhaust equipment to control the dust concentration < 10 mg/m³.
Personal Protection: Wear a NIOSH-certified dust mask, protective gloves, and goggles.

Physicochemical properties
Appearance: silvery-white metallic wire or black coated wire, diameter 0.08-0.3 mm
Melting Point: 2623 °C
Density: 10.22 g/cm³
Solubility: insoluble in water, slightly soluble in strong acids.

Stability and reactivity
Stability: Stable at room temperature and WEDM working solution, oxidized in high temperature (>600°C) air.
Incompatible substances: strong oxidizing agents (e.g. nitric acid, hydrogen peroxide).

Toxicological information
Acute toxicity: LD50 (oral, rat) >5000 mg/kg, low toxicity.
Chronic toxicity: Long-term inhalation of high concentrations of molybdenum dust may cause lung irritation, and no evidence of carcinogenicity (IARC classification: none).

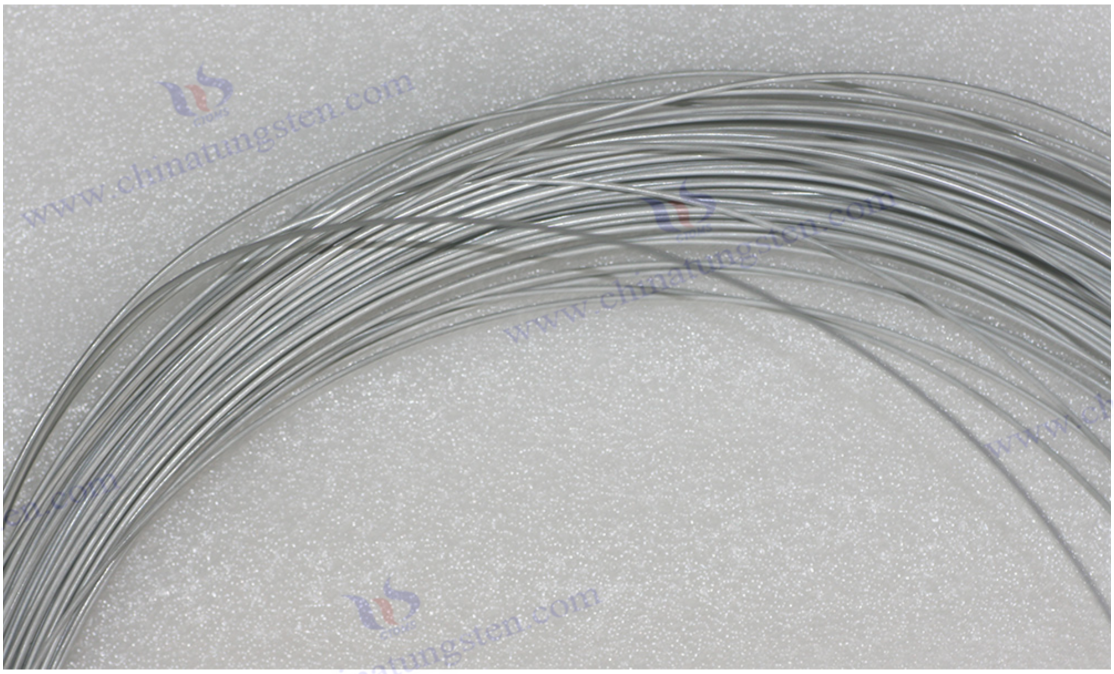
Ecological information
Environmental impact: Molybdenum wire itself has no direct harm to the environment, but the waste needs to be properly recycled to avoid entering the water body.
Bioaccumulation: No significant risk of bioaccumulation.

Disposal
Method: According to local regulations, it will be handed over to a professional institution for recycling, and high-temperature smelting is recommended to recover molybdenum metal.
Precautions: It is forbidden to discard it at will to avoid polluting the soil or water source.

Shipping Information
UN number: non-dangerous goods, no UN number.
Shipping requirements: Use airtight packaging to avoid dust leakage and comply with international shipping regulations (e.g. IATA).

Regulatory Information
Complies with Chinese GB/T 4182-2017, US ASTM B387 and EU REACH regulations.
Subject to OSHA (29 CFR 1910.1200) and GHS chemical classification standards.

Additional Information
Supplier: CTIA GROUP LTD
Tel: 0592-5129696/5129595



CTIA GROUP LTD molybdenum wire EDM

## Chapter 3 Classification of Molybdenum Wire EDM

According to its performance, application scenarios and processing technology, molybdenum wire EDM can be divided into high-efficiency molybdenum wire for EDM, high-precision molybdenum wire for EDM, fast-wire molybdenum wire EDM, medium wire molybdenum wire EDM and Special molybdenum wire for EDM. These classifications reflect the diverse needs of molybdenum wire in wire-cut wire EDM (WEDM) and cover a wide range of applications from high-efficiency, high-volume production to high-precision, complex shape machining. The following is a detailed introduction to the characteristics, manufacturing process, applicable equipment and typical applications of various types of molybdenum wire.

### 3.1 High-efficiency molybdenum wire for EDM

High-efficiency molybdenum wire for EDM is designed for the wire-EDM process that pursues high cutting speed and production efficiency, and is widely used in fast wire equipment, especially in the mold manufacturing and hardware processing industries in China and Southeast Asia. High-efficiency molybdenum wire maximizes discharge efficiency and durability by optimizing material formulation and surface treatment, and is suitable for machining workpieces with medium precision requirements.

#### 3.1.1 Features

Tensile strength: 800-1000 MPa, ensuring that the wire is not easy to break at high tension (15-20 N) and high-speed operation (line speed 8-12 m/s).

Wire diameter: 0.18-0.25 mm is commonly used, and the tolerance is ± 0.001 mm to ensure a stable discharge gap (about 0.27-0.375 mm).

Surface treatment: Black graphite emulsion coating (thickness 1-2 μm) is usually used to enhance

wear resistance and conductivity, and reduce discharge heat loss.
Cutting speed: up to 150-200 mm²/min, about 30% higher than ordinary molybdenum wire (100-150 mm²/min).
Durability: 6,000-10,000 mm² can be cut in a single use, with a cycle life of 500-800 hours (depending on the operating condition).

### 3.1.2 Manufacturing process

High-efficiency molybdenum wire is usually made of high-purity molybdenum (Mo≥99.5%) as the base material, partially doped with 0.3-0.5% rare earth elements (such as lanthanum or yttrium) to improve tensile strength and thermal fatigue resistance. The production process includes:

Powder metallurgy: high-purity molybdenum powder with a particle size of 5-10 μm is selected, and the blank is formed by isostatic pressing.
Rotary swaging and wire drawing: multi-pass hot drawing and cold drawing process, combined with diamond wire drawing dies, to ensure the uniformity of wire diameter.
Surface coating: Graphite emulsion spraying or dipping process is used to form a uniform carbon-based lubricating layer and reduce the coefficient of friction (about 0.1-0.2).
Heat treatment: Vacuum annealing (1000-1200°C) eliminates internal stress and improves toughness and wear resistance.

### 3.1.3 Application Scenarios

High-efficiency molybdenum wire is mainly used in fast wire walking equipment to process materials such as die steel (such as Cr12MoV), carbon steel and aluminum alloy. Typical applications include:

Stamping dies: such as automobile panel molds, cutting thickness 20-100 mm, surface roughness Ra 2.0-3.2 μm.
Hardware parts: such as rough machining of gears and sprockets, efficiency takes precedence over precision.
Mass production: such as large-scale manufacturing of home appliance molds and plastic molds.

## 3.2 High-precision molybdenum wire for EDM

High-precision molybdenum wire for EDM is designed for high-precision and complex shape processing, and is suitable for medium wire and some slow wire walking equipment, and is widely used in aerospace, medical equipment and electronics industries. Compared with high-efficiency molybdenum wire, it emphasizes cutting accuracy and surface quality.

### 3.2.1 Features

Tensile strength: 900-1200 MPa, suitable for high-tension operation (12-18 N), ensuring low vibration and stable discharge.
Wire diameter: 0.08-0.15 mm, tolerance ± 0.0005 mm, suitable for microfabrication (scan gap 0.12-0.225 mm).
Surface treatment: white molybdenum wire (alkali washing or electrolytic polishing) is the main

one, and the surface roughness is Ra 0.1-0.15 μm, which reduces the discharge residue.
Cutting accuracy: up to ±2-3 μm, surface roughness Ra 0.8-1.2 μm.
Durability: 4000-7000 mm² per cutting area, 300-600 hours cycle life.

### 3.2.2 Manufacturing process

High-precision molybdenum wire requires higher purity (Mo≥99.95%) and stricter process control:

Raw materials: Vacuum smelting of molybdenum ingots, impurity content (such as Fe, Ni) is controlled below 0.001%.
Precision wire drawing: using natural diamond mold, multi-pass cold drawing, wire diameter deviation < 0.0005 mm.
Surface treatment: Electrolytic polishing removes surface micro-defects and combines with chemical vapor deposition (CVD) to form an ultra-thin protective layer.
Heat treatment: multi-stage annealing (800-1000°C), grain size control of 3-5 μm, improved thermal shock resistance.

### 3.2.3 Application Scenarios

High-precision molybdenum wire is suitable for high-precision mold and part processing:

Precision molds: such as injection molds, semiconductor molds, processing complex contours (such as micro-tooth shapes) with an accuracy of ± 3 μm.
Aerospace: Machining of titanium alloy (e.g. Ti-6Al-4V) or superalloy (e.g. Inconel 718) parts with a thickness of 10-50 mm.
Medical devices: such as orthopedic implants, microstructure processing of surgical tools, surface roughness Ra<1.0 μm.

## 3.3 Molybdenum wire for HS-EDM

Molybdenum wire for HS-EDM is a standard consumable for fast wire equipment (line speed 8-12 m/s), which is characterized by high-cost performance and recycling, and is widely used in mold manufacturing and hardware processing industries in China and Southeast Asia.

### 3.3.1 Features

Tensile strength: 700-900 MPa, suitable for medium tension (10-15 N).
Wire diameter: 0.16-0.20 mm (0.18 mm is the most common), tolerance ± 0.001 mm.
Surface treatment: Black graphite emulsion coating (1-3 μm thick) to reduce friction and heat loss.
Cutting speed: 100-150 mm²/min, surface roughness Ra 2.5-3.2 μm.
Recycling: 500-1000 cycles, single roll (2000-4000 m) cutting area up to 8000-12000 mm².

### 3.3.2 Manufacturing process

Raw material: Mo ≥99.3%, economic molybdenum wire is often doped or a small amount doped (0.1-0.3% La).
Wire drawing process: multi-pass hot drawing, cemented carbide wire drawing die, the cost is lower but the accuracy is slightly inferior.


TEL: 0086 592 512 9696
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sales@chinatungsten.com

Surface treatment: Dip graphite emulsion, coating uniformity is controlled at ±0.5 μm.
Annealing: Continuous annealing (900-1100°C) to balance strength and toughness.

### 3.3.3 Application Scenarios

Fast wire molybdenum wire is mainly used for cost-sensitive roughing:

Stamping dies: such as home appliance molds, auto parts molds, processing thickness 20-80 mm.
Hardware parts: such as mass production of nuts and fasteners.
Non-high-precision parts: such as construction machinery parts, the accuracy requirements are ± 10-20 μm.

### 3.3.4 Global Market and Technology Trends

China accounts for about 70% of the global market for fast walking wire and molybdenum wire, and the price is as low as 0.1-0.2 yuan/meter, which is much lower than that of brass wire (0.5-1 yuan/meter). The main suppliers include China Jindui City and Ningbo Zhongyuan. Technology trends include the development of low-cost, high-strength molybdenum wires (e.g., Ce-doped), and automated threading technology to reduce labor costs. Demand in Southeast Asian markets (e.g., Vietnam and Thailand) is growing rapidly, with a CAGR of 5% from 2025 to 2030.

## 3.4 Molybdenum wire for MS-EDM

Combining the efficiency of fast wire cutting and the accuracy of slow wire cutting, molybdenum wire for MS-EDM is suitable for medium wire equipment, which has been rapidly popularized in the Chinese market in recent years, gradually replacing some fast wire applications.

### 3.4.1 Features

Tensile strength: 900-1100 MPa, suitable for high tension (12-18 N).
Wire diameter: 0.12-0.18 mm, tolerance ± 0.0008 mm.
Surface treatment: white molybdenum wire (Ra 0.1-0.2 μm) or thinly coated molybdenum wire to reduce discharge residue.
Cutting accuracy: ±3-5 μm, surface roughness Ra 1.0-1.6 μm.
Durability: 5000-8000 mm² per cutting area, 400-700 hours cycle life.

### 3.4.2 Manufacturing process

Raw materials: Mo ≥ 99.7%, often doped with 0.5-1% rare earth elements (such as La, Y).
Precision wire drawing: using diamond die, multi-pass cold drawing, wire diameter deviation < 0.0008 mm.
Surface treatment: electropolishing or thin graphite emulsion coating (thickness < 1 μm).
Heat treatment: vacuum multi-stage annealing (800-1000°C), grain size 3-5 μm.

### 3.4.3 Application Scenarios

Molybdenum wire for MS-EDM is suitable for medium precision and high efficiency machining:

Precision molds: such as mobile phone case molds, electronic connector molds, processing thickness 10-50 mm.

Aviation parts: such as aluminum alloy and titanium alloy structural parts, with an accuracy of ± 5 μm.

Medical devices: e.g. dental tools, miniature implants, surface roughness Ra<1.2 μm.

### 3.5 Special molybdenum wire for EDM

Special molybdenum wire for EDM is designed for specific applications or materials, such as ultra-high hardness materials, ultra-thin workpieces or extreme environment processing, and are customized for high-end WEDM equipment.

#### 3.5.1 Features

Tensile strength: 1000-1400 MPa, doped with rare earth or alloying elements (such as La, Y, Zr).

Wire diameter: 0.05-0.12 mm, tolerance ± 0.0005 mm, suitable for micromachining.

Surface treatment: white molybdenum wire or composite coating (e.g. nano-carbon or ceramic coating), Ra 0.05-0.1 μm.

Cutting accuracy: ±1-2 μm, surface roughness Ra 0.4-0.8 μm.

Special properties: high temperature oxidation resistance (>800°C), corrosion resistance or electromagnetic interference resistance.

#### 3.5.2 Manufacturing process

Raw materials: Mo ≥ 99.97%, doped with 1-2% rare earth or transition metals (such as Zr, Ti).

Ultra-precision wire drawing: single crystal diamond die with a wire diameter deviation of < 0.0003 mm.

Surface treatment: Chemical vapor deposition (CVD) or physical vapor deposition (PVD) to form functional coatings.

Heat treatment: ultra-low temperature annealing (600-800°C), grain size 2-3 μm, enhanced resistance to thermal fatigue.

#### 3.5.3 Application Scenarios

Special molybdenum wire is used in demanding scenarios:

Semiconductor industry: processing silicon wafer molds and microelectronic parts with an accuracy of ± 1 μm.

Aerospace: Processing of superalloys (e.g. GH4169) or ceramic composites with a thickness of 5-30 mm.

Medical industry: e.g. microsurgical instruments, implant microstructures, Ra < 0.5 μm.

Special materials: precision machining of carbon fiber composites and graphite electrodes.

CTIA GROUP LTD molybdenum wire EDM

## Chapter 4 Preparation and Production Process of Molybdenum Wire EDM

The preparation of molybdenum wire EDM is a complex process that involves multiple steps from raw material selection to precision machining, ensuring that the molybdenum wire has excellent high-temperature stability, tensile strength and surface quality to meet the high precision and high efficiency requirements of wire-cut wire EDM (WEDM). This chapter details the raw material selection, production process, key technologies and quality control measures of molybdenum wire EDM, highlighting the importance of the application of advanced manufacturing technology and process optimization on a global scale.

### 4.1 Selection of raw materials for molybdenum wire EDM

The selection of raw materials is the basis for the preparation of molybdenum wire EDM, which directly affects its chemical stability, mechanical properties and processing properties. Molybdenum wire EDM is mainly based on high-purity molybdenum and doped with trace rare earth elements according to performance requirements to optimize its performance in high-temperature discharge environments.

#### 4.1.1 High-purity molybdenum raw materials

The production of molybdenum wire EDM begins with the selection of high-purity molybdenum raw materials, usually available in the form of molybdenum powder or molybdenum ingots. Molybdenum is a silvery-white transition metal with a high melting point and excellent chemical stability, making it suitable for the harsh environment of transient high-temperature discharges in WEDM. The raw material for the production of high-purity molybdenum is first extracted from molybdenum concentrate (mainly $MoS_2$), which is converted into molybdenum oxide ($MoO_3$) by roasting, and then multi-stage reduction in a hydrogen atmosphere to generate high-purity molybdenum powder. The reduction process requires strict control of temperature and atmosphere to remove impurities such as oxygen and sulfur to ensure that the purity of molybdenum powder meets industry requirements.

The particle size uniformity and chemical purity of high-purity molybdenum powder are critical for subsequent processes. The fine and uniform molybdenum powder particles help to form a dense blank, reducing porosity and defects during the sintering process. The world's leading manufacturer uses spray drying and plasma spheroidization technologies to optimize the particle morphology and flowability of molybdenum powders. In addition, impurities such as carbon, iron, and nickel need to be controlled during the production process to avoid affecting the conductivity and mechanical properties of molybdenum wire. The high quality of the molybdenum powder forms the basis for the subsequent sintering and drawing process, ensuring that the molybdenum wire has stable discharge performance and durability in WEDM.

#### 4.1.2 Doping of rare earth elements (e.g. lanthanum, yttrium)

To improve the tensile strength, high temperature resistance and oxidation resistance of molybdenum wire EDM, manufacturers often dope the molybdenum matrix with trace rare earth elements such as lanthanum (La), yttrium (Y) or cerium (Ce). Rare earth doping enhances molybdenum's stability in high-tensile and high-temperature discharge environments by changing its crystal structure and microscopic properties. For example, lanthanum can refine the grain of molybdenum, increase the strength of grain boundaries, and reduce intergranular slip at high temperatures; Yttrium can improve the oxidation resistance and slow down the oxidation loss of the surface of the molybdenum wire during the discharge process.

The doping process is usually carried out in the molybdenum powder preparation or sintering stage. A common method is to mix rare earth oxides (e.g., $La_2O_3$, $Y_2O_3$) with molybdenum powder, which is evenly distributed by ball milling or wet mixing. Another method is to introduce rare earth elements into the molybdenum matrix by chemical co-precipitation to form a homogeneous solid solution or diffuse phase. Global manufacturers have developed high-performance molybdenum wires with precise control of doping ratios and distributions, significantly improving their performance in high-precision medium wire feeding equipment. Rare earth doping should also be avoided in excess to prevent the formation of brittle phases or affect the smoothness of the wire drawing process.

### 4.2 Production process of molybdenum wire EDM

The production process of wire EDM wire includes molybdenum powder metallurgy, sintering and forging, rotary swaging, wire drawing and surface treatment, each step of which needs to be precisely controlled to ensure that the performance of molybdenum wire meets the requirements of WEDM. The technical highlights and global practices for each process step are described in detail below.

#### 4.2.1 Molybdenum powder metallurgy

Molybdenum powder metallurgy is the starting point for the preparation of molybdenum wire blanks, which aims to convert high-purity molybdenum powder into dense molybdenum rods or molybdenum blanks. The process begins with the pressing of molybdenum powder, which is usually pressed into a cylindrical blank at high pressure (100-200 MPa) using cold isostatic pressing (CIP) technology. Cold isostatic pressing ensures uniform billet density and reduces internal porosity. Subsequently, the billet is pre-sintered in a hydrogen or vacuum environment at a temperature controlled in a low range (about 1000-1200°C) to remove volatile impurities and enhance the strength of the billet.

The key to molybdenum powder metallurgy is to control the particle size and compaction process of the powder. Fine molybdenum powder particles (5-10 µm in size) contribute to the formation of high-density blanks, but powders that are too fine may result in poor flow and affect the uniformity of compression. Global manufacturers ensure a homogeneous microstructure of the billet by optimizing the powder screening and mixing process. In addition, air contamination must be avoided during the pressing process to prevent oxidation or porosity formation, which can lead to the risk of wire breakage in subsequent drawing.

#### 4.2.2 Sintering and forging

Sintering is a critical step in converting pressed blanks into high-density molybdenum rods, usually in a high-temperature vacuum or hydrogen protection furnace. The sintering temperature gradually rises to 1800-2000°C, allowing the molybdenum particles to combine to form a dense metal structure. During the sintering process, the heating rate and holding time need to be controlled to avoid overgrowth of grains or the formation of cracks. The density of high-quality sintered molybdenum rods is close to the theoretical value (10.22 g/cm³) and the internal porosity is less than 1%, which provides a solid foundation for subsequent forging.

Forging further improves the density and mechanical properties of molybdenum rods, usually using hot forging or warm forging techniques. Hot forging is carried out at 1200-1500°C, and the molybdenum rod is plastically deformed by hammering or pressing, refining the grains and eliminating minor defects. The world's leading companies use a multi-stage forging process, combined with precise temperature control, to ensure that the crystal structure of molybdenum rods is homogeneous, and the tensile strength and toughness are optimal. The forged molybdenum rod is typically 10-20 mm in diameter and is ready for subsequent rotary swaging and wire drawing.

#### 4.2.3 Rotary swaging process

Rotary forging is a key step in processing molybdenum rods into slender molybdenum wire blanks, and the radial pressure on the molybdenum rods is applied by rotary forging equipment to gradually reduce its diameter. Rotary swaging is performed at high temperatures (1000-1300°C) combined with hydrogen protection against oxidation. The rotary forging equipment is equipped with multiple sets of high-precision dies, and the diameter of the molybdenum rod is gradually reduced from 10-20 mm to 1-3 mm to form a coarse wire blank suitable for wire drawing.

At the heart of the rotary swaging process is the control of the deformation rate and temperature gradient. Rapid deformation may lead to cracks on the surface of the molybdenum rod, while too high a temperature can cause coarse grains and reduce strength. Manufacturers around the world achieve precise control with automated rotary swaging equipment to ensure the roundness and surface quality of coarse wire blanks. Rotary swaging can also enhance the fibrous crystal structure of molybdenum, improve tensile strength and toughness, and lay the foundation for the subsequent wire drawing process.

**4.2.4 Wire drawing process (cold drawing and hot drawing)**

The wire drawing process draws the coarse wire blank after rotary forging into the final wire diameter (0.08-0.3 mm) of molybdenum wire EDM, which is divided into two ways: hot drawing and cold drawing. Heat drawing is carried out at 800-1000°C, and the ductility of the molybdenum wire is maintained using a heating furnace, which is suitable for large deformations in the initial stage. Cold drawing is carried out at room temperature or low temperature (<200°C), and the wire diameter is gradually reduced by multi-pass drawing, which is suitable for high-precision molding.

High-precision drawing dies (usually natural diamond or polycrystalline diamond) are used in the drawing process to ensure wire diameter uniformity and surface smoothness. Lubricants such as graphite emulsion or oil-based lubricants are used to reduce friction and prevent scratches on the surface of the molybdenum wire. Global manufacturers use a multi-stage drawing process combined with intermediate annealing (600-800°C) to relieve stress and ensure the mechanical properties and geometric accuracy of molybdenum wire. The cold drawing process is particularly critical to refine the grains and improve the tensile strength and low elongation characteristics of the molybdenum wire.

**4.2.5 Surface treatment of molybdenum wire EDM (graphite emulsion coating, alkali washing, electrolytic polishing)**

Surface treatments optimize the discharge performance, abrasion and corrosion resistance of molybdenum wire, common methods include graphite emulsion coating, caustic washing and electrolytic polishing:

Graphite emulsion coating: Molybdenum wire is immersed or sprayed with carbon-based graphite emulsion to form a black lubricating layer 1-3 μm thick, which enhances electrical conductivity and wear resistance, and reduces frictional heat during discharge. Graphite emulsion coating is suitable for fast walking molybdenum wire, which is widely used in mold processing in the Chinese market.
Caustic washing: Use sodium hydroxide or potassium hydroxide solution to clean the surface of the molybdenum wire to remove oxides and impurities to form a bright white molybdenum wire. The surface roughness of the molybdenum wire after alkali washing is low, which is suitable for high-precision medium wire walking equipment.
Electrolytic polishing: The surface of the molybdenum wire is further smoothed by electrochemical reaction to achieve a mirror effect (Ra 0.1-0.15 μm), reducing the discharge residue and making it suitable for precision machining. This process is commonly used by European and Japanese manufacturers to produce high-end molybdenum wire.

The surface treatment needs to be selected according to the use of molybdenum wire. For example, graphite emulsion-coated molybdenum wire is suitable for high-speed cutting, while alkali-washed or electrolytically polished white molybdenum wire is used for high-precision machining. Global companies automate coating and polishing equipment to ensure uniformity and consistency in surface treatment.

### 4.3 Key technologies of molybdenum wire EDM

The performance of molybdenum wire EDM relies on the synergy of several key technologies, including high-precision drawing dies, temperature control and heat treatment, and doping process optimization. These technologies ensure high precision and stability of molybdenum wire in WEDM.

#### 4.3.1 High-precision wire drawing die technology

High-precision drawing dies are at the heart of achieving the uniformity of the wire diameter and surface quality of the molybdenum wire. Natural diamond or polycrystalline diamond (PCD) dies are widely used due to their high hardness and wear resistance. The aperture accuracy of the drawing die needs to be controlled at the micron level, and the surface finish of the die hole is high to avoid scratching or deformation on the surface of the molybdenum wire. The global manufacturer uses laser processing and ultra-precision grinding technology to manufacture drawing dies that ensure a hole diameter deviation of less than 0.5 µm.

The design of the drawing die also needs to consider the thermal expansion and stress distribution of the molybdenum wire. The cone angle and lubrication area of the die hole need to be optimized to reduce frictional heat and stress concentration during the drawing process. The multi-pass drawing process combined with real-time monitoring (e.g. laser caliper) ensures the consistency and roundness of the molybdenum wire diameter and meets the requirements of high-precision WEDM.

#### 4.3.2 Temperature control and heat treatment technology

Temperature control runs through the sintering, swaging, wire drawing and surface treatment of molybdenum wire preparation. Sintering and rotary swaging are carried out under vacuum or hydrogen protection, and the temperature is precisely controlled in the range of ±10°C to avoid oxidation or coarse grains. Heat treatment (annealing) is a key step to eliminate the internal stress of molybdenum wire, optimize the crystal structure, and balance strength and toughness by heating and slow cooling at 600-1000°C.

Manufacturers around the world use vacuum annealing furnaces or continuous heat treatment furnaces to ensure temperature uniformity. The heat treatment also needs to be adjusted according to the type of molybdenum wire, for example, high-efficiency molybdenum wire is biased towards high-toughness annealing, and high-precision molybdenum wire needs to refine the grain to improve strength.

#### 4.3.3 Doping process optimization

Rare earth doping processes (e.g., lanthanum, yttrium) improve the tensile strength and high temperature resistance of molybdenum by changing its microstructure. The doping process needs to ensure that the rare earth elements are evenly distributed and local segregation is avoided. Common methods include:

Powder doping: Rare earth oxides are added in the preparation stage of molybdenum powder, and homogeneous mixing is achieved by high-energy ball milling.
Liquid-phase doping: Rare earth elements are introduced into the molybdenum matrix through chemical co-precipitation to form a nanoscale diffuse phase.
Vapor phase doping: The introduction of rare earth elements by vapor deposition during the sintering or heat treatment phase.

**4.4 Quality control of molybdenum wire EDM**

Quality control is the key to ensuring the consistency and reliability of wire EDM wire performance, covering wire diameter consistency, surface defect detection and tensile strength testing. Global manufacturers ensure that molybdenum wire meets the stringent requirements of WEDM through advanced inspection technology and automated systems.

**4.4.1 Wire diameter consistency control**

Wire diameter consistency is the core quality index of molybdenum wire EDM, which directly affects the discharge gap and machining accuracy. During the production process, the diameter of the molybdenum wire is monitored in real time by a laser caliper, and the drawing parameters are adjusted in combination with an automatic feedback system. Regular inspection and replacement of drawing dies ensure the accuracy of die holes and prevent wire diameter deviations. The world's leading company uses multi-point laser measurement technology to detect changes in the roundness and diameter of molybdenum wires in real time, ensuring micron-level consistency.

In addition, wire diameter consistency needs to be stable across the entire reel of molybdenum wire (2000-4000 m). By optimizing the drawing speed and lubricant formulation, the manufacturer reduces wire diameter fluctuations and ensures stable performance of molybdenum wire at high speeds and multiple cycles.

**4.4.2 Surface defect detection and treatment**

Surface defects (e.g., scratches, cracks, oxide layers) can reduce the discharge efficiency and durability of molybdenum wire. Quality control uses a variety of non-destructive testing techniques:

Light microscope: check surface scratches and coating uniformity with 100-500x magnification.
Eddy current testing: Detects internal microcracks and non-uniform areas, suitable for continuous production.
Scanning electron microscopy (SEM): Analyzes surface microstructure to identify nanoscale defects.

Defect handling includes re-polishing or rejecting non-conforming segments. China Xiamen Tungsten Co., Ltd. identifies and rejects surface defects in real time through an automated visual inspection system, with a pass rate of more than 99.5%. European manufacturers combine X-ray microscopes to detect internal defects and ensure that the surface quality of molybdenum wire meets the needs of high-precision machining.

**CTIA GROUP LTD**

**Molybdenum Wire EDM Introduction**

### 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

### 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

### 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

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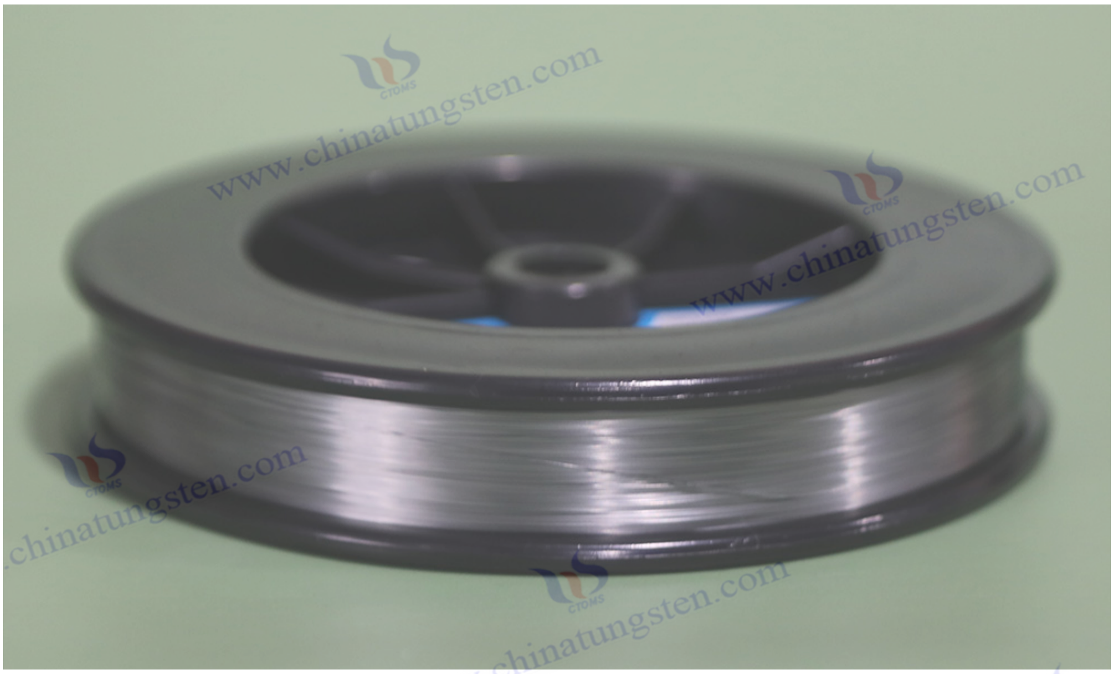
Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

### 4.4.3 Tensile strength test

Tensile strength testing verifies the mechanical properties of molybdenum wire to ensure that it can withstand the high tensile and cyclic stresses found in WEDM. The test uses a universal materials testing machine to apply a tensile force to a standard specimen and record the maximum load before fracture. The test environment simulates WEDM conditions (e.g., room temperature or high temperature) and combines elongation and fracture topography analysis to evaluate the toughness and fatigue resistance of the molybdenum wire.

Global manufacturers use automated test equipment, combined with statistical process control (SPC), to ensure consistent tensile strength of molybdenum wire from batch to batch. The test also includes a fatigue test to simulate the performance of the molybdenum wire under high-frequency discharge and tension cycles to verify its durability. For non-conforming batches, the manufacturer optimizes by adjusting the annealing parameters or redrawing.



CTIA GROUP LTD molybdenum wire EDM

# Chapter 5 Uses of Molybdenum Wire EDM

As a high-performance metal material, molybdenum wire plays an important role in several industrial fields due to its excellent physical and chemical properties, such as high melting point, high strength, corrosion resistance, and good electrical and thermal conductivity. Especially in wire-cut EDM processing, electric light source manufacturing, thermal spraying technology and other high-tech fields, molybdenum wire has become an indispensable material due to its unique properties. This chapter will discuss the specific applications of molybdenum wire in these fields in detail, and analyze its technical advantages and practical cases in depth to fully demonstrate the importance of molybdenum wire in modern industry.

## 5.1 Wire EDM processing

Wire Electrical Discharge Machining (WEDM) is an advanced technology that uses the principle of electrical discharge to perform high-precision machining, which is widely used in mold making, complex shape machining and high-precision parts manufacturing. Molybdenum wire has become the most commonly used electrode wire material in wire EDM due to its high strength, high temperature resistance and excellent electrical conductivity. The following will elaborate on the specific uses of molybdenum wire in wire EDM from three aspects: mold manufacturing, complex shape and microstructure processing, and high-precision parts processing.

### 5.1.1 Mould making

Mould making is one of the most important areas of application for wire EDM technology, in which molybdenum wire plays a central role. Molds are key components in industrial production, widely used in automobile manufacturing, home appliance production, plastic products and metal stamping and other fields, and its precision and quality directly affect the performance of the final product. The application of molybdenum wire in mold manufacturing is mainly reflected in the following aspects:

High-precision mold processing

Molybdenum wires are typically between 0.1 mm and 0.3 mm in diameter, small and homogeneous, capable of achieving micron-level machining accuracy in wire EDM machines. For example, in the processing of stamping dies, molybdenum wire can precisely cut out complex contours and narrow gaps, ensuring that the geometry of the mold meets the design requirements. Compared with traditional machining methods, molybdenum wire wire cutting can process die steels with extremely hard hardness (e.g., Cr12MoV, SKD11) without tool wear due to material hardness.

Implementation of complex mold structures

Modern mold designs often include complex geometries such as multi-curved structures, deep grooves, and sharp corners. Molybdenum wire is able to easily cope with these complex structures by discharging corroded materials in wire EDM. For example, in the manufacture of automotive panel molds, molybdenum wire can be cut into complex curved surfaces with high surface quality, which meets the requirements of precision and aesthetics of automotive exterior parts. In addition, the high tensile strength of molybdenum wire ensures that it is not easy to break during long-term processing, thus ensuring the continuity and stability of processing.

Efficient production and cost control

The use of molybdenum wire significantly improves the efficiency of mold making. Compared with traditional brass wire, molybdenum wire has higher wear resistance and high temperature resistance, and can be used for a long time in a high-intensity discharge environment, reducing the frequency of replacing the electrode wire, thereby reducing production costs. For example, in the mass production of injection molds, the high durability of molybdenum wire can support continuous processing for hours on end, reducing downtime and increasing production efficiency.

Practical examples

Taking an auto parts manufacturer as an example, when manufacturing precision stamping dies, it uses molybdenum wire with a diameter of 0.18 mm for EDM wire cutting, and successfully processes mold parts with tolerances within ±0.005 mm. This high-precision mold is widely used in the production of automotive engine blocks and transmission housings, significantly improving the quality and consistency of the product.

**5.1.2 Complex shape and microstructure processing**

Molybdenum wire is also widely used in wire EDM to process complex shapes and microstructures, especially in industrial areas where high precision and complex geometries are required. The following are several key points of molybdenum wire application in this field:

Ability to process microstructures

The fine diameter and excellent electrical conductivity of molybdenum wire make it particularly suitable for machining parts with micron structures. For example, in microelectromechanical systems (MEMS) manufacturing, molybdenum wire can cut micro gears, microchannels, or micro connectors with a width of only a few tens of microns. These microstructures are widely used in sensors, micromotors, and medical devices. The high strength and tensile properties of molybdenum wire ensure that it does not deform or break when processing microstructures.

Realization of complex three-dimensional structures

Wire EDM technology can realize the processing of complex three-dimensional structures by controlling the movement trajectory of molybdenum wire. For example, in the aerospace sector, molybdenum wire is used to cut cooling holes in turbine blades, which are typically less than 0.2 mm in diameter and have complex three-dimensional paths. The high melting point and high temperature resistance of molybdenum wire enable it to work stably in a high-energy discharge environment, ensuring machining accuracy and surface finish.

Multi-material compatibility

Molybdenum wire is capable of machining a wide range of high-hardness materials (such as titanium, ceramics and cemented carbide) in wire EDM, which makes it widely applicable in complex shape machining. For example, in the manufacture of precision gears, molybdenum wire can cut complex gear structures with an ISO 5 tooth profile accuracy to meet the needs of high-performance machinery and equipment.

Practical examples

In an optical instrument manufacturing company, molybdenum wire is used to process mold parts for high-precision optical lenses. These components contain complex aspherical structures and micro-grooves, and are machined to tolerances of ±0.002 mm. By using 0.12 mm diameter molybdenum wire, the company has successfully processed these complex structures on a wire-cut EDM machine, significantly improving the image quality of the optical lens.

### 5.1.3 High-precision parts processing

High-precision component machining is another important application area of molybdenum wire in wire EDM, especially in industries where dimensional accuracy and surface quality are extremely demanding. The application of molybdenum wire in the processing of high-precision parts has the following characteristics:

Ultra-high-precision machining

The fine diameter and stable discharge performance of molybdenum wire enable it to achieve sub-micron machining accuracy. For example, in the precision machinery industry, molybdenum wire is used to machine high-precision bearing housings and transmission components, which are typically required to tolerances within ±0.001 mm. The high conductivity and uniform discharge characteristics of molybdenum wire ensure the stability of the discharge gap during processing, thus ensuring the dimensional accuracy of the parts.

Excellent surface quality

Wire-cut EDM uses molybdenum wire to machine parts with an extremely high surface finish, typically below Ra 0.1 microns. This high surface quality is especially important in parts that require low friction and high wear resistance. For example, in the manufacture of high-precision hydraulic spools, molybdenum wire cutting can ensure the smoothness of the surface of the spool, reduce fluid resistance, and improve the efficiency of the valve.

Adaptability to complex materials and special structures. Here is a further detailed analysis of the field:

Processing complex materials

In the aerospace sector, molybdenum wire is widely used to process precision parts from superalloys (e.g., Inconel 718, GH4169) and titanium alloys (e.g., Ti-6Al-4V). For example, the tenon and groove structure of an aero engine turbine disc requires extremely high geometric accuracy and surface finish, and molybdenum wire can accurately control the discharge gap through EDM wire cutting, cutting out complex tenon and groove with tolerances within ±0.002 mm, while avoiding material stress concentration and micro-crack problems that may result from traditional machining. In addition, molybdenum wire can maintain stable performance when processing ceramic matrix composites (CMC), meeting the needs of next-generation aero engines for high-temperature resistant parts.

Multi-axis simultaneous machining

Modern wire-EDM equipment is often equipped with a multi-axis CNC system, which, combined with the flexibility of molybdenum wire, can achieve complex three-dimensional part machining. For example, in the manufacture of micro gear sets in precision instruments, molybdenum wire can be used to cut tooth structures with complex spatial curves through five-axis linkage with ISO 4 accuracy. This capability is particularly important in the manufacture of optical devices, precision instruments, and high-end watches.

Practical examples

Taking a precision instrument manufacturing enterprise as an example, in the production of high-precision mirror brackets for laser rangefinders, it uses 0.15 mm diameter molybdenum wire for EDM wire cutting, and successfully processes a bracket with complex geometric shapes, the dimensional tolerance is controlled within ±0.0015 mm, and the surface roughness reaches Ra 0.08 microns. This high-precision bracket significantly improves the measurement accuracy of the rangefinder and is widely used in the fields of geological exploration and building surveying and mapping.

Environmental protection and sustainability

The use of molybdenum wire in the processing of high-precision parts also has certain environmental advantages. Compared to conventional machining, wire EDM does not require the use of a large amount of cutting fluid, reducing the generation of liquid waste. In addition, the high durability of molybdenum wire means lower consumption rates and less material waste. For example, in the mass production of precision parts, the reuse rate of molybdenum wire can reach more than 80%, which significantly reduces production costs and environmental impact.

**5.2 Electric light source application**

Due to its high melting point (about 2623°C), good conductivity and oxidation resistance, molybdenum wire is widely used in the electric light source industry to manufacture various key components, such as gates, hooks, struts, cores and heating wires.

**5.2.1 Gates, hooks, struts**

In electric light sources such as fluorescent, halogen, and high-pressure discharge lamps, molybdenum wire is used as a key component such as gates, hooks, and struts because of its ability to maintain structural stability and electrical properties in high temperature and high vacuum environments.

Gate fabrication

Gates are important components in some electric light sources, such as metal halide lamps, to control the flow of electrons or to stabilize the discharge process. Due to its high strength and corrosion resistance, molybdenum wire can work for a long time in a high-temperature discharge environment without deformation. For example, in the gate manufacturing of high-pressure sodium lamps, molybdenum wires are processed into filaments with a diameter of 0.05 mm to 0.2 mm, which are precisely wound to form a gate structure to ensure arc stability and light output of the lamp.

Hooks and struts

Hooks and struts are used to hold the light-emitting elements (e.g. tungsten wires or electrodes) inside the electric light source. The high melting point and mechanical strength of molybdenum wire make it an ideal material. For example, in the production of automotive halogen lamps, molybdenum wire is processed into a miniature hook for hanging tungsten filament luminaires to ensure that they do not break or deform in a high-temperature (about 3000°C) operating environment. In addition, the low coefficient of thermal expansion of molybdenum wire ensures the dimensional stability of the hook and strut during thermal cycling, and avoids the structural failure of the lamp due to thermal expansion and contraction.

Practical examples

For example, an international lighting company uses 0.1 mm diameter molybdenum wire to manufacture struts and hooks in the production of high-intensity gas discharge lamps (HID lamps). These components are able to operate stably at a working temperature of more than 2,000°C, ensuring a luminaire life of more than 20,000 hours. This high reliability makes HID lamps widely used in the field of road lighting and industrial lighting.

**5.2.2 Core wire and heating wire**

Another important application of molybdenum wire in electric light sources is as a core and heating wire, especially in incandescent lamps, vacuum tubes and some special light sources.

Core applications

Molybdenum wire is often used as a core in incandescent lamps and vacuum tubes to support tungsten filament or other light-emitting materials. The high melting point and good electrical conductivity of molybdenum wire enable it to transmit current stably in high-temperature environments. For example, in traditional incandescent lamps, molybdenum wire is wound into a spiral core that supports the tungsten filament luminaire and ensures that it does not sag or break at high temperatures. In addition, the oxidation resistance of molybdenum wire makes it suitable for use in vacuum or inert gas environments, extending the service life of the lamp.

Heating wire application

In some special light sources, such as infrared heating lamps, molybdenum wire is used directly as a heating wire. Its high resistivity and high temperature resistance allow it to generate high temperatures in a short period of time for rapid heating or infrared radiation. For example, in industrial infrared drying equipment, molybdenum wire heating wire can quickly increase the temperature to more than 1000°C, which is used for rapid drying of wood, paint or food.

Practical examples

In an infrared heating equipment manufacturing enterprise, molybdenum wire is used to produce heating wire for high-power infrared lamp, and the molybdenum wire with a diameter of 0.3 mm is precisely wound to form a heating element, which can raise the temperature to 1200 °C in 5 seconds. This efficient heating performance is widely used in automotive coating lines and in the food processing industry.

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**Molybdenum Wire EDM Introduction**

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| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

### 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
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| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

## 5.3 Thermal spraying

Thermal spraying technology is a surface treatment technology that sprays molten or semi-molten materials onto the surface of the substrate to form a coating, and molybdenum wire is widely used in this field due to its high melting point and excellent wear resistance. The following is a detailed analysis from two aspects: surface strengthening and repair, and wear-resistant coating preparation.

### 5.3.1 Surface strengthening and repair

Molybdenum wire is used as a spraying material in thermal spraying technology to form a high-performance coating by arc spraying or plasma spraying, which is used to strengthen the surface of the substrate or repair worn parts.

Surface strengthening

Molybdenum wire spray coatings offer extremely high hardness and corrosion resistance, which can significantly improve the surface properties of substrates. For example, in the petrochemical industry, molybdenum wire is sprayed onto the surface of pipeline valves to form a molybdenum coating with a thickness of about 0.2 mm, which can effectively resist acid gases and high-temperature corrosion, and prolong the service life of the valve. In addition, the low coefficient of friction of the molybdenum coating gives it excellent anti-wear properties in sliding parts such as piston rings.

Component repairs

Molybdenum wire thermal spraying is also used to repair worn mechanical parts. For example, in the heavy machinery industry, worn shaft parts (e.g., crankshafts, drive shafts) can be restored to their original size and performance by molybdenum wire spraying. The high bond strength of the molybdenum coating (up to more than 70 MPa) ensures that the repaired parts can withstand high loads and impacts. In addition, the cost of molybdenum wire spray repair is much lower than replacing new parts, which has significant economic benefits.

Practical examples

Taking a shipbuilding enterprise as an example, when repairing the crankshaft of a marine diesel engine, it used molybdenum wire for arc spraying to form a 0.3 mm thick molybdenum coating, which successfully restored the dimensional accuracy and surface hardness of the crankshaft. The repaired crankshaft exhibits excellent wear and fatigue resistance during high-load operation, extending the service life by about 30%.

### 5.3.2 Preparation of wear-resistant coatings

Molybdenum wire is also used in thermal spraying to prepare wear-resistant coatings, which are widely used in industrial scenarios that require high wear resistance.

Abrasion resistant coating properties

The coating formed by the spraying of molybdenum wire has a high hardness (approx. HV 800-1000) and excellent anti-wear properties, making it suitable for high-friction environments. For example, in mining equipment, molybdenum wire is sprayed onto the surface of the excavator's teeth to form a wear-resistant coating that can effectively resist the wear and tear of sand and minerals and extend the life of the teeth. In addition, the self-lubricating properties of the molybdenum coating make it excellent in high-temperature friction environments.

Multi-industry applications

In the steel industry, molybdenum wire spray coatings are applied to roll surfaces to enhance their wear resistance and thermal fatigue resistance. For example, rolls of hot-rolled steel plates are prone to surface wear in high-temperature and high-pressure environments, and the coating formed by molybdenum wire spraying can extend roll life by 2-3 times. In addition, in wind power plants, molybdenum wire spraying is used for the surface treatment of blade bearings, which significantly improves the wear resistance of the bearings.

Practical examples

In a cement production company, molybdenum wire is used to spray the lining plate of a cement mill to form a wear-resistant coating with a thickness of 0.5 mm. The high hardness and corrosion resistance of the coating make it resistant to the intense wear of cement clinker, and the service life of the liner is extended from 6 months to 18 months, significantly reducing maintenance costs.

### 5.4 Other industrial applications

In addition to the main application areas mentioned above, molybdenum wire also plays an important role in several high-tech fields such as aerospace, medical device and electronics industries. Here's the analysis.

5.4.1 Aerospace material processing

The aerospace industry has extremely high-performance requirements for materials, and molybdenum wire is widely used in the processing of critical components due to its high strength, high temperature resistance and corrosion resistance.

Turbine blade machining

Molybdenum wire is used in wire EDM to machine cooling holes and complex contours of turbine blades of aero engines. These cooling holes are typically between 0.1-0.3 mm in diameter and have complex spatial paths, which are met by the fine diameter and high-precision machining capabilities of molybdenum wire. For example, when machining nickel-based superalloy blades, molybdenum wire is able to achieve a hole tolerance of ± 0.002 mm, ensuring cooling and blade performance.

Composite processing

Carbon fiber composites (CFRP) and ceramic matrix composites (CMC), which are widely used in the aerospace industry, have high hardness and low conductivity, which are difficult to process with traditional machining. Molybdenum wire can be efficiently processed by wire EDM to process these materials, for example in the manufacture of aircraft wing skins, where it is used to cut complex openings and connecting holes in composite panels.

Practical examples

Taking an aero-engine manufacturing enterprise as an example, in the production of turbofan engine blades, it uses 0.18 mm diameter molybdenum wire for EDM wire cutting, and successfully processes a cooling hole with a diameter of 0.2 mm, and the roughness of the hole wall reaches Ra 0.1 microns. This high-precision machining significantly improves the thermal efficiency and service life of the blades.

### 5.4.2 Medical device manufacturing

The application of molybdenum wire in medical device manufacturing is mainly focused on scenarios with high precision and biocompatibility requirements.

Minimally invasive surgical instruments

Molybdenum wire is used to process minimally invasive surgical instruments such as endoscopic components, guidewires, and stents. For example, in the manufacture of cardiac stents, molybdenum wire can be machined into a miniature grid structure with a diameter of less than 0.05 mm by wire EDM, ensuring the elasticity and biocompatibility of the stent. In addition, the high surface finish of molybdenum wire reduces the friction and inflammatory response caused by the device in the human body.

Dental & Orthopedic Implants

Molybdenum wire is used in the processing of dental implants and orthopedic fixation devices such as dental implants and bone screws. These components often require complex geometries and high surface quality, and the precision machining capabilities of molybdenum wire are able to meet these requirements. For example, in the manufacture of dental implants, molybdenum wire can be used to cut micron-sized threads to improve the bonding strength of the implant.

Practical examples

In a medical device company, molybdenum wire is used to process titanium alloy bone screws, the thread tolerance is controlled within ±0.003 mm, and the surface roughness reaches Ra 0.05 microns. This high-precision screw is widely used in fracture fixation surgery, significantly improving the success rate of surgery and the speed of patient recovery.

### 5.4.3 Applications in the electronics industry

The application of molybdenum wire in the electronics industry is mainly reflected in semiconductor manufacturing and microelectronic device processing.

Semiconductor mold processing

Molybdenum wire is used in wire EDM to process semiconductor chip packaging molds and wafer dicing templates. For example, in the production of integrated circuit (IC) packaging molds, molybdenum wire is able to cut microscopic grooves with a width of only 0.02 mm, ensuring high precision and consistency of the mold.

Microelectronic connectors

Molybdenum wire is used to process the complex structures of microelectronic connectors, such as the connecting holes of high-density interconnect (HDI) circuit boards. These connecting holes are typically less than 0.1 mm in diameter, and the high-precision machining capability of molybdenum wire is able to meet its tight tolerances.

Practical examples

In a semiconductor manufacturing company, molybdenum wire is used to process wafer dicing templates, and the groove width tolerance of the template is controlled within ±0.001 mm, and the surface roughness reaches Ra 0.03 microns. This high-precision template significantly improves the yield rate of wafer dicing, and is widely used in the production of 5G chips and AI chips.

CTIA GROUP LTD molybdenum wire EDM

## Chapter 6 Production Equipment for Molybdenum Wire EDM

As a high-performance metal material, molybdenum wire is widely used in high-tech fields such as wire EDM, electric light source, thermal spraying and aerospace, and its production process has extremely high requirements for equipment. The production of molybdenum wire involves multiple links from raw material preparation to wire drawing, surface treatment, heat treatment and final quality inspection, each of which requires special equipment to ensure the high precision, high strength and excellent surface quality of molybdenum wire. This chapter will discuss in detail the various types of equipment involved in the production of molybdenum wire, and analyze their functions, technical characteristics and process parameters in depth.

### 6.1 Raw material preparation equipment

The production of molybdenum wire begins with the preparation of high-purity molybdenum materials, and the quality of raw materials directly determines the performance of the final molybdenum wire. The raw material preparation equipment mainly includes molybdenum powder production equipment and sintering furnace, and its functions and applications will be described in detail below.

### 6.1.1 Molybdenum powder production equipment

Molybdenum powder is the basic raw material for the production of molybdenum wire, and its purity, particle size and uniformity are crucial for subsequent processing. The molybdenum powder production equipment mainly includes reduction furnaces, ball mills and screening equipment, which are used to convert molybdenum concentrate or ammonium molybdate into high-purity molybdenum powder.

Hydrogen Reduction FurnaceThe hydrogen reduction furnace is the core equipment for the production of molybdenum powder, which reduces ammonium molybdate or molybdenum oxide ($MoO_3$) to metal molybdenum powder by using hydrogen as a reducing agent at high temperatures. The reduction furnace usually adopts a multi-stage design, and the temperature is controlled between 600°C and 1100°C, which is divided into two stages: low-temperature reduction and high-temperature reduction. Molybdenum oxide is reduced to molybdenum dioxide ($MoO_2$) in the low temperature stage (600-800 °C) and further reduced to metal molybdenum powder in the high temperature stage (900-1100 °C). Modern reduction furnaces are equipped with precise temperature control systems and gas flow control devices to ensure that the purity of molybdenum powder reaches more than 99.95% and the particle size is evenly distributed (usually 1-5 microns).

Ball Mill Ball Mill is used to refine the preliminarily reduced molybdenum powder to further control the particle size distribution. The inside of the equipment adopts high-hardness ceramic or tungsten steel lining plate to avoid the introduction of impurities into the grinding process of molybdenum powder. The speed and grinding time of the ball mill need to be precisely controlled, usually at 200-400 rpm, and too high speed may lead to the agglomeration of molybdenum powder, which will affect the subsequent sintering effect. Wet ball milling can also improve grinding efficiency by adding media such as ethanol and prevent oxidation of molybdenum powder.

Screening & Grading EquipmentScreening equipment (e.g. vibrating screens or jet classifiers) is used to separate molybdenum powders of different particle sizes to ensure that the particle size distribution meets the drawing requirements. The air classifier separates molybdenum powder by particle size through high-speed air flow, with an accuracy of ±0.1 microns, which is suitable for the raw materials required for the production of ultra-fine molybdenum wire. In addition, the screening equipment is equipped with dustproof and anti-oxidation devices to prevent molybdenum powder from oxidizing in the air.

### 6.1.2 Sintering furnaces

The sintering furnace is used to press molybdenum powder into molybdenum blanks, providing a high-density, uniform blank for the subsequent wire drawing process. The sintering process needs to be carried out at high temperatures and in a protective atmosphere to avoid oxidation of the molybdenum material.

High-temperature sintering furnaceHigh-temperature sintering furnace usually adopts resistance heating or induction heating, and the working temperature can reach 1800-2200 °C. Hydrogen or argon is introduced into the furnace as a protective atmosphere to prevent the oxidation of


TEL: 0086 592 512 9696
CTIAQCD -MA-E/P 2018- 2024V
sales@chinatungsten.com

molybdenum billets. Modern sintering furnaces are equipped with a multi-stage temperature control system, which can precisely control the heating rate (typically 5-10°C/min) and holding time (2-4 hours) to ensure that the density of the molybdenum billet reaches more than 98%.

In order to further improve the uniformity and strength of molybdenum billets, some enterprises use hot isostatic pressing (HIP) sintering furnaces. HIP equipment uses high-pressure argon (100-200 MPa) and high temperature (1800-2000 °C) to close the internal pores of the molybdenum billet and significantly improve the strength of the material.

### 6.2 Wire drawing equipment

Wire drawing is the core process of molybdenum wire production, and the molybdenum blank is gradually processed into filament through multi-pass drawing. Wire drawing equipment includes high-precision wire drawing machine and gemstone wire drawing die, and its functions and technical requirements will be analyzed in detail below.

#### 6.2.1 High-precision wire drawing machine

The high-precision wire drawing machine is a key equipment for molybdenum wire production, which is used to draw molybdenum blanks into filaments with a diameter of 0.05-0.3 mm. The wire drawing machine needs to have high-precision tension control and stable running speed to ensure the dimensional consistency and surface quality of the molybdenum wire.

The drawing of molybdenum wire of multi-pass wire drawing machine usually requires 20-30 passes, and the diameter is gradually reduced. Modern multi-pass drawing machines are driven by servo motors and equipped with a tension control system, which is able to adjust the drawing speed (5-20 m/s) and tension (0.1-2 N) in real time to avoid the breaking of molybdenum wire during the drawing process.

Lubrication and cooling systems generate a lot of heat during the drawing process, and high-precision wire drawing machines are equipped with efficient lubrication and cooling systems, often using oil-based or water-based lubricants. The lubricant not only reduces friction, but also prevents scratches on the surface of the molybdenum wire.

#### 6.2.2 Gemstone drawing dies

The gemstone drawing die is the core component of the drawing process, which directly affects the dimensional accuracy and surface quality of the molybdenum wire. Brushed dies are usually made of natural diamond or synthetic polycrystalline diamond (PCD).

Diamond Drawing Die Diamond drawing dies have extremely high hardness and wear resistance, and are suitable for processing high hardness molybdenum wires. The diameter of the die hole is gradually reduced from 1 mm to 0.05 mm, and the surface roughness of the die hole needs to be controlled below Ra 0.01 micron to ensure that the surface of the molybdenum wire is smooth. Modern wire drawing dies use laser drilling technology, and the roundness error of the die hole is less than 0.5 microns.

Die Hole Design & MaintenanceThe die hole design includes the inlet, work and exit areas, and the angles and lengths of each area need to be accurately calculated to optimize the drawing effect. For example, the inlet zone angle is typically 30-40° and the work zone length is 0.5-1 times the diameter of the die hole. The drawing die needs to be cleaned and polished regularly during use to remove molybdenum powder residue and surface wear.

### 6.3 Surface Treatment Equipment

The surface quality of molybdenum wire is critical to its performance in wire EDM, and surface treatment equipment is used to remove surface oxide layers, improve finishes, and apply functional coatings. The following is a detailed analysis from three aspects: alkali washing, electrolytic polishing and graphite emulsion coating.

#### 6.3.1 Caustic washing equipment

Caustic washing equipment is used to remove oxides, oils and other impurities from the surface of molybdenum wire to improve surface cleanliness.

Caustic baths and solution caustic baths are usually made of stainless steel or corrosion-resistant plastics, and the solution is sodium hydroxide (NaOH) or potassium hydroxide (KOH) aqueous solution with a concentration of 5-10%. The caustic washing temperature is controlled at 60-80 °C, and the molybdenum wire passes through the continuous caustic washing tank at a speed of 5-10 m/min, and the cleaning time is 10-20 seconds.

The waste liquid generated in the process of environmental protection treatment of alkali washing needs to be neutralized to meet environmental protection requirements. Modern caustic washing equipment is equipped with a waste liquid recovery system, which increases the removal rate of heavy metal ions in the waste liquid to more than 95% through acid-alkali neutralization and filtration devices.

#### 6.3.2 Electrolytic polishing equipment

Electrolytic polishing further improves the finish and corrosion resistance of the surface of molybdenum wire through electrochemical reactions.

Electrolytic Polishing TankThe electrolytic polishing tank is made of acid-resistant materials such as PTFE, and the electrolyte is usually a sulfuric acid or phosphoric acid solution with a concentration of 20-30%. As the anode, the microscopic protrusion on the surface of the molybdenum wire is dissolved after being energized, and the surface roughness can be reduced to less than Ra 0.02 microns. The electrolytic polishing equipment is equipped with a constant current power supply, the current density is controlled at 10-20 A/dm², and the polishing time is 5-15 seconds.

The quality of the process-controlled electropolishing depends on the precise matching of the electrolyte temperature (50-70°C), the current density and the speed at which the molybdenum wire passes. Modern equipment adopts PLC control system to monitor electrolytic parameters in real time to ensure consistent polishing results.

### 6.3.3 Graphite emulsion coating equipment

Graphite emulsion coating equipment is used to apply a graphite coating on the surface of molybdenum wire to improve its lubricity and wear resistance, especially in the application of wire EDM.

Coating EquipmentGraphite emulsion coating equipment typically includes a coating tank, a drying oven, and a traction system. The molybdenum wire passes through the coating tank containing graphite emulsion at a speed of 5-10 m/min, and the coating thickness is controlled at 1-2 microns. The oven temperature is 100-150°C, which ensures that the coating cures quickly.

Graphite emulsion formulationGraphite emulsion is usually composed of high-purity graphite powder, binder and solvent with a graphite content of 10-20%. The coating equipment is equipped with a stirring device to ensure the homogeneity of the graphite milk.

## 6.4 Heat Treatment Equipment

Heat treatment is an important part of molybdenum wire production, which is used to eliminate internal stresses and improve the ductility and mechanical properties of materials during the wire drawing process. The heat treatment equipment mainly includes vacuum heat treatment furnace and annealing furnace.

### 6.4.1 Vacuum heat treatment furnaces

Vacuum heat treatment furnaces are used to heat treat molybdenum wire in a high-temperature vacuum environment to avoid oxidation and improve the crystal structure.

Vacuum furnace structureThe vacuum heat treatment furnace uses molybdenum or tungsten as the heating element, the working temperature can reach 1600-1800 °C, and the vacuum degree is controlled below $10^{-3}$ Pa. The furnace is equipped with a multi-stage temperature control system, the heating rate is controlled at 5-10°C/min, and the holding time is 1-2 hours.

Process optimization vacuum heat treatment can effectively eliminate the residual stress inside the molybdenum wire, improving its ductility and toughness. Modern vacuum furnaces are equipped with an online monitoring system to detect the temperature and vacuum degree of molybdenum wire in real time to ensure that the heat treatment effect is consistent.

### 6.4.2 Annealing furnaces

Annealing furnaces are used to anneal molybdenum wire at lower temperatures to further optimize its mechanical properties.

Continuous annealing furnace The continuous annealing furnace adopts hydrogen or argon to protect the atmosphere, the temperature is controlled at 800-1200 °C, and the molybdenum wire passes through the furnace body at a speed of 5-15 m/min. The annealing furnace is equipped with an infrared thermometer with a temperature control accuracy of ±5°C.

Segmented annealing processThe annealing process is usually divided into three stages: preheating, heat preservation and cooling, the preheating temperature is 600-800 °C, the holding temperature is 1000-1100 °C, and the cooling adopts inert gas injection to avoid oxidation.

### 6.5 Testing and quality control equipment

The quality of molybdenum wire directly affects its performance in wire EDM, and inspection and quality control equipment is used to ensure that the dimensional accuracy, surface quality and mechanical properties of molybdenum wire meet the requirements. The following is a detailed analysis from three aspects: wire diameter measurement, surface defect detection and tensile strength test.

#### 6.5.1 Wire diameter measuring instrument

Wire diameter gauges are used to accurately measure the diameter of molybdenum wire to ensure that it meets the tolerances.

Laser Wire Diameter Measuring InstrumentThe laser wire diameter measuring instrument adopts a non-contact measuring principle, with an accuracy of ±0.0001 mm, and is suitable for molybdenum wire with a diameter of 0.05-0.3 mm. The equipment is equipped with a high-speed scanning system with a measurement frequency of up to 1000 times per second, which can detect the diameter change of the molybdenum wire in real time.

The modern wire diameter measuring instrument is integrated into the wire drawing production line, and the diameter of the molybdenum wire is monitored in real time through the online inspection system, and fed back to the wire drawing machine for automatic adjustment.

#### 6.5.2 Surface Defect Detector

Surface defect detectors are used to detect defects such as scratches, cracks and oxides on the surface of molybdenum wire to ensure its surface quality.

Optical Microscope InspectionThe optical microscope inspector is equipped with a high-resolution CCD camera with a magnification of up to 1000 times, which is capable of detecting micron-level defects on the surface of molybdenum wire.

Eddy current testing equipmentEddy current testing equipment detects internal defects and surface cracks on the surface of molybdenum wire through the principle of electromagnetic induction, which is suitable for high-speed continuous inspection. The device has a sensitivity of up to 0.1 microns and a detection speed of up to 20 m/min.

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**Molybdenum Wire EDM Introduction**

## 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

## 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

## 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

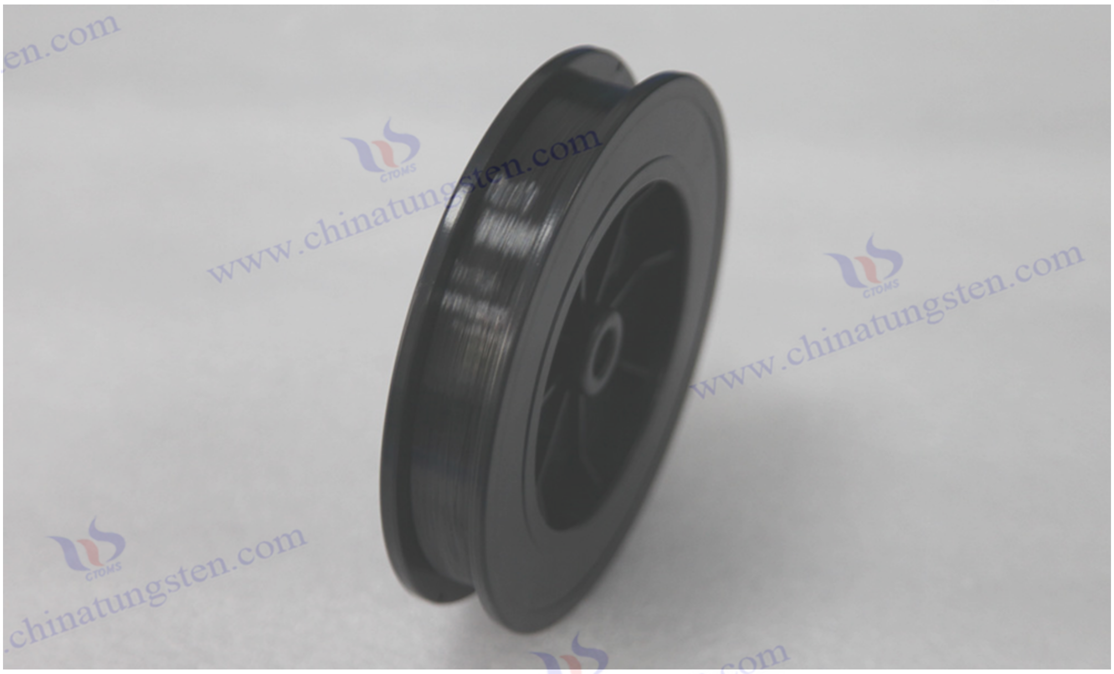
Website: www.molybdenum.com.cn

### 6.5.3 Tensile strength testing machine

Tensile strength testing machines are used to measure the mechanical properties of molybdenum wire to ensure that it does not break in a high-strength wire cutting environment.

Micro tensile testing machineThe micro tensile testing machine is designed for fine diameter molybdenum wires, with a test range of 0.1-100 N and an accuracy of ±0.1%. The equipment is equipped with high-precision fixtures to avoid damage to the molybdenum wire during the clamping process.

Dynamic Testing System Modern tensile strength testers are equipped with dynamic loading functions that simulate the actual stress state of molybdenum wire in wire EDM.



CTIA GROUP LTD molybdenum wire EDM

## Chapter 7 Domestic and Foreign Standards for Molybdenum Wire EDM

In order to standardize the production, testing and application of molybdenum wire, a series of strict standards have been formulated at home and abroad, covering many aspects such as chemical composition, mechanical properties, dimensional accuracy, surface quality and production process control. These standards provide a technical basis for manufacturers, provide users with a reference framework for quality assessment, and promote the continuous progress of molybdenum wire manufacturing technology. This chapter will comprehensively discuss the domestic and international standards of molybdenum wire EDM and the comparative analysis of the two, and deeply analyze the technical requirements, process impacts and application scenarios of the standards.

### 7.1 Domestic standard for molybdenum wire EDM

As a major country in the world's molybdenum reserves and production of molybdenum products,


TEL: 0086 592 512 9696
CTIAQCD -MA-E/P 2018- 2024V
sales@chinatungsten.com

China has formulated a number of national standards (GB/T) and industry standards to regulate the production and application of molybdenum wire. These standards put forward strict requirements for the chemical purity, mechanical properties, dimensional accuracy and surface quality of molybdenum wire EDM, which are widely used in the fields of wire-EDM, mold making, electronics industry and electric light source. The following is a detailed analysis of its technical content and application significance from the specific standards.

### 7.1.1 GB/T 4182-2017

GB/T 4182-2017 "Molybdenum Wire" is the core national standard for molybdenum wire formulated by China, which is suitable for molybdenum wire in wire EDM, electronic industry, electric light source and other high-tech fields. The standard comprehensively regulates the quality of molybdenum wire from many aspects such as chemical composition, mechanical properties, dimensional accuracy, surface quality and testing methods.

Chemical composition requirements

GB/T 4182-2017 stipulates that the molybdenum content of molybdenum wire for wire cutting must reach more than 99.95%, and the total content of impurity elements (such as iron, nickel, carbon, oxygen, nitrogen, etc.) shall not exceed 0.05%. Specifically, the iron (Fe) content ≤ 0.005%, nickel (Ni) content ≤ 0.003%, carbon (C) content ≤ 0.01%, oxygen (O) content ≤ 0.003%, and nitrogen (N) content ≤ 0.002%. High purity requirements ensure that molybdenum wire has excellent chemical stability in high-frequency discharge and high-temperature environments. For example, in wire EDM, high-purity molybdenum wire can significantly reduce electrode losses during discharge, extend service life and improve cutting efficiency. In addition, the strict control of trace elements in the standard also reduces the oxidation tendency of molybdenum wire at high temperatures, enhancing its reliability in complex processing environments.

Mechanical property requirements

The tensile strength and elongation at break of molybdenum wire are specified in detail in the standard. The tensile strength of molybdenum wire EDM in the range of 0.05-0.3 mm and the elongation at break should reach 1800-2200 MPa, and the elongation at break should be ≥2%. These performance indicators ensure that molybdenum wire can withstand continuous mechanical stress and discharge shock without breaking during high-tensile wire cutting. The standard also requires that molybdenum wire undergo appropriate heat treatment (such as vacuum annealing or hydrogen annealing) during the production process to optimize its crystal structure and eliminate the internal stresses generated during the drawing process, thereby improving toughness and fatigue resistance.

Dimensional accuracy and surface quality

GB/T 4182-2017 has extremely strict requirements for the dimensional accuracy of molybdenum wire, the diameter tolerance needs to be controlled within ±0.002 mm, and the roundness error ≤ 0.001 mm to ensure the uniformity of the discharge gap and the stability of the machining accuracy in the wire cutting process. In terms of surface quality, the standard requires that the surface roughness of molybdenum wire is Ra≤0.05 microns, and there shall be no cracks, scratches, oxides, oil stains or other microscopic defects on the surface. These requirements are critical to the discharge stability and surface finish of wire EDM, especially when machining microstructures or high-precision molds, where the surface quality of molybdenum wire directly affects the geometric accuracy and surface roughness of the machined parts.

Testing Methods & Quality Control

The standard specifies in detail the testing methods for molybdenum wire, including chemical composition analysis, mechanical property testing, dimensional measurement, and surface quality testing. Chemical composition analysis uses high-precision instruments such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or Atomic Absorption Spectroscopy (AAS) to ensure accurate measurement of impurity content. The mechanical properties test uses a miniature tensile testing machine to measure tensile strength and elongation at break with an accuracy of ±0.1%. The size measurement adopts a laser wire diameter measuring instrument, and the detection frequency can reach 1000 times/second to ensure the consistency of diameter. Surface quality inspection combines an optical microscope (1000x magnification) and an eddy current detector to identify surface defects in the 0.1 micron range. The standard also requires manufacturers to establish a sound quality control system, including raw material incoming testing, production process monitoring and finished product factory inspection, to ensure the consistency of the performance of each batch of molybdenum wire.

Significance of the application

GB/T 4182-2017 provides a unified technical specification for the production of molybdenum wire EDM, and promotes the standardization and large-scale development of the domestic molybdenum wire industry. The high requirements of this standard have prompted manufacturers to optimize raw material preparation, wire drawing processes and surface treatment techniques to improve the performance and reliability of molybdenum wires. In addition, the standard provides users with clear performance indicators for material selection and quality assessment in areas such as mold making, aerospace and electronics.

### 7.1.2 GB/T 3462-2017

GB/T 3462-2017 "Molybdenum rod and molybdenum wire" is a general national standard for molybdenum rod and molybdenum wire in China, which is suitable for various application scenarios such as wire cutting, electric light source, thermal spraying, etc. On the basis of GB/T 4182-2017, this standard further refines the classification, performance requirements and production process specifications of molybdenum wire.

Classification & Specifications

The standard divides molybdenum wire into three categories according to its application: molybdenum wire for wire cutting, molybdenum wire for electric light source and molybdenum wire for special purposes. The diameter range of molybdenum wire for wire cutting is 0.05-0.3 mm, and the diameter tolerance requirement is ±0.002 mm. The standard also classifies the surface condition of molybdenum wire, including black wire (unpolished with an oxide layer on the surface), white wire (electropolished with a smooth surface) and coated wire (coated with graphite emulsion or other lubricating coating). For example, white wire for wire EDM requires a surface roughness of Ra ≤0.02 microns to improve discharge stability, while coated wires need to ensure uniform coating thickness (1-2 microns) to reduce the coefficient of friction and extend service life.

Mechanical properties and heat treatment

GB/T 3462-2017 requires that the tensile strength of molybdenum wire for wire cutting is 1800-2300 MPa, and the elongation at break is ≥1.5%. Compared with GB/T 4182-2017, this standard has slightly higher strength requirements, reflecting the special needs of molybdenum wire EDM in a high-tensile processing environment. The standard also specifies that molybdenum wire should be annealed or vacuum heat treated at a temperature range of 800-1200°C and a protective atmosphere of hydrogen or high vacuum (≤$10^{-3}$ Pa) to eliminate residual stresses during the drawing process and optimize grain size (typically controlled at 5-10 microns). The standardization of the heat treatment process ensures the stability of the molybdenum wire in high-frequency discharge and mechanical stretching, and reduces the risk of wire breakage.

Packaging & Storage Requirements

The standard puts forward detailed requirements for the packaging and storage of molybdenum wire, which needs to be moisture-proof and oxidation-proof packaging, such as vacuum plastic bags or inert gas (argon or nitrogen) filled packaging, to prevent molybdenum wire from oxidation or moisture during transportation and storage. The packaging should be marked with the specification, batch number, weight and length of the molybdenum wire, for example, the length of each reel of molybdenum wire is usually 1000-3000 meters, and the weight is 0.5-2 kg. The standard also requires that the packaging material has sufficient compressive strength to avoid damage to the molybdenum wire during transportation. These requirements ensure that the molybdenum wire is delivered to the user at its best.

Significance of the application

GB/T 3462-2017 provides targeted technical guidance for different application scenarios by refining the classification and performance requirements of molybdenum wire. For example, the high strength and surface finish requirements of molybdenum wire for wire cutting make it suitable for high-precision mold processing; The high temperature stability of molybdenum wire for electric light source meets the needs of lamp manufacturing. The implementation of this standard has promoted the optimization of the production process of molybdenum wire and promoted the development of the domestic molybdenum wire industry in the direction of high performance and high added value.

### 7.1.3 Other relevant industry standards

In addition to national standards, China has also formulated a number of industry standards that put forward more specific requirements for molybdenum wire in specific application areas. These standards play an important role in high-tech fields such as aerospace, medical devices, and the electronics industry.

YS/T 357-2006

This industry standard is specifically developed for molybdenum wire for wire-EDM, with a focus on its chemical composition, dimensional accuracy and surface quality. The standard requires a molybdenum content of ≥ 99.95%, a total impurity content of ≤ 0.05%, a diameter tolerance of ±0.0015 mm, and a surface roughness of Ra≤0.02 microns. The standard also puts forward requirements for the wear resistance and stability of molybdenum wire in high-frequency discharge environments, such as when cutting cemented carbide or superalloy, the loss rate of molybdenum wire should be less than 0.1%. In addition, the standard requires that the molybdenum wire be electropolished or graphite emulsion coated to improve surface finish and lubricity, thereby reducing uneven arc and electrode losses during discharge.

HB 7742-2004

This aerospace industry standard is targeted at molybdenum wire applications in the aerospace sector, emphasizing high-temperature performance, fatigue resistance, and dimensional stability. The standard requires that the molybdenum wire maintain stable mechanical properties in a high temperature environment of 1500°C, with a tensile strength of ≥ 1800 MPa and a fatigue life of ≥ $10^6$ times. In terms of surface quality, the standard requires a surface roughness of Ra≤0.015 microns and no microscopic defects on the surface to meet the high-precision requirements of aero engine parts processing. The standard also puts forward specific requirements for the heat treatment process of molybdenum wire, such as heat treatment in a vacuum environment of 1600-1800°C to optimize the crystal structure and mechanical properties.

Other industry standards

In the field of medical devices, relevant industry standards (such as YY/T series) put forward higher requirements for the biocompatibility and surface quality of molybdenum wire. For example, medical molybdenum wire needs special surface treatment (such as electrolytic polishing and ultrasonic cleaning) to ensure non-toxicity and low surface roughness (Ra ≤ 0.01 microns), which is suitable for processing high-precision medical devices such as heart stents and bone screws. In addition, in the electronics industry, standards require molybdenum wire with extremely high dimensional consistency and conductivity to meet the processing needs of semiconductor molds and microelectronic connectors.

Significance of the application

These industry standards supplement the deficiencies of national standards and put forward more refined requirements for the application needs of specific fields. For example, YS/T 357-2006 promotes the application of molybdenum wire EDM in the processing of high-hardness materials; HB 7742-2004 ensures the reliability of molybdenum wire in the aerospace sector. The implementation of these standards not only improves the quality of molybdenum wire, but also promotes the technological progress and market competitiveness of related industries.

### 7.2 International standard for molybdenum wire EDM

International standards provide a global technical framework for the production and application of molybdenum wire, which is widely used in cross-border trade, technology exchange and international cooperation. The following is a detailed analysis of the international standard requirements for molybdenum wire EDM based on ASTM, ISO and other international standards.

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**Molybdenum Wire EDM Introduction**

### 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

### 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

### 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

**7.2.1 ASTM B387 Standard Specification for Molybdenum and Molybdenum Alloy Rods, Wires, and Plates**

ASTM B387 is a standard for molybdenum and molybdenum alloy products formulated by the American Society for Testing and Materials (ASTM), which is widely used in various scenarios such as molybdenum wire EDM, electric light source molybdenum wire and thermal spray molybdenum wire. This standard puts forward detailed requirements for the chemical composition, mechanical properties, dimensional accuracy and surface quality of molybdenum wire.

Chemical composition and classification

ASTM B387 classifies molybdenum wire into several grades, with Type 361 (high-purity molybdenum, molybdenum content ≥ 99.95%) being the main type of molybdenum wire for wire cutting. The standard requires the total content of impurity elements to be ≤ 0.05%, including ≤ 0.005% of iron (Fe), 0.003% ≤ nickel (Ni), 0.01% ≤ carbon (C), 0.005% ≤ oxygen (O), and 0.002% ≤ nitrogen (N). Compared to the domestic standard, ASTM B387 has slightly less stringent requirements for oxygen content, but the control of other impurities is just as strict. High purity requirements ensure the stability of molybdenum wire in high temperature and corrosive environments, and are suitable for wire EDM and electric light source manufacturing.

Mechanical property requirements

The standard stipulates that the tensile strength of molybdenum wire for wire cutting is 1700-2200 MPa, and the elongation at break is ≥2%, and the specific performance varies depending on the diameter and application. For example, molybdenum wire with a diameter of 0.1-0.2 mm needs to have a high tensile strength (≥2000 MPa) to withstand the high tension during wire cutting. The standard also requires that the molybdenum wire be annealed at a temperature of 800-1200°C and a protective atmosphere of hydrogen or vacuum to optimize mechanical properties and toughness. The annealing process requires strict control of the heating rate (5-10°C/min) and holding time (1-2 hours) to avoid excessive grain size or internal stress residues.

Dimensional accuracy and surface quality

ASTM B387 requires a molybdenum wire diameter tolerance of ±0.002 mm, a roundness error of ≤0.001 mm, a surface roughness of Ra≤0.05 microns, and no cracks, scratches, oxides, or other defects on the surface. These requirements ensure the uniformity of discharge and machining accuracy of molybdenum wire in wire EDM. In addition, the standard also puts forward requirements for the surface treatment of molybdenum wire, such as electrolytic polishing or chemical cleaning to remove the surface oxide layer to improve the surface finish and corrosion resistance.

Testing & Certification

The standard specifies the detection methods of molybdenum wire, including chemical composition analysis (using X-ray fluorescence spectroscopy or ICP-MS), mechanical property testing (using a micro tensile testing machine), dimensional measurement (using a laser wire diameter measuring instrument) and surface quality testing (using an optical microscope or scanning electron microscope). The test results are recorded in a quality certificate and provided to the user to ensure


TEL: 0086 592 512 9696
CTIAQCD -MA-E/P 2018- 2024V
sales@chinatungsten.com

traceability of product quality. The standard also requires manufacturers to regularly calibrate their testing equipment to ensure that the measurement accuracy meets the requirements (e.g., laser measuring instruments need to be accurate to ±0.0001 mm).

Significance of the application

ASTM B387 provides a unified technical specification for global molybdenum wire manufacturers, and promotes the circulation and application of molybdenum wire in the international market. The high requirements of this standard have driven improvements in production processes, such as the application of high-precision wire drawing, vacuum heat treatment, and surface polishing technology, which have improved the performance and reliability of molybdenum wire. In addition, the standard provides users with clear performance indicators for material selection and quality evaluation in the aerospace, electronics industry and mold making.

**7.2.2 ISO 9001 Quality Management System Certification**

ISO 9001 is a quality management system standard formulated by the International Organization for Standardization (ISO), although it is not a special standard for molybdenum wire, it is widely used in the quality management of molybdenum wire production enterprises to ensure the standardization of the production process and the stability of product quality.

Quality management system requirements

ISO 9001 requires manufacturers to establish a comprehensive quality management system, covering raw material procurement, production process control, product testing, packaging and transportation, and after-sales service. For the production of molybdenum wire, it is necessary to ensure the controllability of the whole process from molybdenum powder preparation, sintering, wire drawing, surface treatment to heat treatment. The standard requires enterprises to formulate a detailed quality control plan, including raw material acceptance standards, production parameter monitoring, finished product testing specifications, etc. For example, raw material molybdenum powder needs to undergo chemical composition analysis and particle size testing, diameter tolerance and surface quality need to be monitored in real time during the wire drawing process, and finished molybdenum wire needs to be tested for tensile strength and surface roughness.

Process Control & Traceability

ISO 9001 emphasizes the traceability of the production process and requires companies to record the production parameters (e.g., drawing speed, annealing temperature, surface treatment process) and testing data (e.g., diameter tolerance, surface roughness, tensile strength) of each batch of molybdenum wire. These records are kept for a minimum of 3 years and can be made available to users to track the quality of their products. In addition, the standard requires companies to conduct regular internal audits and management reviews to identify potential problems in the production process and implement improvements. For example, by analyzing data on the breakage rate during the drawing process, companies can optimize lubricant formulations or drawing die designs to improve production efficiency.

Continuous improvement and customer satisfaction

The standard requires enterprises to improve product quality and customer satisfaction through continuous improvement. For example, molybdenum wire manufacturers can reduce rejection rates and improve product consistency by introducing automated inspection equipment such as in-line laser wire diameter measuring instruments or optimizing heat treatment processes. ISO 9001 also requires companies to establish customer feedback mechanisms to deal with quality issues and improve production processes in a timely manner, thereby enhancing market competitiveness.

Significance of the application

ISO 9001 certification provides an international quality management framework for molybdenum wire manufacturers, which helps to improve production efficiency and product quality. For example, by implementing the ISO 9001 standard, companies can reduce the failure rate of molybdenum wire from 0.1% to 0.02% and shorten the production cycle by 20%. In addition, ISO 9001 certification enhances the company's competitiveness in the international market, facilitating access to markets with stringent quality requirements such as Europe, the United States and Japan.

### 7.2.3 Other international standards for molybdenum products

In addition to ASTM B387 and ISO 9001, there are several international standards related to molybdenum wire, which put forward more specific requirements for specific application areas.

JIS H 4461

The Japanese Industrial Standard (JIS H 4461) is suitable for molybdenum wire in electric light sources, wire EDM, and high-temperature applications. The standard requires a molybdenum content of ≥ 99.95%, a total impurity content of ≤0.05%, a tensile strength of 1700-2100 MPa, and a diameter tolerance of ± 0.002 mm. The standard places special emphasis on the performance stability of molybdenum wire in high-temperature environments, such as maintaining mechanical properties and dimensional stability at 1500°C. JIS H 4461 also imposes requirements on the surface treatment of molybdenum wire, such as the removal of the surface oxide layer by electrolytic polishing or chemical cleaning, and the surface roughness of Ra ≤0.03 microns to meet the high requirements of electric light source manufacturing.

DIN EN 10204 "Inspection Documentation for Metal Products"

This European standard requires molybdenum wire manufacturers to provide inspection documents to prove that the product meets the technical specifications. Document types include 2.1 (Declaration of Conformity), 3.1 (Manufacturer Certification) and 3.2 (Third Party Certification). For molybdenum wire EDM, the inspection file needs to contain test data on chemical composition, mechanical properties, dimensional accuracy and surface quality. For example, the 3.1 certificate shall record the tensile strength, diameter tolerance and surface roughness of the molybdenum wire, and be signed and confirmed by the quality department of the enterprise. DIN EN 10204 ensures the traceability of the quality of molybdenum wires and strengthens the trust of users in their products.

ISO 22489 Microbeam Analysis - Microprobe Microanalysis

This standard applies to the analysis of the surface and internal microstructure of molybdenum wire, especially in the aerospace and electronics industries. The standard specifies the use of an electron probe microanalyzer (EPMA) to detect the chemical composition and microscopic defects of molybdenum wires with an accuracy of 0.01%. For example, with EPMA analysis, molybdenum wire can be detected for oxides or inclusions in the range of 0.1 microns on the surface of the molybdenum wire, thus optimizing the surface treatment process. ISO 22489 provides advanced technical support for the inspection of high-precision molybdenum wires.

Significance of the application

These international standards provide technical support for the global production and application of molybdenum wire. For example, JIS H 4461 promotes the standardized production of molybdenum wire in the field of electric light source and wire cutting; DIN EN 10204 ensures traceability of product quality; ISO 22489 provides technical support for the microscopic analysis of high-precision molybdenum wires. The implementation of these standards has promoted the wide application of molybdenum wire in aerospace, electronics and medical fields, and improved the overall technical level of the global molybdenum wire industry.

**7.3 Standard comparative analysis of molybdenum wire EDM**

The difference between domestic and foreign standards directly affects the production process, quality control and market application of molybdenum wire. Through comparative analysis, we can deeply understand the applicability of domestic and foreign standards, technical requirements and their impact on product quality.

7.3.1 Differences between domestic and foreign standards

Chemical composition requirements

Domestic standards (such as GB/T 4182-2017, GB/T 3462-2017) require a molybdenum content of ≥ 99.95% and a total impurity content of ≤0.05%, which is basically consistent with the requirements of ASTM B387 (Type 361). However, domestic standards are more stringent in the control of specific impurities (such as oxygen and nitrogen), for example, GB/T 4182-2017 requires oxygen content ≤ 0.003% and nitrogen content ≤ 0.002%, while ASTM B387 allows oxygen content ≤ 0.005% and nitrogen content ≤ 0.003%. This difference reflects the higher stability requirements of domestic standards for molybdenum wire EDM in high-frequency discharge environments, especially when processing high-hardness materials (such as cemented carbide and titanium alloy), the low oxygen content can reduce the electrode loss during discharge.

Mechanical property requirements

The domestic standard requires the tensile strength of molybdenum wire EDM to be 1800-2300 MPa, which is slightly higher than the 1700-2200 MPa of ASTM B387. This is because domestic wire-cutting EDM equipment generally adopts high tension settings (tension up to 2-3 N), which has higher requirements for the strength of molybdenum wire. In addition, the requirements for elongation at break in the domestic standard (≥1.5%-2%) are slightly lower than those of ASTM B387 (≥2%), reflecting the domestic focus on the strength of molybdenum wire rather than toughness. This difference leads to the fact that domestic molybdenum wire is more suitable for the processing of high-strength and high-hardness materials, while international standard molybdenum wire has more advantages in scenarios with high toughness requirements (such as electric light source manufacturing).

Dimensional accuracy and surface quality

Both domestic and foreign standards require a diameter tolerance of ±0.002 mm, but domestic standards have stricter requirements for surface roughness (Ra≤0.02 micron vs. Ra ≤0.05 μm). This is related to the higher requirements of domestic EDM wire cutting for discharge stability and machining accuracy. For example, when machining microstructures (such as MEMS parts), the low surface roughness required by domestic standards can significantly reduce the uneven arc during discharge and improve the surface quality of the machined parts. In addition, the domestic standard has stricter control of surface defects, requiring the surface to be free of any microscopic scratches or oxides, while ASTM B387 allows trace surface defects (< 0.1 microns in diameter).

Testing Methods & Quality Control

The domestic and international standards are basically the same in terms of detection methods, such as ICP-MS to analyze chemical composition, laser wire diameter measuring instrument to detect dimensional accuracy, optical microscope and eddy current detector to detect surface quality. However, domestic standards place more emphasis on on-line testing and whole-process quality control. For example, GB/T 4182-2017 requires real-time monitoring of diameter tolerances and surface roughness during wire drawing and surface preparation, while ASTM B387 focuses more on off-line inspection of finished products. This difference reflects the higher requirements of domestic manufacturers for production efficiency and consistency, especially in high-volume production, where in-line inspection can significantly reduce the failure rate.

Packaging & Storage Requirements

Domestic standards (such as GB/T 3462-2017) have more detailed requirements for packaging and storage, clearly stipulating that vacuum or inert gas packaging is required to prevent molybdenum filament from oxidation or moisture, and requires the batch number, specification and weight to be marked. ASTM B387 has relatively lenient requirements for packaging, requiring only that the packaging protects the molybdenum wire from physical damage. This difference reflects the increased focus of domestic standards on the long-term storage and transportation stability of molybdenum wire, especially in humid or high-temperature environments.

### 7.3.2 The impact of standards on product quality

Production process optimization

The strict requirements of domestic and foreign standards have promoted the continuous improvement of molybdenum wire production process. For example, the requirements of GB/T 4182-2017 for low oxygen content have prompted enterprises to adopt high-vacuum sintering furnaces and hydrogen reduction furnaces to reduce the oxidation of molybdenum powder and molybdenum wire; ASTM B387's surface quality requirements have driven the widespread use of electropolishing, graphite emulsion coating, and ultrasonic cleaning techniques. These process improvements significantly improve the chemical stability, mechanical properties, and surface finish of molybdenum wire. For example, by optimizing the vacuum annealing process (1700°C, holding for 1.5 hours), the tensile strength of molybdenum wire can be increased from 1800 MPa to 2200 MPa, and the breakage rate can be reduced by 60%.

Quality consistency and reliability

The standardized requirements of the standard ensure the consistency and reliability of the quality of molybdenum wire. For example, the ISO 9001 quality management system requires enterprises to establish a whole-process quality control system, from raw material procurement to finished product testing, which needs to be recorded and monitored, so as to reduce the failure rate. The strict control of surface defects in domestic standards (such as YS/T 357-2006) has prompted enterprises to introduce high-precision testing equipment (such as scanning electron microscopes) to increase the detection rate of surface defects to more than 99.5%. These measures ensure the stable performance of molybdenum wire in applications such as wire EDM, electric light source and thermal spraying.

Market competitiveness is enhanced

Molybdenum wire that meets international standards has stronger competitiveness in the global market. For example, molybdenum wire that meets ASTM B387 and JIS H 4461 standards can be directly entered into the European, American and Japanese markets and is suitable for use in the semiconductor, aerospace and electric light source fields. ISO 9001 certification further enhances the company's brand reputation and market trust, and promotes the export of molybdenum wire and international cooperation. In addition, the high requirements of domestic standards have driven local companies to invest in technology research and development and quality control, enabling them to compete with global leaders in the international market.

Expansion of application areas

Strict standards promote the wide application of molybdenum wire in high-tech fields. For example, the HB 7742-2004 standard ensures the high-temperature performance and fatigue resistance of molybdenum wire in the aerospace field, and is suitable for machining turbine blades and titanium alloy parts; The JIS H 4461 standard promotes the application of molybdenum wire in the manufacture of electric light sources to extend the life of lamps; The ISO 22489 standard provides technical support for the microscopic analysis of molybdenum wires, meeting the ultra-high precision requirements in the semiconductor and medical device sectors. The implementation of these standards enables molybdenum wire to meet the needs of different industries for high-performance materials, and promotes the technological progress of related industries.

Technological innovation and future development

The high requirements of domestic and foreign standards have stimulated the continuous innovation of molybdenum wire production technology. For example, in order to meet the requirements of GB/T 4182-2017 for surface roughness, the company has developed a new electrolytic polishing slurry formulation (sulfuric acid: phosphoric acid = 3:1) to reduce the surface roughness from Ra 0.05 microns to Ra 0.01 microns. In order to meet the tensile strength requirements of ASTM B387, the company has introduced multi-pass drawing technology and high-precision drawing dies, which significantly improve the mechanical properties of molybdenum wire. In the future, with the rapid development of high-tech industries, molybdenum wire standards will be further refined and unified, and the development of intelligent production equipment, automated testing technology and green production process will be promoted.

CTIA GROUP LTD molybdenum wire EDM

## Chapter 8 Detection Methods of Molybdenum Wire EDM

The performance of molybdenum wire EDM directly affects the machining accuracy, efficiency and reliability of the final product. To ensure that molybdenum wire meets stringent quality requirements, a series of advanced testing methods are required to comprehensively evaluate its chemical composition, physical properties, mechanical properties, thermophysical properties, surface quality and environmental adaptability. These testing methods not only provide a basis for quality control for manufacturers, but also provide users with a reference framework for performance evaluation. This chapter will discuss in detail the various detection methods of molybdenum wire EDM, and deeply analyze their technical principles, equipment requirements, process parameters and application significance.

### 8.1 Chemical composition testing of molybdenum wire EDM

Chemical composition testing is the basis of quality control of molybdenum wire, which is designed to ensure high purity and low impurity content of molybdenum wire to meet the needs of high-precision applications such as wire EDM. The following is a detailed analysis from two aspects: spectral analysis and molybdenum purity detection.

#### 8.1.1 Spectroscopic analysis (ICP-MS)

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is a high-precision method for detecting the chemical composition of molybdenum wires, and is widely used for the analysis of molybdenum content and trace impurities.

Technical principle

ICP-MS uses a liquid sample to form a liquid sample by dissolving it in an acid solution (e.g., nitric acid or hydrochloric acid), which is then ionized using plasma (at a temperature of about 6,000-10,000°C) and analyzed by mass spectrometry to determine the mass to charge ratio of the ions. ICP-MS has detection limits down to ppb (parts per billion) and is capable of accurately measuring trace impurities in molybdenum wires such as iron (Fe), nickel (Ni), carbon (C), oxygen (O), nitrogen (N), etc. The standard requires a molybdenum content of ≥ 99.95% and a total impurity content of ≤0.05%, such as 0.005% ≤ iron and 0.003% oxygen ≤.

Equipment and process parameters

Modern ICP-MS equipment, such as the Agilent 7900 or Thermo Fisher iCAP Q, is equipped with a high-resolution mass spectrometer and an automated sampling system with an analytical accuracy of ±0.001%. Sample preparation needs to be performed in an ultra-clean environment to avoid contamination from the outside world. During the test, the plasma power is typically 1200-1500 W, the carrier gas (argon) flow rate is 0.8-1.2 L/min, and the analysis time is 5-10 minutes. In order to improve the detection efficiency, the multi-element simultaneous analysis mode can be adopted, covering molybdenum and more than 10 impurity elements.

Process Optimization & Challenges

The dissolution of molybdenum wire requires the use of high-purity acids (electronic grade nitric acid or hydrochloric acid) to avoid the introduction of additional impurities. During the test, the instrument needs to be calibrated, and the high-purity molybdenum standard sample (purity ≥ 99.999%) is used as a reference to ensure the accuracy of the measurement results. In addition, the detection of non-metallic elements such as oxygen and nitrogen requires a special detection module (e.g., collision reaction cell) to eliminate argon interference. The high sensitivity of ICP-MS enables it to detect impurities in the 0.1 ppb range, meeting the requirements of high-precision molybdenum wire for EDM.

Significance of the application

ICP-MS detection ensures high purity of molybdenum wire and reduces the impact of impurities on wire-EDM discharge stability and electrode loss. For example, the low oxygen content can reduce the oxidation tendency of molybdenum wire in high-temperature discharge and prolong the service life; The low iron content reduces the uneven arc during the discharge process and improves the machining accuracy. ICP-MS also provides traceable data for the quality certification of molybdenum wire, which meets the requirements of standards such as GB/T 4182-2017 and ASTM B387.

### 8.1.2 Molybdenum purity testing

Molybdenum purity testing is an accurate measurement of the content of the main component of molybdenum wire (molybdenum), usually in combination with methods such as ICP-MS, X-ray fluorescence spectroscopy (XRF) or atomic absorption spectroscopy (AAS).

Technical principle

Molybdenum purity testing verifies whether it meets the standard requirements of more than 99.95% by analyzing the relative content of molybdenum. XRF excites the surface of the molybdenum wire by X-rays, analyzes the intensity of the fluorescence spectrum, and determines the content of molybdenum and impurities, which is suitable for rapid and non-destructive detection. AAS accurately determines the molybdenum content by measuring the absorption of molybdenum atoms by a specific wavelength of light, with a detection accuracy of ±0.01%. Both methods need to be combined with ICP-MS to improve the comprehensiveness and accuracy of the assay.

Equipment and process parameters

XRF equipment (e.g., the Bruker S8 TIGER) uses a high-energy X-ray source (50 kV, 1 mA) with an inspection time of 1-3 minutes, making it suitable for in-line inspection. AAS devices, such as the PerkinElmer PinAAcle 900, use a molybdenum hollow cathode lamp with a wavelength of 313.3 nm and a detection limit of 0.01 ppm. Sample preparation involves cutting the molybdenum wire into small segments (1-2 cm) and cleaning the surface to remove oil and oxides to ensure reliable results.

Process Optimization & Challenges

Molybdenum purity testing requires strict control of environmental conditions to avoid moisture or oxidation of the sample. XRF testing requires calibration of the instrument using a high-purity molybdenum standard sample (NIST certified) as a reference; AAS detection needs to optimize the flame temperature (about 2700°C) and gas flow (acetylene 2 L/min, air 10 L/min) to improve the measurement sensitivity. During the detection process, special attention should be paid to the interference of non-metallic elements such as carbon and oxygen, and surface impurities can be removed through chemical pretreatment (such as pickling).

Significance of the application

Molybdenum purity testing is the core link of quality control, which directly affects the performance of molybdenum wire in wire EDM. High-purity molybdenum wire (≥ 99.95%) has excellent conductivity and high temperature resistance, which can maintain stability in high-frequency discharge environments and reduce electrode losses. The test results also provide data to support the optimization of the production process of molybdenum wire, for example by analyzing the source of impurities, which can improve the molybdenum powder reduction and sintering process.

## 8.2 Testing of physical properties of molybdenum wire EDM

Physical property testing is used to evaluate the dimensional accuracy and surface properties of molybdenum wire to ensure that it meets the high precision and surface quality requirements of wire EDM. The following is a detailed analysis from two aspects: wire diameter and tolerance measurement, and surface roughness test.

### 8.2.1 Wire Diameter and Tolerance Measurement

Wire diameter and tolerance measurement is a key test to ensure the dimensional consistency of molybdenum wire, which affects the discharge gap and machining accuracy in the wire cutting process.

Technical principle

Wire diameter measurement usually uses non-contact laser measurement technology, which scans the surface of the molybdenum wire through a laser beam to obtain diameter data with an accuracy of ±0.0001 mm. The standard (such as GB/T 4182-2017) requires the diameter tolerance of molybdenum wire EDM to be ±0.002 mm, and the roundness error ≤ 0.001 mm. During the measurement process, the influence of the ovality and surface unevenness of the molybdenum wire on the results should be considered.

Equipment and process parameters

Laser wire diameter gauges, such as the Keyence LS-9000, are equipped with a high-frequency laser scanning system with a measurement frequency of up to 1000 times/sec and are suitable for both in-line and off-line inspections. The device needs to be calibrated to the standard filament (diameter error ± 0.00005 mm) to ensure measurement accuracy. During the inspection, the molybdenum wire passes through the measuring area at a speed of 5-20 m/min and the ambient temperature is controlled at 20±2°C to avoid the effects of thermal expansion.

Process Optimization & Challenges

In-line testing needs to ensure the operational stability of the molybdenum wire and avoid measurement errors caused by vibration or tension changes. For offline detection, multi-segment molybdenum wires (10-20 meters per section) need to be sampled and measured, and the mean diameter and standard deviation are counted to ensure consistency. During the inspection process, the laser lens needs to be cleaned regularly to avoid dust interference. To increase efficiency, multi-point simultaneous measurement technology can be used to simultaneously inspect multiple cross-sections of molybdenum wires.

Significance of the application

Accurate wire diameter and tolerance measurement ensures the uniformity of the discharge gap of the molybdenum wire in EDM wire cutting, avoiding deviations during processing. For example, molybdenum wire with a diameter tolerance of ±0.0015 mm can control the machining tolerance within ±0.005 mm, which meets the needs of high-precision molds and microstructure processing. The measured data also provides the basis for the optimization of the drawing process, e.g. by analyzing diameter deviations, adjusting the drawing die hole size or lubricant formulation.

### 8.2.2 Surface roughness test

The surface roughness test is used to evaluate the finish of the surface of the molybdenum wire, which directly affects the discharge stability and the surface quality of the machined parts in wire cutting.

Technical principle

Surface roughness testing is usually done using a contact or non-contact method. Contact methods (e.g., profilometers) scan the surface of the molybdenum wire with a probe, measure the change in surface height, and calculate the Ra value (arithmetic mean roughness). Non-contact methods, such as laser microscopy, analyze surface topography by laser reflection with an accuracy of 0.001

microns. The standard requires a surface roughness of Ra ≤0.02 microns for molybdenum wire EDM to ensure uniform discharge and low friction performance.

Equipment and process parameters

Contact profilers (e.g., Mitutoyo SJ-410) are equipped with a diamond probe with a scanning speed of 0.5-1 mm/s and a measurement length of 2-5 mm. Non-contact laser microscopes, such as the Keyence VK-X1000, employ a 405 nm laser with a magnification of 1000-2000x and a measurement accuracy of ± 0.002 μm. During the inspection, the molybdenum wire should be fixed on a non-vibration platform, and the ambient humidity should be controlled at 40-60% to avoid the influence of moisture.

Process Optimization & Challenges

The surface roughness test ensures that the surface of the molybdenum wire is clean, free of oil or oxides, and that the sample can be pretreated with ultrasonic cleaning (frequency 40 kHz, time of 5 minutes). The contact test needs to control the probe pressure (0.1-0.5 mN) to avoid scratching the surface of the molybdenum wire; Non-contact testing requires calibration of the laser focal length to ensure the accuracy of the topography data. During the detection process, multi-segment molybdenum wire (5-10 cm per segment) needs to be sampled and tested, and the distribution range of Ra value is counted.

Significance of the application

Molybdenum wire with low surface roughness can reduce the uneven arc in EDM wire cutting, improve discharge stability and machining accuracy. For example, a molybdenum wire ≤ 0.015 microns can control the surface roughness of the machined parts below Ra 0.1 microns, which meets the requirements of optical lens molds and semiconductor parts. The test data also provides a basis for the optimization of surface treatment processes such as electropolishing.

## 8.3 Testing of mechanical properties of molybdenum wire EDM

Mechanical property testing is used to evaluate the strength and toughness of molybdenum wire to ensure that it does not break or deform in a high-tensile wire cutting environment. The following is analyzed from two aspects: tensile strength test, elongation and curl test.

### 8.3.1 Tensile strength test

Tensile strength testing is a core method for evaluating the mechanical properties of molybdenum wire, reflecting its ability to withstand tensile loads.

Technical principle

The tensile strength test calculates the tensile strength (unit: MPa) by fixing the molybdenum wire on a tensile testing machine, applying a gradually increasing tensile force, and measuring the maximum load before breakage. The standard requires a tensile strength of 1800-2300 MPa for molybdenum wire EDM to meet the needs of high-tension (2-3 N) wire-cutting. The test also measures the deformation at the breaking point and evaluates the toughness of the molybdenum wire.

Equipment and process parameters

Micro tensile testing machines (e.g., Instron 5948) are designed for fine diameter molybdenum wires with a test range of 0.1-100 N and an accuracy of ± 0.1%. The fixture is wrapped with a soft material such as rubber or PTFE to avoid damage to the molybdenum wire during the clamping process. The test speed is 1-5 mm/min, the sample length is 50-100 mm, and the ambient temperature is controlled at 20±2°C to ensure consistent results.

Process Optimization & Challenges

The test needs to ensure that the molybdenum wire is clamped evenly to avoid premature fracture caused by local stress concentrations. Samples are randomly selected (10-20 samples per batch) covering different production stages to assess performance consistency. During the test, the stress-strain curve is recorded to analyze the elastic modulus (about 320 GPa) and fracture behavior of the molybdenum wire. To increase efficiency, automated test systems can be used to record and analyze data in real time.

Significance of the application

Molybdenum wire with high tensile strength is able to withstand the high tension and discharge impact during the wire cutting process, reducing the risk of wire breakage. For example, molybdenum wire with a tensile strength of 2200 MPa can be stable and long service life in the machining of high-hardness materials such as cemented carbide. The test data also provides the basis for the optimization of the heat treatment process, e.g. by adjusting the annealing temperature (1000-1200°C), which can increase the tensile strength by 10-15%.

**8.3.2 Elongation and curl test**

Elongation and curvature tests are used to evaluate the toughness and winding properties of molybdenum wire, affecting its suitability in winding and wire cutting.

Technical principle

The elongation test calculates the elongation at break (1.5%-2% as required by the standard≥ by measuring the elongation of the molybdenum wire before breakage. The curvature test evaluates the flexibility of molybdenum wire by winding it around a standard mandrel (1-5 mm diameter) to see if cracks or fractures appear. The combination of the two reflects the deformation ability and winding stability of molybdenum wire in a high-tensile environment.

Equipment and process parameters

The elongation test uses a miniature tensile testing machine under the same conditions as the tensile strength test, and records the elongation before break (accuracy ± 0.01 mm). The curvature test uses a special winding device and the mandrel diameter is selected according to the molybdenum wire specification (e.g., a 2 mm mandrel is used for 0.18 mm molybdenum wire). The test should be carried out in a vibration-free environment with a winding speed of 10-20 cycles per minute and a winding cycle of 5-10 turns.

Process Optimization & Challenges

The elongation test needs to ensure that the surface of the molybdenum wire is free of defects, and the sample is pretreated with ultrasonic cleaning. The curl rate test needs to control the winding tension (0.1-0.5 N) to avoid scratching the molybdenum wire on the surface of the mandrel rod. During the test, multi-segment molybdenum wires need to be sampled, and the elongation and curl defect rate should be counted to ensure consistent performance. In order to improve the accuracy of the test, digital image analysis technology can be used to record the microscopic deformation during the winding process.

Significance of the application

Molybdenum wire with high elongation and curvature has excellent toughness and winding properties, and is suitable for high-precision wire cutting machines and electric light source manufacturing. For example, a molybdenum wire with an elongation of 2% can be stabilized at high tension (3 N), reducing wire breakage; The molybdenum wire with qualified curvature can be smoothly wound on a 2000-meter-long bobbin to meet the needs of continuous processing.

**8.4 Testing of thermophysical properties of molybdenum wire EDM**

The thermophysical performance test is used to evaluate the stability and electrical and thermal conductivity of molybdenum wire in high-temperature environments, which affects its application effect in wire-EDM and electric light source.

**8.4.1 High temperature stability test**

The high-temperature stability test is used to evaluate the mechanical properties and structural stability of molybdenum wire in a high-temperature environment.

Technical principle

The test measures the tensile strength, elongation and crystal structure of the molybdenum wire by exposing it to a high temperature environment (1000-1800°C). The standard requires that the molybdenum wire maintain a tensile strength of ≥ 1800 MPa at 1500°C, with no obvious grain growth or oxidation. The test is usually performed in a vacuum or inert gas (argon or hydrogen) environment to avoid oxidation.

Equipment and process parameters

High-temperature test furnaces (e.g. Carbolite Gero HTF 1800) are equipped with molybdenum or tungsten heating elements, with a temperature control accuracy of ±5°C and a vacuum level of $\leq 10^{-3}$ Pa. The length of the test sample was 50-100 mm, the heating rate was 5-10°C/min, and the holding time was 1-2 hours. After the test, the grain size was analyzed by X-ray diffraction (XRD) and the surface topography was observed by scanning electron microscopy (SEM).

Process Optimization & Challenges

The test requires strict control of the protective atmosphere to avoid oxygen infiltration and oxidation of the molybdenum wire. The sample should be heated evenly to prevent abnormal grain growth caused by local overheating. During the test, the temperature-time curve should be recorded to analyze the thermal stability of the molybdenum wire. To increase efficiency, a multi-channel test system can be used to test multiple molybdenum wires at the same time.

Significance of the application

High temperature stability testing ensures the reliability of molybdenum wire in wire EDM and electric light source manufacturing. For example, molybdenum wire stabilized at 1500°C can be used to process superalloy parts and extend electrode life; The test data also provides a basis for the optimization of the heat treatment process, e.g. by adjusting the annealing temperature, which can control the grain size from 5 to 10 microns.

### 8.4.2 Electrical and thermal conductivity tests

Electrical and thermal conductivity tests are used to evaluate the electrical and thermal properties of molybdenum wire, affecting its efficiency in EDM.

Technical principle

The conductivity test measures the resistivity of the molybdenum wire by measuring the resistivity of the molybdenum wire by means of a four-probe method and calculates the conductivity (the standard requires about 18 MS/m). The thermal conductivity test calculates the thermal conductivity by measuring the thermal diffusivity by measuring the laser flash method (the standard requires about 138 W/m·K). The combination of the two reflects the current transfer and heat diffusion capabilities of the molybdenum wire in high-frequency discharge.

Equipment and process parameters

Conductivity testing uses a four-probe resistivity meter (e.g., Keithley 2635B) with a probe spacing of 0.5-1 mm and a current range of 1-10 mA with a measurement accuracy of ± 0.01%. The thermal conductivity test uses a laser flash analyzer (e.g., Netzsch LFA 467) with a laser pulse energy of 10-20 J, a sample thickness of 0.1-0.3 mm, and a test temperature of 20-1000°C.

Process Optimization & Challenges

The test needs to ensure that the surface of the molybdenum wire is clean and that the oxide layer or oil contamination does not affect the resistivity measurement. The thermal conductivity test requires calibration of the sample thickness with an error of ±0.001 mm. During the test, the influence of temperature on electrical and thermal conductivity should be recorded, and the performance change of molybdenum wire in high-temperature discharge should be analyzed. To increase efficiency, automated test systems can be used to record data in real time.

Significance of the application

Molybdenum wire with high electrical and thermal conductivity can improve the discharge efficiency of wire EDM and reduce heat accumulation. For example, a molybdenum wire with a conductivity of 18 MS/m can reduce discharge energy loss by 10%; The molybdenum wire with a thermal conductivity of 138 W/m·K can quickly dissipate heat and extend the life of the electrode. The test data also provides a basis for material selection and process optimization of molybdenum wire.


TEL: 0086 592 512 9696
CTIAQCD -MA-E/P 2018- 2024V
sales@chinatungsten.com

**CTIA GROUP LTD**

**Molybdenum Wire EDM Introduction**

## 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

## 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

## 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

## 8.5 Surface quality inspection of molybdenum wire EDM

Surface quality inspection is used to evaluate the microscopic defects and finish of the surface of molybdenum wire, which directly affects the discharge stability and machining accuracy.

8.5.1 Microscopic observation

Microscopy is a common method for detecting surface defects in molybdenum wires, enabling the identification of scratches, cracks, and oxides at the micron level.

Technical principle

The surface morphology of the molybdenum wire is observed by optical microscope at high magnification (1000-2000x) to identify defects in the 0.1 micron range. Scanning electron microscopy (SEM) provides higher resolution (0.01 microns) through electron beam scanning to analyze surface microstructure and elemental distribution. The standard requires that the surface of the molybdenum wire is free of cracks, scratches or oxides, and the roughness is Ra≤0.02 microns.

Equipment and process parameters

Optical microscopes (e.g., Zeiss Axio Observer) are equipped with a CCD camera with a magnification of 1000x and a field of view of 0.1-1 mm. SEMs (e.g., JEOL JSM-7800F) use a 5-15 kV electron beam with a scanning speed of 1-10 sec/frame. Before the test, the molybdenum wire should be ultrasonically cleaned (frequency 40 kHz, time time 5 minutes) to remove oil and dust from the surface.

Process Optimization & Challenges

The test should be carried out in a vibration-free and dust-free environment to avoid external interference. The light microscope needs to calibrate the light source intensity to ensure that the image is clear; SEM needs to optimize the electron beam energy to avoid surface damage to the molybdenum wire. During the test, multiple segments of molybdenum wire (5-10 cm per section) should be sampled, and the defect distribution and incidence should be counted.

Significance of the application

Microscopic observation ensures that the surface of the molybdenum wire is smooth and free of microscopic defects, and reduces the uneven arc in wire EDM. For example, molybdenum wire with no scratches in the 0.1 micron range can control the surface roughness of the machined part below Ra 0.1 microns, which meets the requirements of high-precision molds. The test data also provides a basis for the optimization of surface treatment processes such as electropolishing.

### 8.5.2 Non-destructive testing techniques (ultrasonic, eddy current)

Non-destructive testing technology is used to detect microscopic defects on the surface and inside of molybdenum wires to ensure consistent quality.

Technical principle

Ultrasonic testing detects inclusions, porosity or cracks inside molybdenum wires by propagating high-frequency sound waves (1-10 MHz) to a depth of up to 0.01 mm. Eddy current testing uses electromagnetic induction to identify surface and near-surface defects (e.g., scratches in the 0.1 micron range) with a sensitivity of 0.05 microns. The combination of the two allows for a comprehensive assessment of the quality of the molybdenum wire.

Equipment and process parameters

Ultrasonic detectors, such as the Olympus EPOCH 650, use a 5 MHz probe with a couplant of high-purity water and a scanning speed of 10-20 mm/s. Eddy current detectors (e.g., Eddyfi Ectane 2) use an excitation frequency of 100 kHz-1 MHz with a probe spacing of 0.1-0.5 mm. The test should be carried out in a constant temperature environment (20±2°C) to avoid temperature fluctuations affecting the results.

Process Optimization & Challenges

Ultrasonic testing needs to optimize the coating uniformity of the couplant to avoid bubble interference. Eddy current testing requires calibration of the probe sensitivity to ensure detection of defects in the 0.1 micron range. During the test, the multi-segment molybdenum wire needs to be continuously scanned to calculate the defect incidence and distribution. To increase efficiency, an automated scanning system can be used to record defect data in real time.

Significance of the application

Non-destructive testing technology ensures that molybdenum wire is free of internal and surface defects, improving its reliability in high-precision wire cutting. For example, eddy current testing can identify surface scratches in the 0.05 micron range to reduce uneven discharge, while ultrasonic testing can detect internal inclusions as deep as 0.01 millimeters, reducing the risk of wire breakage. The test data provides the basis for the optimization of the drawing and surface treatment processes.

## 8.6 Environmental adaptability test of molybdenum wire EDM

Environmental suitability testing is used to evaluate the performance of molybdenum wire in corrosive or high-temperature environments, affecting its stability under complex processing conditions.

### 8.6.1 Corrosion Resistance Test

Corrosion resistance tests are used to evaluate the stability of molybdenum wire in corrosive media such as acids, alkalis, or salt solutions.

Technical principle

The test measures the rate of mass loss or the degree of surface corrosion by immersing the molybdenum wire in a corrosive medium (e.g., a 5% NaCl solution or a 10% $HNO_3$ solution). The standard requires that the mass loss rate of molybdenum wire in the 24-hour corrosion test is ≤0.01%, and there are no obvious corrosion traces on the surface. The test can also be combined with electrochemical methods to measure the corrosion potential and current density of the molybdenum wire.

Equipment and process parameters

Corrosion test chambers (e.g. Q-FOG CCT) control temperature 40-60°C, humidity 80-95%, test time 24-72 hours. Potrentiostats (e.g., Gamry Interface 1010E) use a three-electrode system (molybdenum wire as the working electrode, platinum electrode as auxiliary electrode, and saturated calomel electrode as reference electrode) with a test potential range of -1 to 1 V and a scan rate of 1 mV/s.

Process Optimization & Challenges
Testing is done to ensure the purity of the media and to avoid interference from impurities. Electrochemical testing requires calibration of electrode spacing (1-2 mm) to ensure measurement accuracy. During the test, the corrosion rate and surface morphology changes should be recorded, and the corrosion resistance mechanism of the molybdenum wire should be analyzed. To increase efficiency, a multi-channel test system can be used to test multiple molybdenum wires at the same time.

Significance of the application
Molybdenum wire with high corrosion resistance can be stabilized in wet or acidic environments, making it suitable for wire cutting scenarios with corrosive coolant. For example, a molybdenum wire that has passed the corrosion resistance test can work continuously for 100 hours in a coolant containing 5% NaCl without any traces of corrosion on the surface. The test data provides a basis for the design of surface coatings (e.g. graphite emulsion) of molybdenum wire.

**8.6.2 High temperature oxidation test**
The high-temperature oxidation test is used to evaluate the oxidation resistance of molybdenum wire in a high-temperature air environment.

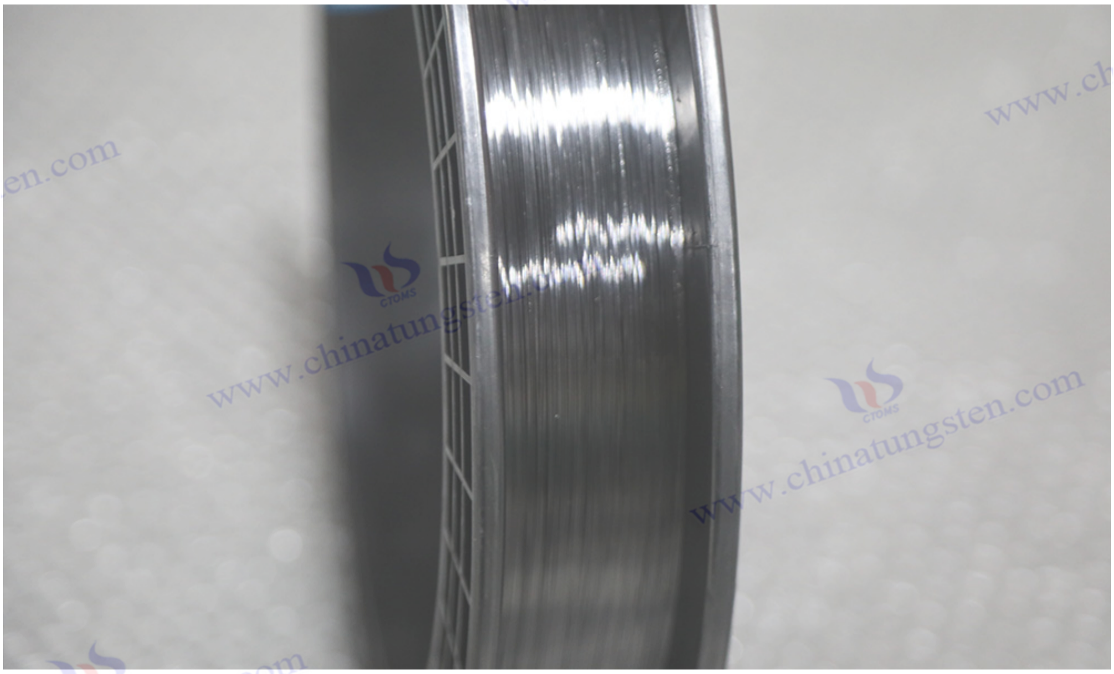
Technical principle
The test measures the oxidative weight gain rate or the thickness of the oxide layer on the surface by placing the molybdenum wire in high-temperature air (500-1000°C). The standard requires that the oxidation weight gain rate of molybdenum wire at 800°C for 24 hours is ≤0.1%, and the oxide layer thickness is ≤ 0.5 microns. The test can also be combined with thermogravimetric analysis (TGA) to record quality changes in real time.

Equipment and process parameters
High-temperature oxidizers (e.g. Nabertherm HT 08/18) control temperature accuracy ± 5°C, air flow 0.1-0.5 L/min, test time 12-48 hours. Thermogravimetric analyzers (e.g., TA Instruments Q500) measure ± 0.1 μg with a heating rate of 5-10°C/min. After the test, the oxide composition and thickness were analyzed using SEM and energy dispersive spectroscopy (EDS).

Process Optimization & Challenges
The test needs to control the air humidity (<10%) to avoid accelerated oxidation of moisture. The sample needs to be heated evenly to prevent local overheating and uneven oxide layer. During the test, the oxidation kinetic curve should be recorded to analyze the oxidation rate and mechanism. To increase efficiency, a multi-channel thermogravimetric analyzer can be used to test multiple

molybdenum wires at the same time.

Significance of the application
Molybdenum wire with high oxidation resistance can remain stable in high-temperature discharge environment and prolong service life. For example, molybdenum wire with an oxidative weight gain rate of ≤0.05% at 800°C can be used in the manufacture of electric light sources, and the high temperature resistance is increased by 20%. The test data provides an optimal basis for the heat treatment and surface protection process of molybdenum wire.



CTIA GROUP LTD molybdenum wire EDM

## Chapter 9 Optimization and Technical Improvement of Molybdenum Wire EDM

With the increasing demand of modern industry for high precision, high efficiency and low cost, the optimization and technical improvement of molybdenum wire have become the focus of industry research. Optimization directions include improving tensile strength and durability, improving surface treatment processes, reducing the rate of wire breakage, improving cutting efficiency, and introducing intelligent production technologies. This chapter will discuss these optimization methods and technical improvements in detail, and deeply analyze their technical principles, process parameters, equipment requirements and application significance, aiming to provide a comprehensive technical reference for the production and application of molybdenum wire.

### 9.1 Methods for improving tensile strength and durability

Tensile strength and durability are the core performance indicators of molybdenum wire EDM, which directly affect its stability and service life in high-tensile wire-cutting environments. The following is a detailed analysis of methods to improve tensile strength and durability from the aspects of material optimization, heat treatment improvement, microstructure control, and doping technology.

Preparation and optimization of high-purity molybdenum powder

The tensile strength and durability of molybdenum wire are closely related to the purity of its raw materials. High-purity molybdenum powder (purity≥99.95%) can significantly reduce the damage of impurity elements (such as iron, nickel, carbon, oxygen, nitrogen) to the crystal structure, thereby improving the strength and toughness of the material. The preparation of high-purity molybdenum powder is usually carried out by a multi-stage hydrogen reduction process, in which molybdenum oxide ($MoO_3$) is gradually reduced to metal molybdenum powder by using a continuous hydrogen reduction furnace (working temperature 600-1100°C, hydrogen flow rate 1-2 L/min, pressure 0.1-0.5 MPa). The reduction process is divided into a low temperature phase (600-800 °C, $MoO_2$ is generated) and a high temperature stage (900-1100 °C, molybdenum metal is generated), and the heating rate (5-10 °C/min) and holding are precisely controlled(1-2 hours) to ensure that the particle size distribution of molybdenum powder is 1-3 microns, and the particle size uniformity deviation is ≤ 0.1 microns. The modern reduction furnace is equipped with a high-precision temperature control system (accuracy ± 5 °C) and a gas purification device (removal rate ≥ 99.9%), which controls the oxygen content in the molybdenum powder at ≤0.003%, the carbon content ≤ 0.01%, and the iron content ≤ 0.005%. In addition, molybdenum powder is screened by an air classifier (air velocity of 10-20 m/s, separation accuracy ±0.05 microns) to remove large and agglomerated particles to further improve the purity and consistency of the raw materials. The optimized molybdenum powder provides a high-density, homogeneous blank for the subsequent sintering process, ensuring that the molybdenum wire has excellent mechanical properties.

Optimization of the heat treatment process

Heat treatment is a key part of improving the tensile strength and durability of molybdenum wire, enhancing performance by eliminating internal stresses during the drawing process, optimizing crystal structure, and improving material toughness. Heat treatment is usually done in a vacuum heat treatment furnace (temperature 1600-1800°C, vacuum degree ≤ $10^{-3}$ Pa) or hydrogen annealing furnace (temperature 800-1200 °C, hydrogen flow 0.5-1 L/min). Vacuum heat treatment can control the grain size of molybdenum wire at 5-10 microns, increase the tensile strength to 2000-2300 MPa, and increase the elongation at break to 2-3% through high temperature (1700°C) for 1-2 hours and the heating rate of 5-10°C/min. Hydrogen annealing is heated in sections (preheating 600-800 °C, holding 1000-1100 °C, cooling rate 5 °C/min), which effectively eliminates residual stress and reduces the risk of fracture. Modern heat treatment furnaces are equipped with a multi-stage temperature control system (accuracy ± 3°C) and an online monitoring device that records temperature, pressure and gas flow in real time to ensure process stability. In addition, by optimizing the heat treatment parameters (e.g., extending the holding time to 2.5 hours or reducing the cooling rate to 3°C/min), the grain uniformity can be further improved and grain boundary defects can be reduced, thereby enhancing the fatigue resistance and durability of the molybdenum wire.

Microstructure control

The tensile strength and durability of molybdenum wire are closely related to its microstructure. By controlling the grain size and grain boundary properties, the mechanical properties of the material can be significantly improved. Using hot isostatic pressing (HIP) sintering technology (temperature 1800-2000°C, pressure 100-200 MPa, argon protection), the density of molybdenum billet can be increased to 99.5%, internal porosity and inclusions can be reduced, and the tensile strength can be increased to more than 2200 MPa. During the wire drawing process, through multi-pass drawing (20-30 passes, single-pass surface reduction rate of 10-15%) and intermediate annealing (900-1100 °C, holding for 10-20 seconds), the grain (size 3-8 microns) can be refined, the fibrous crystal structure can be enhanced, and the strength and toughness of the molybdenum wire can be improved. In addition, X-ray diffraction (XRD) is used to analyze grain size and orientation, and scanning electron microscopy (SEM) is used to observe microscopic defects to ensure that the structure optimization meets the requirements of standards (e.g., GB/T 4182-2017).

Doping technology and alloying

Adding trace elements (e.g., lanthanum, cerium, yttrium) to molybdenum wire can further improve its tensile strength and durability. For example, the doping of 0.1-0.5% lanthanum oxide ($La_2O_3$) can form fine oxide particles (0.1-0.5 μm in diameter), which can increase the tensile strength to 2300-2500 MPa through a precipitation strengthening mechanism, while improving creep resistance at high temperatures. The doping process needs to evenly distribute the doping elements through powder metallurgy technology in the sintering stage, the sintering temperature is controlled at 1900-2100 °C, and the holding time is 2-3 hours. The doped molybdenum wire can still maintain stable mechanical properties in a high temperature environment of 1500°C, and the fatigue life is extended to more than $10^6$ times. In addition, by controlling the particle size (0.05-0.2 microns) and distribution uniformity (deviation ≤5%) of the doped elements, the agglomeration effect can be avoided and the stability of the molybdenum wire properties can be ensured.

Significance of the application

Methods that improve tensile strength and durability significantly enhance the performance of molybdenum wire in high-tensile wire cutting environments. Molybdenum wire with tensile strength of 2200 MPa can withstand the tension of 3-5 N, which is suitable for processing high-hardness materials such as cemented carbide and titanium alloy. The durability-optimized molybdenum wire can work continuously for more than 100 hours in a high-frequency discharge environment, and the wire breakage rate is reduced to less than 0.05%. These improvements provide greater stability and efficiency for wire EDM to meet the demanding requirements of aerospace, mold making, and more.

### 9.2 Optimize the surface treatment process

The surface treatment process directly affects the surface quality, finish and wear resistance of molybdenum wire, which is very important for the discharge stability and machining accuracy of wire EDM. The following is a detailed analysis of the methods for optimizing the surface treatment process from the aspects of alkali washing, electrolytic polishing and coating technology.

Optimization of the caustic washing process

Caustic washing is used to remove oxides, oils and particles from the surface of molybdenum wire to improve surface cleanliness. The optimized caustic washing process adopts a continuous caustic washing tank (material: stainless steel or PTFE), using 5-10% sodium hydroxide (NaOH) solution, the temperature is controlled at 60-80 °C, the molybdenum wire passing speed is 5-10 m/min, and the cleaning time is 10-20 seconds. Modern caustic washing equipment is equipped with an ultrasonic oscillator (frequency 40-60 kHz, power 100-200 W), which increases the removal rate of surface impurities up to 99.9% and reduces the surface roughness to Ra 0.05 microns. In addition, by optimizing the solution formulation (adding 0.5% surfactant), the cleaning effect can be enhanced and surface residues can be reduced. In order to meet the requirements of environmental protection, the caustic washing equipment is equipped with a waste liquid treatment system, which increases the removal rate of heavy metal ions in the waste liquid to more than 95% through acid-alkali neutralization (pH 6-8) and filtration device (pore size 0.1 microns).

Improvement of electropolishing technology

Electrolytic polishing removes microscopic bumps on the surface of molybdenum wire through electrochemical reactions, further improving surface finish and corrosion resistance. The optimized electropolishing process uses a mixed electrolyte of sulfuric acid and phosphoric acid (3:1 ratio, concentration 20-30%) at a temperature of 50-70°C, a current density of 10-20 A/dm², and a polishing time of 5-15 seconds. Modern electropolishing equipment, such as continuous polishing tanks, is equipped with a constant current power supply (accuracy ± 0.1%) and an automatic temperature control system (accuracy ± 2°C), which reduces the surface roughness to less than Ra 0.015 microns and increases the surface reflectivity to 90%. By optimizing the electrolyte cycle rate (0.5-1 L/min) and electrode spacing (1-2 mm), arcing during the polishing process can be reduced and surface uniformity can be improved. In addition, the use of pulsed electrolytic polishing technology (pulse frequency 50-100 Hz, duty cycle 50-70%) can further reduce the incidence of surface microcracks to less than 0.1%.

Improvements in graphite emulsion coating technology

Graphite emulsion coating reduces the coefficient of friction and wear resistance by applying a 1-2 micron thick lubricating coating to the surface of the molybdenum wire, extending the service life in wire cutting. The optimized coating process uses a continuous coating bath (material: corrosion-resistant plastic) and a graphite emulsion formulation of 10-20% high-purity graphite powder (particle size 0.1-0.5 microns), binder (polyvinyl alcohol or sodium silicate) and solvent (deionized water). The coating equipment is equipped with a stirring device (speed 100-200 rpm) and a drying furnace (temperature 100-150°C, drying time 10-20 seconds) to ensure that the coating thickness uniformity is more than 98%, and the bonding strength is increased to 10 MPa. Modern coating equipment uses spray or dip coating technology to control the coating thickness deviation ± 0.1 microns, and the drying temperature is monitored in real time by an infrared thermometer (accuracy ± 1°C) to avoid cracking or peeling of the coating.

New surface treatment technology

In recent years, nano-coating technology and plasma surface modification technology have provided a new direction for the surface treatment of molybdenum wire. Nano coatings (e.g. titanium nitride or molybdenum carbide coatings, 0.5-1 microns thick) are applied by physical vapor deposition (PVD) or chemical vapor deposition (CVD) with hardness up to HV 2000 and a reduced coefficient of friction to less than 0.1. Plasma surface modification treats the surface of the molybdenum wire with a low-temperature plasma (power 100-200 W, pressure 0.1-1 Pa) to form a dense oxide layer (thickness 0.2-0.5 microns) to improve corrosion resistance and wear resistance. These technologies significantly improve the stability of molybdenum wire in high-intensity discharge environments.

Significance of the application

The optimized surface treatment process significantly improves the surface finish and wear resistance of the molybdenum wire. Molybdenum wire with a surface roughness of Ra 0.015 microns can reduce the uneven arc in wire EDM and improve the discharge stability by 30%; The graphite emulsion coating reduces the coefficient of friction by 40% and extends the service life by 50%. These improvements provide a reliable guarantee for high-precision mold machining and microstructure machining, which meet the stringent requirements of the semiconductor and aerospace sectors.

**9.3 Techniques to reduce the rate of broken filament**

Broken wire is a common problem in wire EDM, affecting processing efficiency and cost. Reducing the breakage rate requires material optimization, process improvement, and equipment control, and the following is a detailed analysis of the relevant technologies.

Optimization of material properties

The filament breakage rate is closely related to the tensile strength, toughness and microstructure of molybdenum wire. By using high-purity molybdenum powder (purity ≥ 99.97%) and doping techniques such as 0.3% lanthanum oxide, the tensile strength can be increased to 2300 MPa and the elongation at break can be increased to 2.5%, significantly reducing the risk of wire breakage. In the process of wire drawing, the fibrous crystal structure can be optimized, the grain boundary crack can be reduced, and the wire breakage rate can be reduced to less than 0.05% by controlling the single-pass surface reduction rate (8-12%) and the intermediate annealing temperature (900-1100°C).

Improvement of the wire drawing process

The optimization of the drawing process directly affects the uniformity and surface quality of the molybdenum wire. Using a high-precision wire drawing machine (driven by servo motor, speed 5-20 m/s, tension 0.1-2 N), through multi-pass drawing (20-30 passes) and online tension control (accuracy ±0.01 N), the diameter tolerance can be controlled at ±0.001 mm, and the roundness error ≤ 0.0005 mm. The use of polycrystalline diamond (PCD) drawing dies (die hole surface roughness Ra 0.01 microns, life of more than 1000 hours) can reduce surface scratches and reduce the rate of wire breakage. In addition, the optimized lubricant formulation (oil-based lubricant with 5% graphite with viscosity 10-20 cSt) reduces the frictional heat during wire drawing by 50% and avoids micro-cracks caused by local overheating.

Optimization of wire cutting equipment parameters

The operating parameters of wire cutting equipment have an important impact on the wire breakage rate. Optimizing the discharge parameters (e.g., pulse width 50-100 µs, current density 10-20 A/cm²) can reduce the thermal shock during discharge and reduce the thermal fatigue damage of the molybdenum wire. The adaptive tension control system (tension range 2-5 N, accuracy ± 0.05 N) can adjust the tension in real time according to the processing conditions to avoid wire breakage caused by excessive tension. In addition, by optimizing the coolant formulation (5% rust inhibitor, pH 7-8, flow rate 0.5-1 L/min), the tendency of molybdenum wire to corrode and oxidize during processing can be reduced.

On-line monitoring and feedback control

Modern wire cutting equipment is equipped with an online monitoring system, which monitors the diameter and surface defects of molybdenum wire in real time through a laser wire diameter measuring instrument (accuracy ± 0.0001 mm) and eddy current detector (sensitivity 0.05 microns), and automatically adjusts the tension or discharge parameters when abnormalities are found. For example, when a diameter deviation of ±0.001 mm is detected, the system can reduce the tension by 10% or pause the processing to avoid wire breakage. The monitoring system can also record the discharge frequency and heat distribution, optimize the processing parameters, and reduce the wire breakage rate to less than 0.03%.

Significance of the application

Techniques that reduce the rate of filament breakage significantly improve the continuity and efficiency of wire cutting. Molybdenum wire with a broken wire of less than 0.05% can support continuous processing for more than 100 hours, reduce downtime, and increase production efficiency by 20%. These technologies provide stable support for the machining of highly hardness materials such as titanium alloys and ceramics to meet the demanding requirements of aerospace and mold making.

**9.4 Innovations to improve cutting efficiency**

Improving the cutting efficiency of wire EDM is an important goal to optimize the performance of molybdenum wire, which involves material improvement, discharge optimization and equipment upgrades. The following is a detailed analysis of the relevant innovations.

Development of highly conductive molybdenum wire

Increasing the conductivity of molybdenum wire (conductivity 18-20 MS/m) can enhance discharge efficiency and shorten processing time. By doping trace amounts of silver (Ag, 0.1-0.3%) or copper (Cu, 0.2-0.5%), the conductivity can be increased by 10% and the discharge energy loss can be reduced by 15%. The doping process is carried out in a vacuum sintering furnace (temperature 1900-2100°C, pressure 0.1 MPa) to ensure uniform distribution of doping elements (deviation ≤5%). High conductivity molybdenum wire can increase the discharge frequency (10-20 kHz) and increase the cutting speed by 20-30%.

Optimization of discharge parameters

Optimizing discharge parameters is the key to improving cutting efficiency. Modern wire EDM equipment uses a high-frequency pulsed power supply (frequency 10-50 kHz, pulse width 20-100 μs) that increases material removal rates by up to 30% through precise control of discharge energy (10-50 J/cm²) and pulse spacing (50-200 μs). For example, the cutting speed can be increased from 2 mm/min to 3 mm/min with a short pulse high-frequency discharge (pulse width 30 μs, frequency

30 kHz). In addition, by optimizing the electrode gap (0.01-0.03 mm) and coolant flow rate (0.5-1 L/min), heat accumulation can be reduced and the life of the molybdenum wire can be extended.

New coolant and injection system

The coolant plays a role in heat dissipation, slag removal and corrosion protection in wire cutting. Optimized coolant formulation (5-10% ethylene glycol, 2% rust inhibitor, viscosity 5-10 cSt) can improve thermal conductivity (0.5 W/m·K) and slag removal efficiency, and increase cutting speed by 15%. The new high-pressure injection system (pressure 0.5-1 MPa, injection angle 30-45°) can evenly spray the coolant into the discharge area, reducing electrode thermal damage and increasing processing efficiency by 10-20%.

Multi-axis linkage and adaptive control

Modern wire cutting equipment adopts five-axis or six-axis numerical control system, and realizes the processing of complex three-dimensional structures through multi-axis linkage (rotation accuracy ±0.001°), and the cutting efficiency is increased by 25%. The adaptive control system reduces the processing time by 15-20% by monitoring the discharge current (accuracy ± 0.1 A) and electrode gap (accuracy ± 0.001 mm) in real time, dynamically adjusting the discharge parameters and tension, optimizing the cutting path.

Significance of the application

Innovative technologies that increase cutting efficiency significantly reduce processing times and production costs. High conductivity molybdenum wire and optimized discharge parameters can increase the cutting speed by 30%, which is suitable for processing high hardness materials; New coolant and multi-axis technologies improve the efficiency of machining complex structures to meet the needs of aerospace, semiconductor, and other fields.

## 9.5 Application of intelligent production technology

Intelligent production technology improves molybdenum wire production efficiency and quality consistency through automation and real-time monitoring. The following is an analysis from two aspects: automatic drawing control and real-time quality monitoring system.

### 9.5.1 Automatic wire drawing control

Automated wire drawing control improves the accuracy and efficiency of the wire drawing process by integrating sensors, servo systems, and PLC control.

Technical principle

The automatic wire drawing control system monitors the tension, speed and diameter changes during the wire drawing process in real time through servo motors (power 5-10 kW, speed 100-2000 rpm) and high-precision sensors (tension accuracy ± 0.01 N, diameter accuracy ±0.0001 mm). The system adopts a closed-loop control algorithm to adjust the drawing speed (5-20 m/s) and tension (0.1-2 N) according to real-time data, ensuring a diameter tolerance of ± 0.001 mm and a roundness error of ≤0.0005 mm.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Equipment and process parameters

Automated wire drawing machines (e.g. Schumag or Niehoff) are equipped with multi-pass drawing systems (20-30 passes, surface reduction rate 8-12%) and in-line laser measuring instruments (frequency 1000 passes/second). The lubrication system uses an oil-based lubricant containing 5% graphite (viscosity 10-20 cSt), which is evenly applied by a constant flow pump (flow rate 0.1-0.5 L/min) to reduce frictional heat by 50%. PLC control systems, such as Siemens S7-1500, display process parameters in real time through a touchscreen interface, supporting remote monitoring and data storage.

Process Optimization & Challenges

Automated wire drawing needs to optimize the drawing die design (PCD die hole, surface roughness Ra 0.01 microns, life 1000 hours) to avoid diameter deviation caused by die hole wear. The system needs to calibrate the sensor at regular intervals (every 500 hours) to ensure measurement accuracy. The challenge is to deal with vibration disturbances in high-speed wire drawing, which can be solved by adding damping devices (80% damping rate) and optimizing lubricant formulations.

Significance of the application

Automatic wire drawing control increases production efficiency by 20% and reduces the failure rate to 0.02%, ensuring the consistency of molybdenum wire diameter and surface quality to meet the needs of high-precision wire cutting. The system also supports automatic optimization of process parameters, reducing the production cycle by 15%.

### 9.5.2 Real-time quality monitoring system

The real-time quality monitoring system ensures the quality consistency of the whole process of molybdenum wire production through the integration of testing equipment and data analysis technology.

Technical principle

The real-time quality monitoring system detects the diameter, surface defects and microstructure of molybdenum wire in real time through a laser wire diameter measuring instrument (accuracy ± 0.0001 mm), eddy current detector (sensitivity 0.05 microns) and optical microscope (magnification 1000-2000 times). The system uses Industrial Internet of Things (IIoT) technology to collect data through a network of sensors, combined with big data analytics and machine learning algorithms to predict quality issues and optimize process parameters.

Equipment and process parameters

The monitoring system is equipped with a high-frequency laser measuring instrument (Keyence LS-9000, frequency 1000 times/sec), eddy current detector (Eddyfi Ectane 2, frequency 100 kHz-1 MHz) and SEM (JEOL JSM-7800F, resolution 0.01 microns). Data acquisition frequencies of 10-100 Hz, storage capacity up to 1 TB, cloud backup and remote access. The system is linked with the production equipment through PLC to adjust the drawing speed, tension and surface treatment parameters in real time.

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**Molybdenum Wire EDM Introduction**

## 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

## 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

## 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

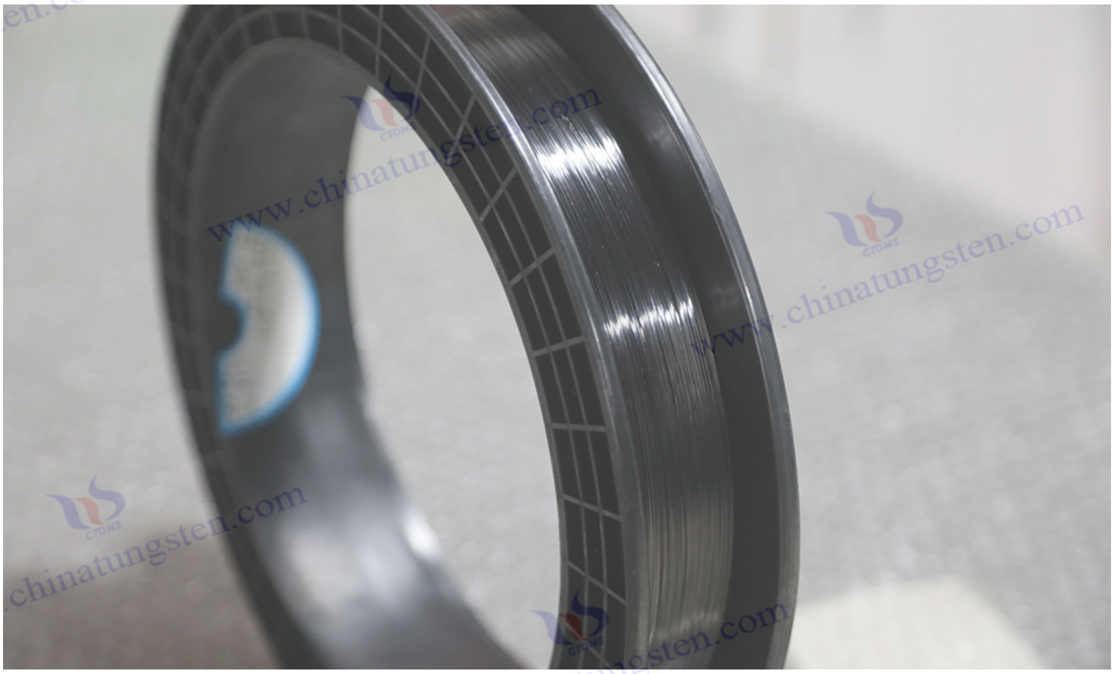
Website: www.molybdenum.com.cn

Process Optimization & Challenges

The monitoring system needs to calibrate the sensor (every 500 hours) to ensure detection accuracy. The challenge is to process real-time analysis of high-frequency data (1000 points/s), which can be increased by edge computing and 5G networks with a latency of < 10 ms. The system also needs to optimize the algorithm to reduce the false alarm rate to less than 0.01% to ensure the reliability of quality control.

Significance of the application

The real-time quality monitoring system reduces the failure rate to 0.01% and increases the production efficiency by 15%, ensuring that the performance of molybdenum wire meets GB/T 4182-2017 and ASTM B387 standards. The system also supports the traceability of quality data, which provides a reliable guarantee for high-precision wire cutting.



CTIA GROUP LTD molybdenum wire EDM

## Chapter 10 Market and Development of Molybdenum wire EDM

With the growing demand for high-precision machining, microelectronics manufacturing and green production, the wire EDM wire market is showing a trend of rapid expansion and diversification. This chapter will comprehensively discuss the global market overview and future development trend of molybdenum wire EDM, and provide an in-depth analysis of the major producing countries, market size, demand drivers, and technological innovation directions, including the research and development of thinner wire diameter molybdenum wire, the promotion of environmentally friendly production processes, and the trend of new material substitution.

### 10.1 Global Market Overview

The global market for molybdenum wire EDM is driven by the demand for high-precision machining, which is widely used in mold manufacturing, aerospace, semiconductors, medical devices, and new energy, among others. The following is a detailed analysis of the current state of the global market from two aspects: major producing countries and regions, market size and demand analysis.

### 10.1.1 Major producing countries and regions

The production of molybdenum wire EDM is highly dependent on molybdenum resources and advanced processing technology, and the world's major production countries and regions include China, the United States, Japan, Europe (represented by Germany and Austria) and Russia. These countries and regions occupy an important position in the global molybdenum wire market by virtue of the synergy of resource advantages, technology accumulation and market demand.

**China**

China is the world's largest producer of molybdenum resources, with rich molybdenum ore reserves (accounting for about 50% of the world's total), such as Luanchuan in Henan Province and Jinduicheng in Shaanxi Province, with an annual output of more than 100,000 tons of molybdenum concentrate. Relying on resource advantages, China has become a major producer of molybdenum wire EDM, accounting for more than 60% of the global market. Domestic enterprises such as Jinduicheng Molybdenum Industry and Luoyang Molybdenum Industry have produced high-performance molybdenum wire in accordance with GB/T 4182-2017 standard with a diameter range of 0.05-0.3 mm, tensile strength of 1800-2300 MPa and surface roughness of Ra≤0.02 microns through the introduction of advanced production equipment (such as high-precision wire drawing machine and vacuum heat treatment furnace) and optimized process (multi-stage hydrogen reduction and hot isostatic pressure sintering). China's molybdenum wire products not only meet the needs of domestic mold manufacturing and aerospace, but also export a large number of them to Southeast Asia, Europe and North America, accounting for more than 40% of the global market. In addition, Chinese companies have maintained price competitiveness through technological innovation (e.g., lanthanum oxide doping) and cost control, with the average price of 0.18 mm molybdenum wire being US$50-70 per kilometer.

**United States**

The United States is the world's second-largest producer of molybdenum wire, with abundant molybdenum ore resources (such as the Climax mine in Colorado) and advanced production technology. Companies such as Climax Molybdenum and Plansee USA specialize in the development of high-performance molybdenum wires that comply with ASTM B387 standards for use in the semiconductor and aerospace fields. The production of molybdenum wire in the United States focuses on high purity (≥99.95%) and surface quality (Ra≤0.05 microns), and improves wear resistance through physical vapor deposition (PVD) coating technologies such as titanium nitride coatings, 0.5-1 microns thick. The U.S. market has a strong demand for fine wire diameter molybdenum wire (0.05-0.1 mm), accounting for 30% of its total production, mainly in microelectronics and medical device processing. The price of molybdenum wire in the United States is relatively high, averaging $80-100 per kilometer, reflecting its high-end market positioning.

**Japan**

Japan is known for its high precision and quality in the production of molybdenum wire, and companies such as Sumitomo Electric and Toshiba Materials produce molybdenum wire in accordance with JIS H 4461 standard, which is widely used in electric light sources and precision mold manufacturing. Japan's molybdenum wire production technology focuses on grain control (size 3-8 microns) and surface treatment (such as electrolytic polishing, Ra ≤0.03 microns), through multi-pass drawing (25-35 passes, surface reduction rate 8-12%) and vacuum annealing (1600-1800 °C), to achieve tensile strength of 2000-2200 MPa. The demand for ultra-fine molybdenum wire (≤0.08 mm diameter) in the Japanese market is growing rapidly, accounting for 25% of its total production, mainly for semiconductor wafer dicing and MEMS manufacturing. Japan's molybdenum wire exports are mainly to Asia and North America, and the price is $70-90 per kilometer.

**Europe**

The production of molybdenum wire in Europe is dominated by Germany and Austria, and companies such as Plansee Group and H.C. Starck uses state-of-the-art production processes (e.g. continuous wire drawing machines, plasma surface modification) to produce molybdenum wire in accordance with DIN EN 10204. The European market focuses on environmentally friendly production, using low-energy sintering furnaces (20% less energy consumption) and recyclable lubricants, in compliance with the EU RoHS directive. Molybdenum wire in Europe is mainly used in aerospace and automotive mold manufacturing, with a diameter of 0.1-0.2 mm accounting for 50% of the total output, a tensile strength of 1900-2300 MPa, and a surface roughness of Ra≤0.02 microns. The price of molybdenum wire in Europe is higher, with an average of US$90-120 per kilometer, reflecting its high-end technology and strict quality control.

**Russia**

Russia has a strong presence in the global market with rich molybdenum ore resources, such as the Siberian mining area, with an annual output of about 20,000 tons of molybdenum concentrate. Molybdenum wire manufacturers in Russia, such as the Chelyabinsk Metallurgical Plant, specialize in large-diameter molybdenum wire (0.2-0.3 mm) for thermal spraying and aerospace applications. The product conforms to GOST standard, with a tensile strength of 1800-2100 MPa and a surface roughness of Ra≤0.05 microns. The price of molybdenum wire in Russia is relatively low, averaging $40-60 per kilometer, and it is mainly exported to Eastern European and Asian markets.

**Other regions**

Other countries such as Chile, Canada and Australia also produce molybdenum wire, but the production is smaller and mainly relies on imported molybdenum concentrate for processing. The production of molybdenum wire in these areas is mainly to meet the needs of the local market, and the technical level is relatively low, and the products are mostly used in general mold manufacturing, with a price of 50-80 US dollars per kilometer.

**Market distribution and competitive landscape**

The global molybdenum wire market presents a regional competition pattern, with China dominating with low cost and high output, the United States and Japan focusing on high-tech and high-end applications, Europe focusing on environmental protection and quality certification, and Russia competing with price advantages. Multinational enterprises have enhanced their competitiveness in the global market by integrating resources through technical cooperation and mergers and acquisitions. In the future, inter-regional cooperation will further promote technology sharing and market expansion.

### 10.1.2 Market size and demand analysis

The global market size of molybdenum wire EDM continues to expand with the growth of demand for high-precision machining, and the following is analyzed from three aspects: market size, demand drivers and regional distribution.

Market size

According to industry data, the global molybdenum wire EDM market size will be about $500 million in 2024 and is expected to reach $750 million by 2030, with a compound annual growth rate (CAGR) of about 7%. The growth in the market size is mainly due to the wide application of wire EDM equipment in mold making, aerospace and semiconductor industries. In terms of production, the global production of molybdenum wire in 2024 will be about 12,000 tons, of which China will account for 60% (7,200 tons), the United States will account for 15% (1,800 tons), Japan will account for 10% (1,200 tons), Europe will account for 10% (1,200 tons), and other regions will account for 5% (600 tons). By application area, mold manufacturing accounted for 40% of the market share, aerospace accounted for 25%, semiconductors accounted for 20%, electric light sources accounted for 10%, and other fields accounted for 5%.

Demand drivers

Mold manufacturing needs: Mold making is the largest application area of wire EDM wire, especially in the automotive, electronics and home appliance industries. High-precision molds (tolerances ± 0.005 mm) have strict requirements for the diameter tolerance (±0.001 mm), tensile strength (≥2000 MPa) and surface roughness (Ra ≤0.02 microns) of molybdenum wires, driving the growth of market demand.

Aerospace demand: The aerospace field has a strong demand for high temperature stability (tensile strength at 1500°C ≥ 1800 MPa) and fatigue resistance (life ≥ $10^6$ times) of molybdenum wire, which is used to process turbine blades, titanium alloy parts, etc., accounting for 25% of the market demand.

Semiconductor & Microelectronics Demand: The semiconductor industry has a rapidly growing demand for ultra-fine molybdenum wire (0.05-0.08 mm diameter) for wafer dicing and MEMS manufacturing, increasing its market share from 10% in 2015 to 20% in 2024.

Demand for new energy and electric light sources: The new energy field (such as photovoltaic cell manufacturing) and the electric light source industry (such as high-pressure sodium lamp) have high requirements for high conductivity (18-20 MS/m) and high temperature resistance (1500-2000°C) of molybdenum wire, which promotes the development of market diversification.

Globalization and technological advancement: The digital transformation of the global manufacturing industry and intelligent production technologies (such as five-axis CNC wire cutting machines) have improved the efficiency of molybdenum wire use and stimulated market demand.

Regional demand distribution

Asian market: Asia (especially China, Japan and South Korea) is the world's largest consumer market for molybdenum wire, accounting for 50% of the market. The rapid development of China's mold manufacturing industry has driven the demand for 0.18-0.2 mm molybdenum wire, with an annual consumption of about 4,000 tons. Japan and South Korea are dominated by semiconductor and electric light source applications, and the demand for ultra-fine molybdenum wire accounts for 30%.

North American market: The North American market accounts for 25% of the global market share, with the aerospace and semiconductor industries providing the main demand. There is a strong demand for high-performance molybdenum wire (tensile strength ≥ 2200 MPa) from American companies, with an annual consumption of about 1,500 tons.

European market: The European market accounts for 20% of the global market share, dominated by Germany, France and Italy, and the demand is concentrated in aerospace and automotive mold manufacturing, with an annual consumption of about 1,000 tons. The demand for environmentally friendly molybdenum wire (RoHS compliant) is growing rapidly in Europe.

Other regions: South America, Africa and the Middle East have a smaller demand for molybdenum wire, accounting for 5% of the global market share, mainly used for general mold manufacturing and thermal spraying, with an annual consumption of about 500 tons.

Market Challenges and Opportunities

Market challenges include volatile raw material prices (10-15% fluctuations in molybdenum concentrate prices), stringent environmental regulations (e.g. EU REACH) and competitive pressures from new materials (e.g. galvanized steel wire). The opportunities lie in the growing demand for high-precision machining, the spread of intelligent production technologies, and the rapid rise of emerging markets such as India and Southeast Asia. In the future, the market will develop in the direction of high performance, environmental protection and low cost.

**10.2 Development Trends**

The future development of molybdenum wire EDM is influenced by technological innovation, environmental protection requirements and competition in new materials. The following is a detailed analysis of the development trend of the industry from three aspects: the research and development of thinner wire diameter, environmental protection production process and the trend of new material substitution.

### 10.2.1 Research and development of thinner wire diameter

With the rapid development of the microelectronics, semiconductor, and medical device industries, the demand for ultra-fine wire diameter molybdenum wire (≤0.08 mm diameter) continues to grow. The following analyzes the R&D trend of thinner wire diameter molybdenum wire from three aspects: technical challenges, process improvement and application prospects.

Technical challenges

The production of ultra-fine molybdenum wire (diameter 0.03-0.08 mm) puts forward higher requirements for raw materials, wire drawing process and testing technology. The raw material needs to use ultra-high purity molybdenum powder (purity ≥ 99.99%, particle size 0.5-2 microns) to reduce the damage of impurities to the microstructure. The wire drawing process requires an ultra-high-precision wire drawing machine (tension control accuracy ± 0.005 N, speed 2-10 m/s) and a natural diamond wire drawing die (die hole surface roughness Ra 0.005 microns, life life 500 hours), and the single-pass surface reduction rate is controlled at 5-8% to avoid wire breakage. The inspection technology requires the use of a high-resolution laser wire measuring instrument (accuracy ± 0.00005 mm) and a scanning electron microscope (resolution 0.01 micron) to ensure a diameter tolerance of ± 0.0005 mm and a surface roughness of Ra ≤ 0.01 microns.

Process improvements

Micro wire drawing technology: using 40-50 times drawing process, combined with intermediate annealing (temperature 800-1000 °C, heat preservation 5-10 seconds, hydrogen protection), the diameter of molybdenum wire can be gradually reduced from 0.5 mm to 0.05 mm, and the wire breakage rate is controlled below 0.01%.

Surface treatment optimization: Pulse electrolytic polishing (frequency 100 Hz, duty cycle 60%, current density 15 A/dm²) reduces the surface roughness to Ra 0.008 microns and improves discharge stability.

Doping and alloying: 0.1-0.3% cerium oxide ($CeO_2$) or yttrium oxide ($Y_2O_3$) is added to increase the tensile strength to 2400 MPa through precipitation strengthening to meet the high strength requirements of ultra-fine molybdenum wire.

On-line monitoring: The introduction of on-line laser measurement and eddy current detection system can monitor diameter and surface defects in real time, automatically adjust drawing parameters, and increase production efficiency by 15%.

Application prospects

The research and development of ultra-fine molybdenum wire has promoted its application in the microelectronics and medical fields. Molybdenum wire with a diameter of 0.05 mm can be used for semiconductor wafer dicing, and the groove width tolerance ± 0.001 mm; The 0.03 mm diameter molybdenum wire is suitable for the processing of medical devices (e.g. cardiac stent molds) and has a surface roughness of Ra 0.005 microns, which meets the requirements of ultra-high precision. In the future, with the development of 5G, artificial intelligence and biomedical technology, the market demand for ultra-fine molybdenum wire is expected to grow at a compound annual growth rate of 10%, accounting for 30% of the global market by 2030.

### 10.2.2 Environmentally friendly production process

Environmentally friendly production process is an important development trend of the molybdenum wire industry, which responds to the requirements of global green manufacturing and sustainable development. The following analyzes the development of environmentally friendly processes from three aspects: low-energy production, waste liquid treatment and recyclable materials.

Low-energy production technology

Conventional molybdenum wire production (e.g. sintering, heat treatment) consumes a high level of energy (approx. 5000 kWh per ton of molybdenum wire). New low-energy technologies include:

High-efficiency sintering furnace: Medium frequency induction sintering furnace (temperature 1800-2000°C, energy consumption reduced by 20%), equipped with heat recovery system (recovery rate 30%), the total energy consumption is reduced to 4000 kWh/ton.

Energy-saving wire drawing machine: Using a wire drawing machine driven by a servo motor (5-8 kW power, 15% more efficient), the frictional energy consumption is reduced by 30% by optimizing the drawing speed (10-15 m/s) and lubricant formulation (viscosity 8-15 cSt).

Low-temperature heat treatment: The development of low-temperature vacuum annealing technology (temperature 1000-1200°C, vacuum degree $\leq 10^{-4}$ Pa) reduces the energy consumption of heat treatment by 25%, while maintaining the tensile strength of more than 2000 MPa.

Liquid and gas waste treatment

Caustic washing and electropolishing in the production of molybdenum wire produce waste liquids containing heavy metals, which are expensive and inefficient to dispose of. New environmentally friendly treatment technologies include:

Closed-cycle waste liquid treatment: Acid-base neutralization (pH 6-8) and membrane filtration technology (pore size 0.1 microns) are used to increase the removal rate of heavy metal ions in the waste liquid to 98%, and reduce the treatment cost by 30%.

Exhaust gas purification: In the hydrogen reduction and heat treatment process, activated carbon adsorption and catalytic combustion units (removal rate ≥ 99%) are used to reduce volatile organic compounds (VOCs) and oxide emissions to less than 0.01 mg/m³, in line with EU emission standards.

Resource recovery: Develop molybdenum ion recovery technology in waste liquid (such as ion exchange resin, recovery rate of 90%), and use the recovered molybdenum to produce low-purity molybdenum products, reducing raw material costs by 10%.

Recyclable materials and green packaging

The use of recyclable lubricants (containing 5% bio-based oil, 95% degradation rate) and environmentally friendly packaging materials (e.g. biodegradable plastics, vacuum packaging thickness 0.05 mm) reduces environmental pollution in the production process. The drawing die is made of renewable polycrystalline diamond (PCD), which extends the life by 20% and reduces resource consumption. Green packaging is filled with vacuum or inert gas (argon or nitrogen, purity ≥ 99.99%) to ensure the oxidation resistance of molybdenum wire during storage and reduce packaging waste by 50%.

Application prospects

The environmentally friendly production process reduces the environmental impact of molybdenum wire production and is in line with global green manufacturing trends (e.g. the EU Green Deal). Low energy consumption technology and waste liquid treatment system reduce production costs by 15-20% and enhance market competitiveness. The use of recyclable materials is driving the circular economy model, and environmentally friendly molybdenum wire is expected to account for 40% of the global market by 2030, with rapid growth in Europe and North America, especially in Europe.

### 10.2.3 Substitution of new materials

With the development of new material technology, molybdenum wire EDM is facing competitive pressure from other high-performance materials. The following analyzes the substitution trend of new materials from three aspects: the types of alternative materials, technical challenges and market prospects.

Alternative material types

Galvanized steel wire: Galvanized steel wire improves conductivity and corrosion resistance by galvanizing the surface of the steel wire (thickness 5-10 microns) at 50% of molybdenum wire ($20-30 per kilometer). Its tensile strength (1500-1800 MPa) is lower than that of molybdenum wire, but it is suitable for low-precision mold making.

Copper-based composite wire: Copper-based composite wire (e.g., copper-tungsten alloy with 20-30% tungsten content) has high conductivity (25-30 MS/m) and wear resistance, suitable for medium and high precision wire EDM, and the price is $40-60 per kilometer.

Carbon Fiber Composite Filament: Carbon Fiber Composite Filament is lightweight (density 1.8 g/cm³) and high strength (2000 MPa) by applying a conductive coating (graphite or metal, thickness 1-2 microns), but the conductivity (10-15 MS/m) is lower than that of molybdenum wire, making it suitable for specific microfabrication scenarios.

Ceramic-coated wires: Ceramic-coated wires (e.g. zirconia or silicon nitride, 0.5-1 micron thick) have high hardness (HV 2000) and high temperature resistance (1500°C), but are expensive to produce ($80-100 per kilometer).

Technical challenges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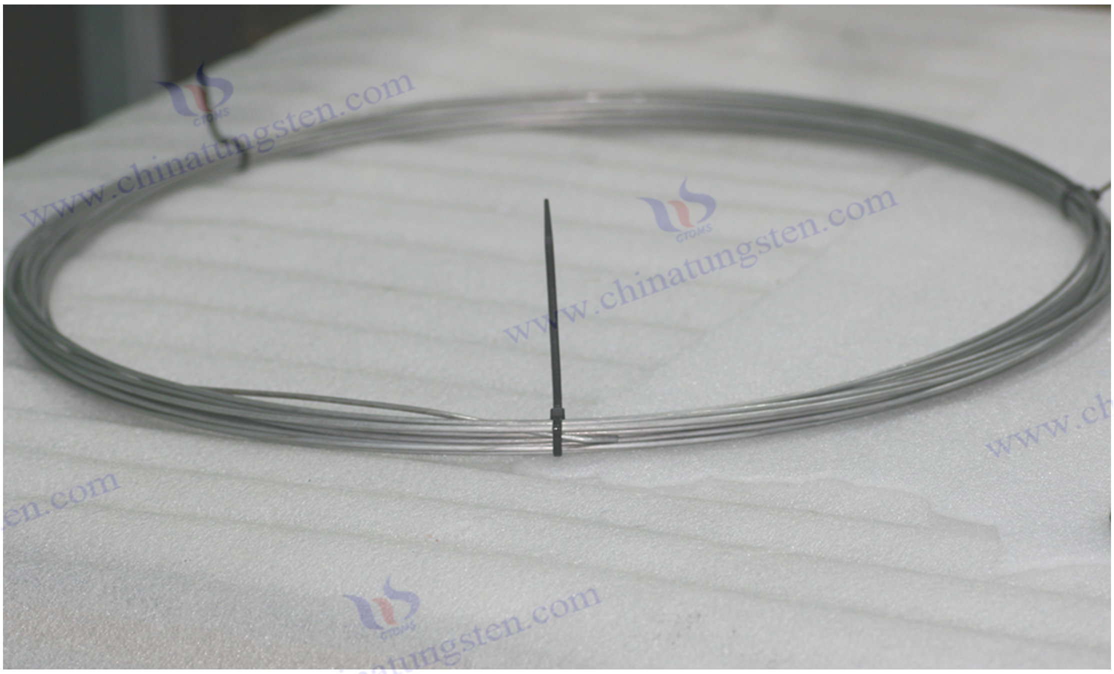
Alternative materials have limitations in terms of performance and cost. The high temperature resistance and tensile strength of galvanized steel wire are insufficient, which is difficult to meet the needs of aerospace and semiconductor processing; The production process of copper-based composite wire is complex, and the uniformity (deviation ±0.002 mm) is difficult to compare with molybdenum wire; The poor conductivity and discharge stability of carbon fiber composite filament limit its application in high-frequency discharge environments. The production cost of ceramic-coated wire is high, and the coating binding strength (≤8 MPa) is lower than that of graphite emulsion coating of molybdenum wire (10 MPa). In addition, testing standards for alternative materials (e.g., diameter tolerances, surface roughness) have not been harmonized, limiting their market adoption.

Market outlook

Despite the cost advantages of alternative materials, molybdenum wire will remain the mainstream material for wire EDM due to its high tensile strength (2000-2300 MPa), excellent electrical conductivity (18-20 MS/m) and surface quality (Ra ≤0.02 microns), and its market share is expected to remain above 70% by 2030. Alternative materials will occupy a certain market in low-precision and low-cost areas such as general mold manufacturing, and are expected to account for 20% of the global market. In the future, the composite technology of molybdenum wire and new materials (such as molybdenum-copper composite wire or molybdenum-carbon fiber coated wire) may become a new development direction, combining the advantages of both to meet the diversified market demand.

Application prospects

The trend of substitution of new materials has promoted the diversified development of wire EDM technology. Molybdenum wire will continue to dominate the field of high-precision and high-hardness material processing, while galvanized steel wire and copper-based composite wire will grow rapidly in the low-end market. Composites, such as molybdenum-ceramic coated wires, are expected to open up new applications in microelectronics and medical devices, with a market share of 10% expected to reach 10% by 2030.



CTIA GROUP LTD molybdenum wire EDM

## Chapter 11 Installation and Use of Molybdenum Wire EDM

As the core consumables in EDM wire cutting, the installation, operation and maintenance of molybdenum wire EDM directly affect the processing accuracy, efficiency and service life of the equipment. Correct installation steps, standardized use methods and scientific maintenance measures can maximize the performance of molybdenum wire, reduce the wire breakage rate and improve the processing quality. This chapter will discuss in detail the installation steps, precautions for use, and maintenance and replacement methods of molybdenum wire EDM, and analyze the technical principles, operation specifications, equipment requirements, and process parameters in depth.

### 11.1 Wire EDM wire installation steps

Proper installation of molybdenum wire EDM is the basis for ensuring processing stability and precision. The installation process involves threading, fixing, wheel adjustment, and contact control of the conductive block, which requires precise operation to avoid damage to the molybdenum wire or equipment failure. The following is a detailed analysis from two aspects: threading and fixing, and contact control between guide wheel and conductive block.

#### 11.1.1 Molybdenum wire threading and fixing

The threading and fixing of molybdenum wire is a key step before the wire cutting equipment is started, which directly affects the tension stability and smooth operation of molybdenum wire.

Technical principle

Wire threading is the process of passing the molybdenum wire from the wire storage barrel through the guide wheel, the conductive block and the processing area, and finally fixing it on the winding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wheel. The fixing process should ensure that the tension of the molybdenum wire is uniform (usually 2-5 N) and avoid tensile deformation or relaxation. The diameter of the molybdenum wire is usually 0.05-0.3 mm, the tolerance is ± 0.001 mm, and the surface roughness Ra ≤0.02 microns. The fixture needs to provide a stable clamping force (10-20 N) to prevent slipping or breakage.

Procedure

Preparation: Check the appearance of the molybdenum wire to ensure that there are no surface scratches, oxides or curling defects (using a magnifying glass, 20-50x magnification). Confirm the cleanliness of the storage drum and winding wheel, remove dust and oil (wipe with absolute ethanol, purity ≥ 99.9%). Calibrate the position of the guide wheel and the conductive block of the wire EDM to ensure that the alignment accuracy ± 0.01 mm.

Threading process: The molybdenum wire is led out of the wire storage cylinder and passed through the upper guide wheel, the processing area, the lower guide wheel and the conductive block by a manual or automatic threading device (speed 1-5 m/min) in turn. When threading, it is necessary to keep the molybdenum wire straight, avoid winding or knotting, and control the operating environment temperature at 20±2°C and humidity 40-60% to prevent electrostatic interference.

Fixing the molybdenum wire: The end of the molybdenum wire is fixed on the take-up wheel and a special clamping device (clamping force 15 N, contact area 2-5 $mm^2$) is used. The initial tension (2-3 N) is set by means of a tension adjustment device (accuracy ± 0.05 N) to ensure that the molybdenum wire is evenly stressed in the machining area. Check the molybdenum wire path to ensure that there is no excessive bending (bend radius ≥ 10 mm).

Verification and adjustment: start the equipment to run at low speed (0.1-0.5 m/s), observe the running trajectory of the molybdenum wire, and use a laser rangefinder (accuracy ± 0.001 mm) to check the tension uniformity and path deviation. Adjust the position of the guide wheel (accuracy ±0.005 mm) to ensure that the molybdenum wire runs smoothly without vibration or offset.

Process Optimization & Challenges

During the threading process, special threading tools (such as molybdenum wire guide needles, 0.5 mm diameter) should be used to avoid surface damage caused by manual operation. The automatic threading device (equipped with servo motor with speed control accuracy ±0.1 m/min) increases efficiency by 30%, but requires regular calibration (every 500 hours). The challenge is to deal with the breakage of fine wire diameter molybdenum wire (≤0.08 mm diameter), which can be solved by reducing the threading speed (1-2 m/min) and optimizing the guide wheel material (ceramic or polycrystalline diamond, surface roughness Ra 0.01 μm). During the fixing process, it is necessary to avoid excessive clamping force (>20 N) to prevent local deformation of the molybdenum wire.

Significance of the application

Correct threading and fixing ensure the tension stability and smooth operation of the molybdenum wire during processing. Molybdenum wire with a tension deviation of ±0.05 N can reduce the


TEL: 0086 592 512 9696

sales@chinatungsten.com

discharge gap fluctuation to 0.001 mm and improve the machining accuracy by 20%. Standardized installation steps also reduce wire breakage (from 0.1% to 0.03%) and extend the service life of molybdenum wire (100-150 hours) for high-precision tooling and aerospace parts.

### 11.1.2 Contact control between the guide wheel and the conductive block

The guide wheel and conductive block are the key components in the wire cutting machine to control the operation and discharge of molybdenum wire, and their contact control directly affects the processing stability and electrode loss.

Technical principle

Guide pulleys are used to guide the molybdenum wire along a predetermined path with low friction (coefficient of friction ≤ 0.1) and high accuracy (eccentricity ≤ 0.005 mm). The conductive block transmits a discharge current (10-20 A/cm²) through contact molybdenum wires, and the contact resistance should be guaranteed to be ≤ 0.01 ohms to avoid overheating or arc damage. The materials of the guide wheels and conductive blocks (e.g. ceramic guide wheels, copper-tungsten alloy conductive blocks) need to have high wear resistance (hardness HV 1500-2000) and electrical conductivity (conductivity 20-30 MS/m).

Procedure

Guide wheel installation and calibration: Select high-precision ceramic guide wheel (diameter 10-20 mm, surface roughness Ra 0.01 micron), install it on the guide wheel seat, and use a laser alignment instrument (accuracy ± 0.002 mm) to calibrate the guide wheel axis to ensure that the eccentricity ≤ 0.005 mm. Check the roundness of the guide wheel groove (error ≤ 0.001 mm) to ensure that the molybdenum wire runs without offset.

Conductive block installation: Copper-tungsten alloy conductive block (tungsten content 70-80%, conductivity 25 MS/m) is selected and installed on the conductive device, the contact pressure is controlled at 5-10 N, and the contact area is 2-5 mm². The contact resistance is measured using a high-precision meter (accuracy ± 0.001 ohms) to ensure a ≤ of 0.01 ohms.

Contact control: The contact pressure of the guide wheel and the conductive block is adjusted by the servo control system (accuracy ± 0.01 N) to maintain the molybdenum wire tension of 2-5 N. Real-time monitoring of guide wheel speed (100-500 rpm) and conductive block temperature (≤80°C) to avoid frictional heat or arc damage.

Dynamic adjustment: Start the device to run at low speed (0.1-0.5 m/s), use a vibration sensor (sensitivity 0.01 mm/s²) to detect the vibration of the guide wheel, adjust the guide wheel angle (accuracy ± 0.01°) to eliminate the deviation. An infrared thermometer (accuracy ± 1°C) is used to monitor the conductive block temperature and adjust the coolant flow rate (0.5-1 L/min) to dissipate heat.

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**Molybdenum Wire EDM Introduction**

**1. Overview of Molybdenum Wire EDM**

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

**2. Characteristics of Molybdenum Wire EDM (Typical)**

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

**3. Molybdenum Wire EDM from CTIA GROUP LTD**

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

Process Optimization & Challenges

The guide wheels need to be cleaned regularly (every 100 hours, using an ultrasonic cleaner, frequency 40 kHz, 5 minutes) to remove surface deposits and keep friction low. The conductive block needs to be polished regularly (every 200 hours, using diamond sandpaper, grain size 2000 mesh) to ensure that the contact surface is flat and the contact resistance is ≤ 0.01 ohms. The challenge lies in the high sensitivity of handling fine wire diameters (≤0.08 mm), which can be solved by optimizing the guide wheel groove design (V-groove, angle 30-45°) and the contact area of the conductive block (1-2 mm²). The automatic control system (PLC, response time <10 ms) adjusts the contact parameters in real time and improves stability by 30%.

Significance of the application

Precise contact control between the guide wheel and the conductive block can control the molybdenum wire running deviation to ±0.001 mm, and the discharge stability can be improved by 25%. Low contact resistance (≤0.01 ohms) reduces electrode losses by 20% and extends conductive block life (500-1000 hours). These measures ensure high-precision machining (e.g. mold tolerances ± 0.005 mm) to meet the needs of the aerospace and semiconductor industries.

### 11.2 Precautions for the use of molybdenum wire EDM

The correct use of molybdenum wire EDM is the key to ensure processing quality and equipment efficiency, involving current and voltage parameter setting, preventing wire breakage and slippage and other aspects. The following is a detailed analysis from two aspects.

#### 11.2.1 Current and voltage parameter settings

Current and voltage parameters directly affect discharge efficiency, processing speed and molybdenum wire loss, and need to be optimized according to the workpiece material, processing requirements and molybdenum wire specifications.

Technical principle

Wire EDM removes material by creating a spark between the molybdenum wire and the workpiece by means of a high-frequency pulse discharge (frequency 10-50 kHz). The current density (10-20 A/cm²) and voltage (50-100 V) need to match the conductivity of the molybdenum wire (18-20 MS/m) and the conductivity of the workpiece material (e.g. 7-10 MS/m for steel). Excessive current or voltage will cause the molybdenum wire to overheat (temperature > 500°C), increasing the risk of wire breakage; Parameters that are too low will reduce the processing efficiency. Standards (e.g., YS/T 357-2006) recommend pulse widths of 20-100 μs and pulse intervals of 50-200 μs.

Code of Conduct

Parameter selection: Select the current and voltage parameters according to the workpiece material. For example, when machining tungsten carbide (hardness HRC 60-70), the current density is set at 15 A/cm², the voltage is 80 V, and the pulse width is 50 μs. When machining aluminum alloy (conductivity 30 MS/m), the current density is 10 A/cm², the voltage is 60 V, and the pulse width is 30 μs.


TEL: 0086 592 512 9696

sales@chinatungsten.com

Pulse power settings: Using a high-frequency pulse power supply (frequency 20-30 kHz, accuracy ±0.1%), the pulse width and spacing are adjusted by a numerical control system (CNC, response time < 10 ms) to ensure uniform discharge energy.

Coolant matching: Use a coolant containing 5% ethylene glycol (viscosity 5-10 cSt, pH 7-8) with a flow rate of 0.5-1 L/min, maintain the temperature of the discharge area ≤80°C, and reduce the thermal damage of molybdenum wire.

Real-time monitoring: Real-time monitoring of discharge parameters through current sensors (accuracy ± 0.1 A) and voltmeter (accuracy ± 0.1 V), and automatically reduce the pulse frequency (20% reduction) or suspend processing when abnormal (such as current fluctuation >10%) is found.

Process Optimization & Challenges

The parameter settings need to be optimized according to the diameter of the molybdenum wire, e.g. 0.18 mm molybdenum wire for current densities of 12-15 A/cm², 0.08 mm molybdenum wire for 8-10 A/cm². The challenge is to balance the processing speed with the life of the molybdenum wire, and to optimize the discharge efficiency by dynamically adjusting the parameters with an adaptive control system (based on the PID algorithm with a response time of <5 ms). The coolant needs to be filtered regularly (pore size 0.1 microns) to avoid impurities affecting the discharge stability.

Significance of the application

Optimized current and voltage parameters increase the processing speed by up to 20 percent (from 2 mm/min to 2.4 mm/min) and reduce molybdenum wire losses by up to 15 percent. Precise parameter setting ensures uniform discharge gap (0.01-0.03 mm), and the machining tolerance is controlled at ±0.005 mm, which meets the processing needs of high-precision molds and microelectronic parts.

**11.2.2 Prevent broken and slippery wires**

Broken and slippery wires are common problems in wire cutting, leading to machining interruptions and loss of accuracy. The following is an analysis of preventive measures in terms of tension control, discharge optimization, and environmental management.

Technical principle

Broken filaments are usually caused by excessive tension (>5 N), thermal fatigue (temperature > 500°C), or surface defects (scratches > 0.1 microns); The slippery wire is caused by insufficient tension (<2 N) or a high coefficient of friction of the guide wheel (>0.2). Preventing wire breakage and slippage can be achieved by optimizing the tension (2-5 N), discharge parameters (current density 10-15 A/cm²) and guide wheel quality (surface roughness Ra 0.01 μm).

Code of Conduct

Tension control: Maintain tension at 2-3 N (0.18 mm molybdenum wire) or 1-2 N (0.08 mm molybdenum wire) using a servo tension control system (accuracy ± 0.05 N). The tension sensor (sensitivity 0.01 N) is monitored in real time and automatically adjusts when the tension fluctuates >


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sales@chinatungsten.com

10%.

Discharge optimization: Set the pulse interval of 100-150 μs to reduce heat accumulation and avoid overheating of the molybdenum wire. The use of short pulse discharge (width 30-50 μs) reduces thermal shock and reduces the wire breakage rate to 0.03%.

Wheel & Block Maintenance: Regularly inspect the guide wheel groove (every 100 hours) to ensure that there is no wear (groove depth< 0.1 mm). The conductive block should be kept clean (ultrasonically cleaned, frequency 40 kHz) with a contact resistance of ≤ 0.01 ohms.

Environmental management: Maintain the temperature of the processing area at 20±2°C, the humidity at 40-60%, and use the anti-static device (ionizing air, power 100 W) to avoid electrostatic adsorption of impurities. The coolant should be kept clean (impurity content < 0.01%) and the flow rate should be 0.5-1 L/min.

Process Optimization & Challenges

To prevent broken wires, it is necessary to monitor the surface defects of molybdenum wire in real time, and an in-line eddy current tester (sensitivity 0.05 microns) can be used to identify scratches in the 0.1 micron range, and the processing can be suspended when defects are found. The problem of slippage can be solved by optimizing the material of the guide wheel (ceramic, coefficient of friction 0.08) and lubricant (5% graphite, viscosity 10 cSt). The challenge lies in the breakage of the fine wire diameter (≤0.08 mm), which can be met by reducing the tension (1-1.5 N) and discharge frequency (10-20 kHz).

Significance of the application

Effective precautionary measures for wire breakage and slippage reduce the wire breakage rate to 0.02% and increase processing continuity by 30%. Stable molybdenum wire operation ensures a processing tolerance of ± 0.005 mm and a surface roughness of Ra 0.1 microns to meet the demanding requirements of the aerospace and semiconductor industries.

### 11.3 Maintenance and replacement of molybdenum wire EDM

Regular maintenance and timely replacement of molybdenum wire is the key to ensure the long-term stable operation of wire EDM equipment. The following is an analysis from two aspects: tightness adjustment, regular cleaning and inspection.

#### 11.3.1 Molybdenum wire tightness adjustment

Tightness adjustment is used to maintain the tension stability of the molybdenum wire and avoid processing problems caused by slack or overtightness.

Technical principle

The tension of the molybdenum wire needs to be maintained at 2-5 N (depending on the diameter), too high (>5 N) will cause the wire to break, and too low (<2 N) will cause slippage or offset. The tension adjustment is achieved by servo tension control systems (accuracy ± 0.05 N) and tension sensors (sensitivity 0.01 N), which are dynamically optimized according to the material to be processed and the diameter of the molybdenum wire.

Code of Conduct

Initial Adjustment: After installing the molybdenum wire, set the initial tension using a tension adjustment device (2-3 N for 0.18 mm molybdenum wire and 1-2 N for 0.08 mm). The target tension value is entered through the NC interface (accuracy ± 0.01 N) and the system automatically adjusts the speed of the winding wheel (100-200 rpm).

Dynamic adjustment: During machining, tension fluctuations are monitored in real time (frequency 10 Hz) using a tension sensor, and automatically adjusted (response time < 5 ms) when a deviation of > 10% is detected. For example, when machining cemented carbide, the tension can be increased to 4 N; When processing soft materials such as copper, this is reduced to 2 N.

Calibration & Validation: Calibrate the tension transducer (using standard weights with an accuracy of ± 0.01 N) every 50 hours to ensure accurate measurements. Running the equipment at low speed (0.1 m/s), using a laser rangefinder (accuracy ±0.001 mm) to check the path deviation of the molybdenum wire, adjust the position of the guide wheel (accuracy ± 0.005 mm).

Recording and analysis: The data acquisition system (memory capacity 1 GB) records the tension curve, analyzes the tension stability, and optimizes the processing parameters (e.g. reducing the discharge frequency by 10%).

Process Optimization & Challenges

The thermal expansion of the molybdenum wire (coefficient $5\times10^{-6}$/°C) should be considered for tension adjustment, and the tension should be appropriately reduced (0.2-0.5 N) when the temperature of the processing area increases (>80°C). The challenge is that the fine wire (≤0.08 mm) is sensitive to tension changes and can be solved by adding damping devices (80% damping rate) and optimizing the coolant flow rate (0.8 L/min). The automated tension control system reduces adjustment time by up to 50% and increases efficiency.

Significance of the application

Precise tightness adjustment controls the tension deviation to ±0.05 N, increases machining accuracy by 15%, and reduces the wire breakage rate to 0.02%. The stable tension ensures uniform discharge gap (0.01-0.03 mm), which meets the needs of high-precision mold and microelectronic parts processing.

### 11.3.2 Regular cleaning and inspection

Regular cleaning and inspection can extend the life of molybdenum wire and equipment components, reducing failure rates and processing defects.

Technical principle

Cleaning removes discharge residues, oxides and coolant impurities (particle size > 0.1 microns) from the surface of molybdenum wires, guide wheels and conductive blocks to maintain surface finish and conductivity. The inspection was used to identify wear of the molybdenum wire (reduced diameter >0.002 mm), guide wheel groove wear (depth > 0.1 mm) and increased contact resistance of the conductive block (> 0.01 ohms).

Code of Conduct

Molybdenum wire cleaning: Use an ultrasonic cleaner (frequency 40 kHz, power 100 W, cleaning solution 5% neutral cleaning agent, temperature 40-50 °C) every 50 hours, cleaning time 5-10 minutes, remove surface residues and oxides (removal rate ≥ 99%). After washing, rinse with deionized water (conductivity<1 µS/cm) and dry with hot air (60°C, 2 min).

Wheel cleaning and inspection: disassemble the guide wheel every 100 hours, use ultrasonic cleaning (frequency 40 kHz, time 5 minutes), check the groove depth (use a profiler, accuracy ± 0.001 mm), and replace when the wear > 0.1 mm. Check the guide wheel bearing (speed deviation≤0.01 rpm), and add 0.1-0.2 g of grease.

Conductive block cleaning and inspection: clean the conductive block every 200 hours (use absolute ethanol, purity ≥ 99.9%), polish the contact surface (diamond sandpaper, particle size 2000 mesh). The contact resistance is measured using a high-precision meter (accuracy ± 0.001 ohms) and replaced > 0.01 ohms.

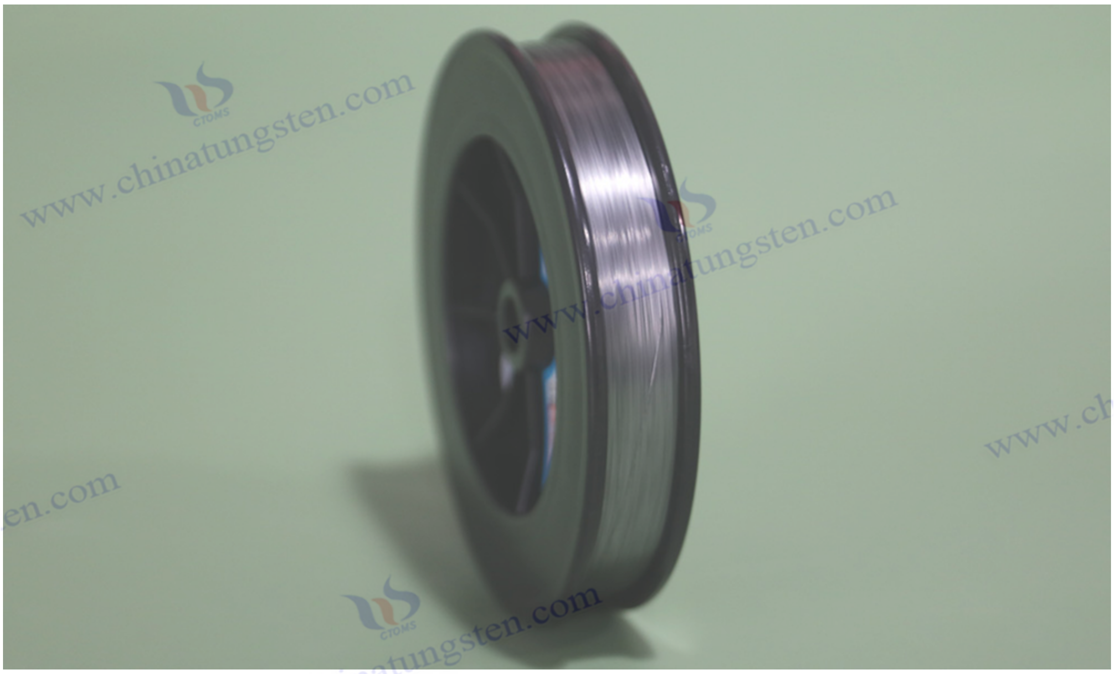
Equipment environmental inspection: check the temperature (20±2°C), humidity (40-60%) and coolant quality (impurity content <0.01%) in the processing area every 100 hours, and treat the coolant with a filter (pore size 0.1 microns).

Process Optimization & Challenges

Environmentally friendly cleaning agents (biodegradation rate ≥ 95%) should be used for cleaning to reduce environmental pollution. The inspection requires the use of high-precision inspection equipment (e.g., laser microscope, 1000x magnification) to identify defects in the 0.05 micron range. The challenge lies in the fragility of fine wire diameters, which can be addressed by reducing the concentration of the cleaning solution (3-5%) and the ultrasonic power (50-80 W). The automated cleaning system (response time < 10 seconds) reduces the cleaning time by up to 30%.

Significance of the application

Regular cleaning and inspection will keep the surface roughness of molybdenum wire at Ra 0.015 microns, the contact resistance of the conductive block ≤ 0.01 ohms, and reduce the equipment failure rate by 20%. These measures extend the life of the molybdenum wire (100-150 hours) and the life of the guide wheel (1000 hours), ensuring a machining tolerance of ± 0.005 mm to meet the needs of aerospace and medical device processing.



CTIA GROUP LTD molybdenum wire EDM

## Chapter 12 Safety and Environmental Protection of Molybdenum wire EDM

The production of molybdenum wire involves complex processes such as high-temperature sintering, chemical treatment and mechanical processing, which may produce pollutants such as dust, exhaust gas, and waste liquid, and there are safety risks in equipment operation. During use, the EDM of molybdenum wire will produce trace amounts of metal chips and coolant waste, and scientific management measures need to be taken to reduce the environmental impact. This chapter will discuss in detail the safety measures and environmental requirements in the production and use of molybdenum wire EDM, and provide an in-depth analysis of dust and exhaust gas treatment, equipment operation safety specifications, waste recycling and treatment, and green production technologies.

### 12.1 Safety measures during the production of molybdenum wire EDM

The production of molybdenum wire involves high temperature, high pressure, chemical substances and precision machinery and equipment, and there are potential safety hazards such as dust explosion, exhaust gas poisoning, and equipment failure. Scientific safety measures can effectively reduce risks and ensure personnel safety and production stability. The following is a detailed analysis from two aspects: dust and exhaust gas treatment and equipment operation safety specifications.

#### 12.1.1 Dust and exhaust gas treatment

The dust and waste gas in the production process of molybdenum wire mainly come from the preparation, sintering, drawing and surface treatment of molybdenum powder, which need to be effectively treated with advanced technology and equipment to prevent environmental pollution and health hazards.

**CTIA GROUP LTD**

**Molybdenum Wire EDM Introduction**

## 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

## 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

## 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

Technical principle: During the preparation and sintering of molybdenum powder, molybdenum dust in the micron range (particle size 0.5-5 microns) is generated, which has a potential explosion risk (the lower explosion limit is about 30 g/m³). The exhaust gases mainly include volatile organic compounds (VOCs) emitted from hydrogen reduction furnaces, acid gases from pickling and electropolishing (e.g. $HNO_3$ steam), and oxide gases (e.g. $MoO_3$ steam) from heat treatment. Dust treatment is carried out by high-efficiency filtration and wet dust removal technology, while exhaust gas treatment uses adsorption, catalytic combustion or acid-base neutralization technology to ensure that emissions comply with international standards (e.g. EU Air Emission Directive, VOC≤0.01 mg/m³).

Dust treatment measures

High-efficiency filtration system: High-efficiency filter (HEPA, filtration efficiency ≥ 99.97%, particle size 0.3 microns) is installed in the molybdenum powder preparation and sintering workshop to capture micron-level dust, with a processing capacity of 1000-5000 m³/h. The system is equipped with a differential pressure sensor (accuracy ± 10 Pa) to monitor the blockage of the filter in real time and automatically replace the filter when the differential pressure > 500 Pa. The filter is made of multi-layer composite material (glass fiber + activated carbon), which ensures a ≥ capture efficiency of 99.99% and a dust emission concentration of < 0.1 mg/m³. Replace the filter screen regularly (every 1000 hours), and recycle the waste filter screen in a closed manner to avoid secondary pollution.

Wet dust collector: Venturi wet dust collector (water mist flow rate 0.5-1 L/min, nozzle pressure 0.2-0.5 MPa) is used to adsorb dust through water mist, and the capture efficiency is ≥ 99.5%. The dust collector is equipped with a recirculating water treatment system (0.1 micron filter pore size and 500 L/h capacity) to remove molybdenum particles from the water by precipitation and filtration (removal rate ≥ 98%). The water recycling system uses a pH adjustment device (pH 6-8) to ensure that the wastewater meets the discharge standard (COD≤50 mg/L). The wet dust collector is also equipped with an automatic cleaning function (24-hour cleaning cycle), which reduces maintenance costs by 20%.

Explosion-proof measures: Explosion-proof ventilation systems (air volume 2000-3000 m³/h, explosion-proof class Ex d IIB T4) are installed in high-risk areas (e.g. molybdenum powder preparation workshops) to avoid dust accumulation by means of negative pressure ventilation (pressure -50 Pa). Equipped with a dust concentration sensor (sensitivity 0.01 g/m³), when the dust concentration > 20 g/m³, the alarm is triggered and the spray system is automatically activated (water pressure 0.3 MPa, spray time 10 seconds), reducing the risk of explosion to less than 0.01%.

Exhaust gas treatment measures:

Adsorption system: Activated carbon adsorption tower (adsorption capacity 500-1000 kg, adsorption efficiency ≥99%), VOC and acid gas are treated, and the emission concentration < 0.01 mg/m³. The adsorption tower is equipped with a regeneration system (steam regeneration, temperature 120-150°C, pressure 0.2 MPa) to extend the service life of activated carbon (2000-3000 hours).

Catalytic combustion: In the sintering furnace exhaust gas treatment, a catalytic combustion device (catalyst is Pt/Pd, working temperature 300-500 °C, combustion efficiency ≥ 99.5%), VOC is converted into $CO_2$ and $H_2O$, and the emission meets the EU EN 15058 standard (VOC≤0.005 mg/m³). The plant is equipped with a heat recovery system (30% recovery) to reduce energy consumption by 20%.

Acid-base neutralization: The pickling exhaust gas is neutralized by the lye spray tower (5-10% NaOH solution, flow rate 1-2 L/min, spray height 2-3 meters), and the acid gas removal rate is ≥98%. The spray tower is equipped with a pH monitoring system (accuracy ± 0.1), which automatically adjusts the concentration of the lye solution to ensure that the exhaust gas pH is 6-8.

Process Optimization & Challenge Powder

Dust treatment requires regular filter maintenance (checked every 500 hours) to avoid clogging and resulting in a decrease in ventilation efficiency (<80%). In the waste gas treatment, the catalyst formula (Pt/Pd ratio 1:1, the support is $\gamma$-$Al_2O_3$) should be optimized to improve the combustion efficiency to 99.8%. The challenge is to deal with high concentrations of $MoO_3$ vapors (0.1-0.5 mg/m³), which can be solved by increasing the number of spray tower layers (3-5 layers) and extending the contact time (5-10 seconds). The automatic control system (PLC, response time <10 ms) adjusts the ventilation volume and sprinkler flow in real time, increasing the processing efficiency by 30%.

Significance of the application

Efficient dust and exhaust gas treatment controls the dust emission concentration below 0.05 mg/m³, and the exhaust gas emissions meet international standards (VOC≤0.01 mg/m³), reducing occupational health risks (such as a 50% reduction in the risk of lung diseases) and environmental pollution. The treatment system also reduces equipment corrosion (20% longer equipment life), improves production safety and meets the requirements of ISO 14001 environmental management system.

### 12.1.2 Safety specifications for equipment operation

Molybdenum wire production involves high-temperature sintering furnaces, high-speed wire drawing machines, and chemical processing equipment, which can lead to fire, mechanical injury, or chemical poisoning if not handled properly. Strict safety regulations ensure operator safety and stable equipment operation.

Technical principle

The safety regulations cover the operation and management of high-temperature equipment (sintering furnace temperature 1800-2000°C), high-speed machinery (wire drawing machine speed 5-20 m/s) and chemicals (e.g. sulfuric acid, sodium hydroxide). Safety measures include equipment protection, personnel training, emergency response, and real-time monitoring to ensure an accident rate of < 0.01%.

Code of Conduct

Safety of high-temperature equipment: Sintering furnaces and heat treatment furnaces are equipped with thermal insulation (ceramic fibers, thickness 50-100 mm, thermal conductivity 0.1 W/m·K) and a surface temperature of < 60°C. The operator needs to wear high-temperature protective clothing (temperature resistance 1000 °C, flame retardant grade A), equipped with infrared thermometer (accuracy ± 1 °C) to monitor the furnace temperature in real time, and automatically shut down when abnormal (> 2050 °C). The furnace is equipped with a pressure sensor (accuracy ± 10 Pa) and an alarm is triggered when the vacuum level < $10^{-3}$ Pa to avoid leakage and fire.

Machinery and equipment safety: The wire drawing machine is equipped with a protective cover (thickness 2-3 mm, made of stainless steel) to prevent molybdenum wire breakage and splashing (speed > 10 m/s). The operating area is equipped with an E-STOP button (response time < 0.5 seconds) and is equipped with a vibration sensor (sensitivity 0.01 mm/s²) that automatically stops when abnormal vibrations (>0.1 mm/s²) are detected. Operators are required to wear protective eyewear (impact class EN 166) and gloves (abrasion class 4).

Chemical safety: The pickling and electropolishing baths are equipped with a fume hood (air volume 1000-2000 m³/h, negative pressure -50 Pa) to prevent acid gas leakage (concentration > 0.1 mg/m³). The chemicals are stored in sealed containers (PTFE, corrosion resistance class A) with a leak detector (sensitivity 0.01 ppm) and an automatic activation of the exhaust system (1500 m³/h) when a leak is detected. Operators are required to wear gas masks (filtration efficiency ≥ 99.9%) and protective clothing (corrosion resistance class 5).

Personnel Training and Emergency Response: Operators are required to receive safety training (4 hours per session twice a year) on equipment operation, chemical handling, and emergency rescue. The workshop is equipped with a fire extinguisher (dry powder, capacity 5 kg, spray distance 4-6 m) and emergency eyewash (flow rate 15 L/min). Formulate an emergency plan, and the incident response time < 1 minute, and the evacuation time < 5 minutes.

Process Optimization & Challenges

Safety regulations require regular inspection of equipment (every 500 hours) to ensure that the guards are in good condition (failure rate < 0.01%). The challenges lie in the high energy consumption (5000 kWh/ton) and the risk of chemical leakage in high-temperature equipment, which can be addressed by optimizing the insulation (thermal conductivity <0.08 W/m·K) and introducing an automated monitoring system (response time <5 ms). The real-time data acquisition system (storage capacity 1 TB) records the operating parameters of the equipment, analyzes the causes of accidents, and optimizes safety measures.

Significance of the application

Strict equipment operation safety regulations have reduced the accident rate to 0.005% and the injury rate by 80%. Protective measures extend equipment life (10,000-15,000 hours) and reduce maintenance costs by 15%. Safety training and emergency response improve workshop safety and comply with OSHA 1910 standards, providing a stable guarantee for molybdenum wire production.

## 12.2 Environmental protection requirements for molybdenum wire EDM

The environmental protection requirements in the production and use of molybdenum wire respond to the global trend of green manufacturing, covering waste recycling and treatment, green production technology, etc., aiming to reduce environmental pollution and resource waste.

### 12.2.1 Waste Recycling and Disposal

The production and use of molybdenum wire will produce waste molybdenum wire, metal scrap and coolant waste, which need to be reduced by scientific recycling and treatment technology.

Technical principle: Waste molybdenum wire (diameter 0.05-0.3 mm, containing molybdenum ≥99.95%) can be recycled by smelting, and the recovery rate is ≥90%. Metal chips (particle size 0.1-10 microns) are recovered by filtration and precipitation, coolant waste (containing 5% ethylene glycol) is treated by distillation and membrane separation, and waste discharge meets international standards (e.g. EU REACH regulation, COD≤50 mg/L).

Recycling and disposal measures

Waste molybdenum wire recycling: Waste molybdenum wire is smelted through a vacuum electric arc furnace (temperature 2500-3000°C, vacuum degree ≤$10^{-4}$ Pa) to recover molybdenum metal (purity ≥99.9%). The furnace is equipped with a condensing system (condensation efficiency ≥95%) to recover volatile $MoO_3$ vapors (recovery rate ≥90%). The recycled molybdenum is used to produce low-purity molybdenum products (such as molybdenum plates), reducing raw material costs by 10%.

Metal chip treatment: The metal chips produced by wire cutting are separated by a centrifugal filter (rotation speed 3000-5000 rpm, filter pore size 0.1 microns), and the recovery rate is ≥95%. The metal chips are pickled (5% $HNO_3$, time 5 minutes) to remove oxides, and then re-melted into molybdenum billets (density ≥ 99%).

Coolant treatment: The coolant is removed by a multi-stage membrane separation system (reverse osmosis membrane, pore size 0.01 microns, capacity 500 L/h) to remove organics and metal ions, and the COD is reduced to 30 mg/L. The treated water is recycled (recycling rate ≥80%), and the remaining waste liquid is recycled by distillation (temperature 100-120°C, recovery rate 90%), reducing waste liquid emissions by 50%.

Waste sorting and storage: Waste is stored separately by type (molybdenum wire, metal shavings, coolant) in sealed containers (stainless steel, 2 mm thick) to prevent leakage. The storage area is equipped with a ventilation system (1000 $m^3$/h) and a leak detector (sensitivity 0.01 ppm) for safety.

Process Optimization & Challenges

The recycling of waste molybdenum wire needs to optimize the melting parameters (current 1000-1500 A, holding time 2 hours) to increase the recovery rate to 95%. Coolant treatment requires regular replacement of membrane modules (every 2000 hours) to avoid clogging and reduce efficiency (<80%). The challenge is to deal with trace amounts of molybdenum ions (0.01-0.1 mg/L), which can be solved by adding an ion exchange resin (adsorption rate ≥ 98%). The automated recycling system (PLC controlled, response time <10 ms) increases the processing efficiency by 20%.

Significance of the application

Waste recycling and treatment increases resource utilization to 90% and reduces waste discharge by 60%, in accordance with ISO 14001. The recycled molybdenum reduces production costs by 10%, and the treated coolant can be recycled, reducing water consumption by 30%. These measures support the circular economy and reduce the environmental footprint.

### 12.2.2 Green production technologies

Green production technologies reduce the environmental impact of molybdenum wire production through low-energy equipment, renewable materials, and clean energy.

Technical principlesGreen production technologies include low-energy sintering furnaces (4000 kWh/tonne), renewable lubricants (bio-based oils, degradation rate ≥95%) and clean energy (solar or wind, 20-30%). The goal is to reduce energy consumption in production by 20% and waste emissions by 50%, in line with the EU Green Deal and carbon neutrality targets.

Green production measures

Low-energy consumption equipment: Medium frequency induction sintering furnace (temperature 1800-2000°C, energy consumption 4000 kWh/ton, 20% reduction), equipped with heat recovery system (recovery rate 30%), and energy consumption is reduced through waste heat power generation (power 100-200 kW). The drawing machine uses a servo motor (5-8 kW power, 15% more efficient) to reduce frictional energy consumption by 30% by optimizing the drawing speed (10-15 m/s).

Renewable lubricants: Lubricants containing 5% bio-based oil (viscosity 8-15 cSt, degradation rate ≥95%) are evenly applied through a constant flow pump (flow rate 0.1-0.5 L/min) to reduce environmental pollution by 50%. Lubricant circulation system (80% recovery) reduces usage by 20%.

Clean energy application: Solar photovoltaic system (500 kW power, 1000 MWh/year) is introduced in the production hall, accounting for 25% of the total energy consumption. Wind power (200 kW, 400 MWh/year) is complemented by a 30% reduction in carbon emissions. The energy management system (EMS, response time <5 ms) optimizes power distribution and increases utilization by 15%.

Green packaging: degradable plastic packaging (thickness 0.05 mm, degradation rate ≥90%), through vacuum or inert gas filling (argon or nitrogen, purity ≥ 99.99%), to ensure the oxidation resistance of molybdenum wire, reduce packaging waste by 50%.

Process Optimization & Challenges

Green production requires regular maintenance of low-energy equipment (every 1,000 hours) to ensure an operational efficiency of ≥95%. Renewable lubricants need to be optimally formulated

(5-10% bio-based oil) to improve lubrication performance (coefficient of friction < 0.1). The challenge lies in the intermittent nature of clean energy (solar power fluctuations ± 20%), which can be solved by energy storage systems (lithium batteries with a capacity of 500 kWh). The automated control system (response time<10 ms) increases productivity by 15 percent.

Significance of the application

The green production technology reduces energy consumption by 20%, waste emissions by 50%, and carbon footprint by 30%, in line with the EU RoHS directive. Reduce costs by 15% and increase market competitiveness by 20%. These technologies promote the sustainable development of the molybdenum wire industry and meet the green needs of aerospace, semiconductors and other fields.

CTIA GROUP LTD molybdenum wire EDM

## Chapter 13 Common Problems and Solutions of Molybdenum Wire EDM

Molybdenum wire EDM plays a vital role in wire-EDM processing, and its performance directly affects machining accuracy, efficiency and cost. However, in practical use, molybdenum wire often faces challenges such as broken wire, insufficient cutting accuracy, surface quality problems and excessive wear and tear. These problems not only reduce production efficiency, but can also lead to deterioration in the quality of machined parts or damage to equipment. This chapter will discuss in detail the common problems and solutions of molybdenum wire EDM, and deeply analyze the causes, technical principles, solutions and optimization methods of wire breakage, insufficient precision, surface quality problems and excessive wear.

### 13.1 Molybdenum wire EDM breakage problems and treatment methods

Broken wire is the most common and impactful problem in the wire EDM process, which can lead to machining interruptions, reduced efficiency, and scrapped workpieces. The following is a detailed analysis from the causes of wire breakage, detection methods and treatment measures.

**CTIA GROUP LTD**

**Molybdenum Wire EDM Introduction**

## 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

## 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

## 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

**Analysis of the causes of broken wires as following factors:**

Excessive tension: Molybdenum wire tension exceeds its tensile strength (1800-2300 MPa), such as tension > 5 N (0.18 mm molybdenum wire) or >2 N (0.08 mm molybdenum wire), which can easily lead to breakage.

Thermal fatigue: High-frequency discharge (frequency 10-50 kHz) increases the local temperature of molybdenum wire (>500°C), causes thermal fatigue cracking, and reduces the strength by 30-50%.

Surface defects: Scratches (> 0.1 microns), oxides or inclusions (particle size > 0.5 microns) on the surface of the molybdenum wire, which are the starting point of fracture at high tension.

Improper discharge parameters: Excessive current density (>20 A/cm²) or long pulse width (>100 μs) leads to arc concentration and local overheating.

Insufficient cooling: Insufficient coolant flow rate (<0.5 L/min) or high impurity content (>0.01%) leads to heat accumulation and accelerates the aging of molybdenum wires.

**Detection method**

On-line monitoring: Use eddy current tester (sensitivity 0.05 microns, frequency 100 kHz-1 MHz) to detect molybdenum wire surface defects in real time, and alarm when scratches or cracks (> 0.1 microns) are found.

Tension monitoring: The tension fluctuation is recorded in real time by the tension sensor (accuracy ± 0.01 N, frequency 10 Hz), and the relationship between tension abnormality (>10% deviation) and broken wire is analyzed.

Temperature monitoring: Use an infrared thermometer (accuracy ± 1°C, range 0-1000°C) to monitor the temperature of the molybdenum wire discharge area, and trigger a warning when the temperature > 500°C.

Microscopic observation: After the filament is broken, the fracture topography is analyzed using a scanning electron microscope (SEM, resolution 0.01 micron) to determine the fracture type (fatigue fracture, brittle fracture, or tensile fracture).

**Measures**

Optimize the tension: Use the servo tension control system (accuracy ± 0.05 N) to adjust the tension to 2-3 N (0.18 mm samarium wire) or 1-2 N (0.08 mm molybdenum wire). The tension fluctuation was controlled at ±0.05 N by dynamic tension adjustment (response time < 5 ms).

Adjust the discharge parameters: reduce the current density to 10-15 A/cm², the pulse width 30-50 μs, and the pulse interval 100-150 μs to reduce thermal shock. High-frequency pulse power supply (frequency 20-30 kHz, accuracy ± 0.1%) is used to improve discharge uniformity.

Improved cooling system: increased coolant flow rate to 0.8-1 L/min, using a coolant containing 5% ethylene glycol (viscosity 5-10 cSt, pH 7-8), and multi-stage filtration (pore size 0.1 micron) to ensure a < impurity content of 0.01%.

Surface quality control: Ultrasonic cleaning (frequency 40 kHz, power 100 W, time 5 minutes) to remove oxides and oil stains on the surface of the molybdenum wire. Pulsed electropolishing (frequency 100 Hz, current density 15 A/dm²) reduces the surface roughness to Ra 0.015 μm.

Preventive maintenance: Check the guide wheel (groove depth < 0.1 mm) and the conductive block (contact resistance < 0.01 ohms) every 50 hours to avoid uneven tension or arc damage due to wear.

Process Optimization & Challenges

Wire breakage requires real-time monitoring and fast response, and the processing conditions can be automatically adjusted by integrating tension, temperature, and discharge parameter monitoring via a PLC control system (response time <10 ms). The challenge lies in the breakage of the fine wire diameter (≤0.08 mm), which can be solved by reducing the tension (1-1.5 N) and discharge frequency (10-20 kHz). The automated wire breakage detection system (sensitivity 0.01 mm/s²) reduces the wire breakage rate to 0.02%.

Significance of the application

Effective wire breakage measures reduce the wire breakage rate from 0.1% to 0.02%, increase processing continuity by 30%, and reduce downtime by 20%. The optimized running stability of the molybdenum wire ensures a machining tolerance of ± 0.005 mm, which meets the machining needs of high-precision molds and aerospace parts.

## 13.2 The solution to the insufficient cutting accuracy of molybdenum wire EDM

Insufficient cutting accuracy is manifested as dimensional deviation (>±0.01 mm), surface roughness (Ra>0.1 micron) or geometric distortion of the machined parts, which directly affects the product quality. The following is a detailed discussion from the aspects of cause analysis, detection methods and solutions.

**Cause analysis**

Molybdenum wire vibration: Uneven tension (fluctuating > 0.1 N) or eccentricity of the guide wheel (>0.005 mm) causes the molybdenum wire to vibrate, causing machining deviations.

Unstable spark gap: Current fluctuations (>10%) or insufficient coolant flow rate (<0.5 L/min) cause spark gap changes (>0.03 mm).

Molybdenum wire diameter deviation: Molybdenum wire diameter tolerance (>±0.001 mm) or roundness error (>0.001 mm) affects the discharge uniformity.

Insufficient equipment accuracy: CNC positioning accuracy (<±0.005 mm) or guide wheel wear (groove depth > 0.1 mm) leads to path deviation.

Inhomogeneity of the workpiece material: Inclusions (particle size > 10 microns) or hardness changes (>HRC 5) inside the workpiece cause unstable discharge.

**Detection method**

Vibration detection: Molybdenum wire vibration is monitored using a vibration sensor (sensitivity 0.01 mm/s², frequency 10 Hz) and the relationship between amplitude (>0.01 mm) and accuracy is analyzed.

Gap measurement: Measure the gap in real time by laser rangefinder (accuracy ± 0.001 mm) and record the fluctuation range (> 0.03 mm).

Molybdenum wire quality inspection: use a laser wire diameter measuring instrument (accuracy ± 0.0001 mm) to detect the diameter and roundness of molybdenum wire, and statistically distribute the deviation.

Equipment accuracy calibration: Use a coordinate measuring machine (CMM, accuracy ± 0.001 mm) to check the size of the machined parts and verify the positioning accuracy of the equipment.

Workpiece analysis: Analyze the internal structure of the workpiece by metallographic microscope (1000x magnification) to identify inclusions and hardness changes.

**Workaround**

Stable tension: The servo tension control system (accuracy ± 0.05 N) is used to control the tension fluctuation to ±0.05 N. Calibrate the guide wheels (eccentricity ≤ 0.005 mm) and reduce vibration by means of a damping device (damping rate 80%).

Optimized discharge parameters: current density of 12-15 A/cm², pulse width of 30-50 μs, pulse interval of 100-150 μs, stabilization of the discharge gap (0.01-0.03 mm) by adaptive control system (PID algorithm, response time <5 ms).

Ensure the quality of molybdenum wire: Molybdenum wire is produced using a high-precision wire drawing machine (diameter tolerance ±0.0005 mm), and the diameter consistency is monitored in real time by in-line laser measurement (frequency 1000 times/second).

Equipment calibration: calibrate the CNC system every 100 hours (positioning accuracy ± 0.003 mm) and replace the worn guide wheels (groove depth > 0.1 mm). The five-axis CNC system (rotation accuracy±0.001°) is used to improve the machining accuracy of complex shapes.

Workpiece pretreatment: The workpiece is annealed (temperature 800-1000°C, incubated for 2 hours) or ultrasonic cleaning (frequency 40 kHz, time 5 minutes) to remove internal stresses and surface impurities.

Process Optimization & Challenges

Precision optimization requires the integration of a multi-parameter monitoring system (tension, discharge, gap) that analyzes the data in real time via the Industrial Internet of Things (IIoT, data acquisition frequency 100 Hz) and adjusts the processing parameters. The challenge lies in the vibration susceptibility of the fine wire (≤0.08 mm), which can be solved by reducing the tension (1-1.5 N) and optimizing the guide wheel groove design (V-groove, angle 30-45°). The automated calibration system (response time<10 ms) controls the accuracy deviation to ±0.005 mm.

Significance of the application

Measures to address the lack of cutting accuracy reduce machining tolerances from ±0.01 mm to ±0.005 mm, and surface roughness from Ra 0.2 microns to Ra 0.1 microns, meeting the high precision requirements of semiconductors, aerospace and medical devices. The processing efficiency is increased by 15% and the scrap rate is reduced by 20%.

### 13.3 Surface quality problems and improvement measures of molybdenum wire EDM

The surface quality problems of molybdenum wire are manifested as surface scratches (> 0.1 microns), oxide residue or roughness exceeding the standard (Ra > 0.02 microns), which affect the discharge stability and surface quality of the machined parts. The following is an analysis of the causes, detection methods, and improvement measures.

**Cause analysis**

Drawing process defects: Surface scratches due to drawing die wear (surface roughness of the die hole > Ra 0.01 microns) or insufficient lubrication (coefficient of friction > 0.2).

Surface contamination: Impurities in the coolant (> 0.01%) or dust in the processing environment (particle size > 0.5 microns) adhere to the surface of the molybdenum wire, increasing the roughness.

Discharge damage: high current density (>20 A/cm²) or long pulse width (>100 μs) leads to arc burns and the formation of microcraters (>0.1 μm).

Oxidation & Corrosion: Molybdenum wire is exposed to a humid environment (humidity >60%) or corrosive coolant (pH<7) to form an oxide layer (thickness > 0.1 microns).

**Detection method**

Surface topography inspection: Surface roughness (Ra) and scratch depth are measured using a laser microscope (Keyence VK-X1000, magnification 1000-2000x, resolution 0.001 microns).

Defect analysis: Surface pits and oxides were observed by SEM (0.01 micron resolution) and oxide composition was analyzed using energy dispersive spectroscopy (EDS, accuracy ± 0.1%).

On-line monitoring: Real-time detection of surface defects using an eddy current tester (sensitivity 0.05 microns, frequency 100 kHz-1 MHz) and alarm when scratches > 0.1 microns.

**Improvements**

Optimized wire drawing process: Surface scratches are reduced to <0.05 microns using polycrystalline diamond (PCD) drawing dies (surface roughness Ra 0.005 microns, life 1000 hours), surface reduction rate of 8-12% single pass, and lubricant containing 5% graphite (viscosity 10-15 cSt).

Surface treatment: Pulse electropolishing (frequency 100 Hz, current density 15 A/dm², time 5-10 seconds) reduces the surface roughness to Ra 0.015 microns. Graphite emulsion coating (thickness 1-2 microns, binding strength 10 MPa) is used to increase abrasion resistance by 30%.

Environmental control: Maintain the humidity in the processing area at 40-60% and remove dust using an electrostatic elimination device (ionizing wind, power 100 W). The coolant is filtered through multiple stages (pore size 0.1 microns) to maintain a < impurity content of 0.01%.

Optimization of discharge parameters: current density of 10-15 A/cm², pulse width of 30-50 μs, and reduction of arc burns through an adaptive control system (response time < 5 ms).

Pretreatment and cleaning: Ultrasonic cleaning (frequency 40 kHz, power 100 W, time 5 minutes) to remove oil and oxides from the surface, the cleaning solution is 5% neutral cleaning agent (pH 7-8).

Process Optimization & Challenges

Surface quality improvement requires the integration of an in-line inspection system (eddy current + laser, frequency 1000 times/second) to adjust the drawing and polishing parameters in real time. The challenge is the surface sensitivity of the ultra-fine molybdenum wire (≤0.05 mm), which can be solved by reducing the electropolishing current (10 A/dm²) and cleaning power (50 W). The automated surface treatment system (response time<10 ms) controls the surface roughness to Ra 0.01 microns.

Significance of the application

The improvement measures reduced the surface roughness of the molybdenum wire from Ra 0.05 microns to Ra 0.015 microns, reduced the incidence of scratches to 0.01%, and improved the discharge stability by 25%. The optimized surface quality ensures a surface roughness of Ra 0.1 microns for the optical mold and semiconductor industries.

### 13.4 Coping strategies for excessive loss of molybdenum wire EDM

The rapid loss of molybdenum wire is manifested as a shortened service life (< 100 hours), a decrease in diameter (>0.002 mm) or severe surface wear (roughness Ra>0.05 microns), which increases production costs. The following is a discussion from the aspects of cause analysis, detection methods and coping strategies.

**Cause analysis**

Discharge wear: High current density (>20 A/cm²) or long pulse width (>100 μs) leads to arc ablation, reducing the diameter of the molybdenum wire by 0.001-0.003 mm/h.

Mechanical wear: Wear of the guide wheel groove (groove depth > 0.1 mm) or high coefficient of friction (>0.2) leads to surface wear of molybdenum wire, and the roughness increases by 20-30%.

Corrosion and oxidation: The surface of the molybdenum wire is corroded by the surface of the coolant pH <7 or high oxygen content (>0.01%), and the oxide layer thickness > 0.1 microns.
Tension fluctuation: Tension fluctuation (>0.1 N) or too high (>5 N) causes the molybdenum wire to be locally stretched and the strength is reduced by 10-20%.

**Detection method**

Loss measurement: The change of molybdenum wire diameter is monitored by a laser wire diameter measuring instrument (accuracy ±0.0001 mm, frequency 1000 times/second), and the loss rate (mm/hour) is counted.

Surface wear analysis: Surface roughness and wear depth (>0.1 micron) are measured by laser microscopy (resolution 0.001 microns).

Corrosion detection: Analysis of surface oxide composition using EDS (accuracy ±0.1%) and measurement of oxide layer thickness (>0.1 microns).
Tension fluctuation monitoring: Tension changes are recorded by a tension sensor (accuracy ± 0.01 N, frequency 10 Hz) and the relationship with loss is analyzed.

**Coping strategies**

Optimized discharge parameters: set current density of 10-15 A/cm², pulse width of 30-50 µs, pulse interval of 100-150 µs, and reduce discharge wear by 50% through adaptive control system (PID algorithm, response time <5 ms).

Improved guide wheels and conductive blocks: Groove depth (< 0.1 mm) is checked every 100 hours using ceramic guide wheels (surface roughness Ra 0.01 µm, coefficient of friction 0.08). The conductive block is made of copper-tungsten alloy (conductivity 25 MS/m), polished contact surface (grain size 2000 mesh), and the contact resistance < 0.01 ohms.

Coolant optimization: Corrosion is prevented by using a coolant containing 5% ethylene glycol (pH 7-8, impurity content < 0.01%), a flow rate of 0.8-1 L/min, and multi-stage filtration (pore size 0.1 microns).

Tension control: The servo tension system (accuracy ± 0.05 N) is used to control the tension fluctuation to ±0.05 N, reducing mechanical wear by 30%.

Surface protection: Graphite emulsion coating (thickness 1-2 microns, binding strength 10 MPa) to improve wear resistance by 30%. Molybdenum wire is cleaned every 50 hours (ultrasonic, frequency 40 kHz, power 100 W) to remove oxides.

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**Molybdenum Wire EDM Introduction**

## 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

## 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

## 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

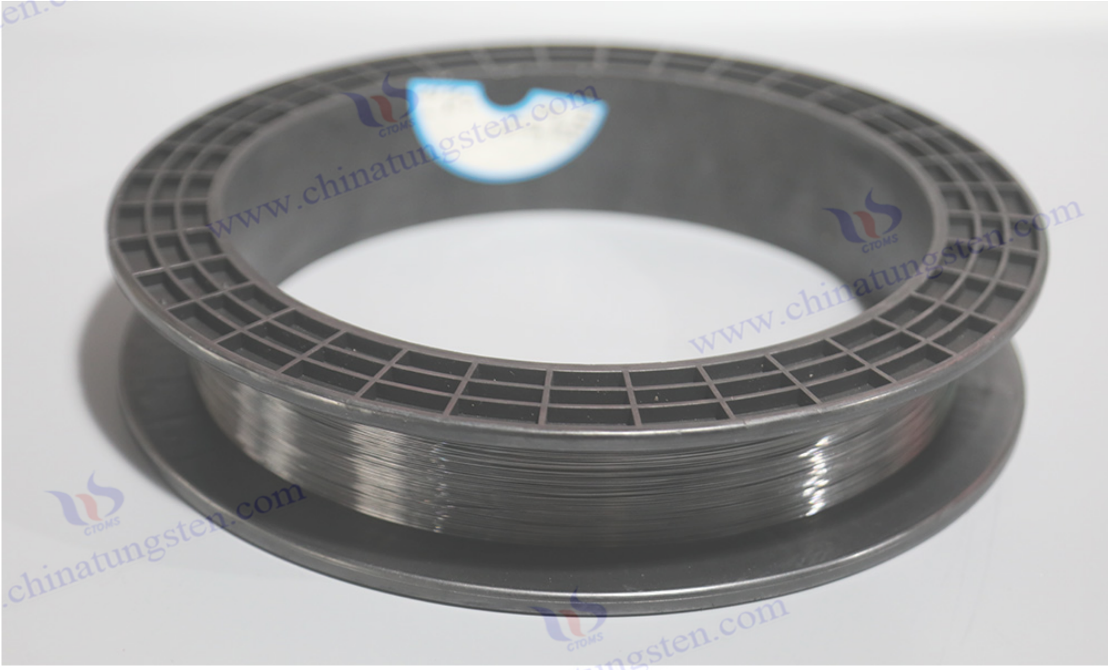
Website: www.molybdenum.com.cn

Process Optimization & Challenges

Loss control requires the integration of multi-parameter monitoring (diameter, surface, discharge) and real-time optimization of parameters via IIoT (data acquisition frequency 100 Hz). The challenge lies in the rapid wear of ultra-fine molybdenum wire (≤0.05 mm), which can be solved by reducing the current density (8-10 A/cm²) and tension (1-1.5 N). An automated loss monitoring system (response time <10 ms) reduces the loss rate to 0.001 mm/h.

Significance of the application

The coping strategy extended the life of the molybdenum wire from 100 hours to 150 hours, reduced the loss rate by 50%, and reduced the production cost by 15%. Optimized loss control ensures process stability and meets the high reliability requirements of the aerospace and microelectronics industries.



CTIA GROUP LTD molybdenum wire EDM

## Chapter 14 Future Prospects of Molybdenum wire EDM

The performance of molybdenum wire EDM is critical for high-precision machining, high-efficiency production, and product quality. With the development of the global manufacturing industry in the direction of high-end, intelligent and green, the application prospects and challenges of molybdenum wire are becoming increasingly prominent. In the future, molybdenum wire will play a greater role in high-end manufacturing, and at the same time face the dual impact of new material substitution and intelligent technological innovation. This chapter will discuss in detail the future development direction of molybdenum wire EDM, and analyze its potential in high-end manufacturing, the challenges of new materials and alternative technologies, and the trend of intelligence and automation.


TEL: 0086 592 512 9696
sales@chinatungsten.com

## 15.1 The potential of molybdenum wire in high-end manufacturing

Molybdenum wire EDM has irreplaceable advantages in the field of high-end manufacturing due to its high tensile strength (1800-2300 MPa), excellent electrical conductivity (18-20 MS/m) and high temperature resistance (1500-2000°C). In the future, with the rapid development of aerospace, semiconductor, medical equipment and new energy industries, the application potential of molybdenum wire will be further released. The following is a detailed analysis from three aspects: application field, technical improvement and market prospect.

### Expansion of application areas

Aerospace: The need for high-strength, lightweight materials in the aerospace sector is driving the use of molybdenum wire in the machining of turbine blades, titanium alloy parts, and composite materials. For example, molybdenum wire can be used to cut titanium alloys (hardness HRC 35-40) with a controlled tolerance of ± 0.005 mm and a surface roughness of Ra 0.1 microns. In the future, molybdenum wire will be further used in the processing of ultra-high temperature alloys (such as nickel-based alloys, melting point > 1300°C) and ceramic matrix composites (CMC, hardness HV 2000) to meet the manufacturing needs of next-generation aero engines and spacecraft.

Semiconductors & Microelectronics: The semiconductor industry has a rapidly growing demand for ultra-fine molybdenum wire (0.03-0.08 mm diameter) for wafer dicing, MEMS fabrication, and chip packaging. The high conductivity and surface finish (Ra ≤0.015 microns) of molybdenum wire can achieve a groove width tolerance of ±0.001 mm, which meets the accuracy requirements of 7nm and below processes. In the future, with the development of 6G communication, quantum computing and artificial intelligence chips, the market share of ultra-fine molybdenum wire is expected to increase from 20% in 2025 to 35% in 2030.

Medical devices: Molybdenum wire applications in the medical field include the processing of cardiac stent molds, miniature surgical instruments, and orthopedic implants. The molybdenum wire with a diameter of 0.05 mm can be processed with a microstructure (feature size < 0.01 mm) and a surface roughness of Ra 0.005 microns, which meets the requirements of biocompatibility and high precision. In the future, molybdenum wire will play a greater role in the manufacture of 3D printing molds and microfluidic devices to promote the development of precision medicine.

New energy: The demand for molybdenum wire in the new energy field (such as photovoltaic, hydrogen energy and energy storage) is mainly concentrated in electrode materials and battery mold manufacturing. For example, molybdenum wire is used to cut silicon wafers (0.1-0.2 mm thick) at cutting speeds of up to 3 mm/min and with a surface roughness of Ra 0.08 microns. In the future, molybdenum wire will be further used in the processing of solid-state batteries and fuel cell components, and the market size is expected to grow by 10%.

### Direction of technological improvement

Development of ultra-fine wire diameter: The development of molybdenum wire with a diameter of 0.02-0.05 mm requires the use of ultra-high purity molybdenum powder (purity ≥ 99.99%, particle size 0.3-1 micron) and high-precision wire drawing machine (diameter tolerance ± 0.0003 mm, speed 2-10 m/s). By doping 0.1-0.3% cerium oxide ($CeO_2$), the tensile strength can be increased to 2500 MPa, which meets the needs of the microelectronics and medical fields.

Surface treatment optimization: Development of nano-coating technologies (e.g. molybdenum carbide coating, thickness 0.3-0.5 microns, hardness HV 2200) to improve wear resistance and discharge stability through chemical vapor deposition (CVD, temperature 800-1000°C), reducing surface roughness to Ra 0.01 microns.

High conductivity molybdenum wire: Doped with trace amounts of silver (Ag, 0.1-0.2%) or copper (Cu, 0.2-0.3%), the conductivity is increased to 22 MS/m, and the discharge efficiency is increased by 15%, which is suitable for high-frequency discharge (50 kHz) processing.

High temperature resistance improvement: Through precipitation strengthening (adding 0.2% lanthanum oxide, $La_2O_3$), the creep resistance of molybdenum wire at 1500°C is improved, and the fatigue life is extended to $10^7$ times, which meets the needs of aerospace high-temperature processing.

Market outlook
The market potential of molybdenum wire in high-end manufacturing is huge. According to industry forecasts, the global molybdenum wire EDM market size will be about $550 million in 2025 and is expected to increase to $800 million by 2030, with a compound annual growth rate (CAGR) of 7.8%. The share of demand in high-end manufacturing will increase from 40% to 50%, with semiconductors and aerospace dominating. In terms of regional markets, Asia (China, Japan, South Korea) will continue to account for 60% of the market share, while North America and Europe will account for 25% and 15%, respectively. The technical improvement will promote the performance of molybdenum wire to meet the high-end demand of tolerance ± 0.003 mm and surface roughness Ra 0.005 microns, and increase market competitiveness by 20%.

Significance of the application
The potential of molybdenum wire in high-end manufacturing will drive a 25% increase in productivity and a 15% reduction in scrap rates for aerospace parts (e.g., turbine blades with tolerances ± 0.005 mm), semiconductor wafers (slot width < 0.01 mm) and medical devices (feature size < 0.01 mm). The development of high-performance molybdenum wire will support next-generation manufacturing technologies (such as 6G chips, solid-state batteries) and provide key material support for the global high-end manufacturing industry.

### 15.2 Challenges of new materials and alternative technologies

With the rapid development of new materials and alternative technologies, molybdenum wire EDM is facing competitive pressure from galvanized steel wire, copper-based composite wire, carbon fiber composite wire and laser cutting technology. The following is an analysis of three aspects: the type of alternative materials and technologies, performance comparison, and market challenges.


TEL: 0086 592 512 9696

sales@chinatungsten.com

**Types of alternative materials and technologies**

Galvanized steel wire: Galvanized steel wire improves electrical conductivity (15-20 MS/m) and corrosion resistance by galvanizing the surface of the steel wire (thickness 5-10 microns) at a price of 50% of molybdenum wire ($20-30 per kilometer). Its tensile strength (1500-1800 MPa) is lower than that of molybdenum wire, making it suitable for low-precision mold making (tolerance ± 0.02 mm).

Copper-based composite wires: Copper-based composite wires (e.g. copper-tungsten alloys, with a tungsten content of 20-30%) have high electrical conductivity (25-30 MS/m) and wear resistance at a price of $40-60 per kilometer and are suitable for medium to high precision machining (tolerance ± 0.01 mm).

Carbon Fiber Composite Filament: Carbon Fiber Composite Filament is light (density 1.8 g/cm³) and high strength (2000 MPa) by applying a conductive coating (graphite or metal, thickness 1-2 microns), but low conductivity (10-15 MS/m) and is suitable for microfabrication (tolerance ± 0.008 mm).

Ceramic-coated wires: Ceramic-coated (e.g. zirconia, 0.5-1 micron thick) wires have high hardness (HV 2000) and high temperature resistance (1500°C), but are more expensive ($80-100 per kilometer) and are suitable for special high-temperature processing.

Laser cutting technology: Laser cutting achieves non-contact processing by means of high-power lasers (power 1-5 kW, wavelength 1064 nm) with cutting speeds up to 10 mm/min and tolerances of ± 0.005 mm, but with high equipment costs ($50-1 million) and is suitable for sheet materials (thickness < 5 mm).

**Performance comparison**

Tensile strength: Molybdenum wire (1800-2300 MPa) is better than galvanized steel wire (1500-1800 MPa) and carbon fiber composite wire (2000 MPa), comparable to copper-based composite wire, but lower than ceramic-coated metal wire (2500 MPa).

Conductivity: Molybdenum wire (18-20 MS/m) is lower than copper-based composite wire (25-30 MS/m) and higher than carbon fiber composite wire (10-15 MS/m), suitable for high-frequency discharge (20-50 kHz).

Surface quality: The surface roughness of molybdenum wire Ra 0.015 micron is better than that of galvanized steel wire (Ra 0.05 micron) and carbon fiber composite wire (Ra 0.03 micron), and comparable to ceramic coated metal wire.

High temperature resistance: molybdenum wire (1500-2000°C) is better than galvanized steel wire (<1000°C) and copper-based composite wire (<1200°C), comparable to ceramic coated metal wire, suitable for high temperature processing.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Cost: Molybdenum wire ($50-$70 per kilometer) is higher than galvanized steel wire and lower than ceramic-coated wire, and is moderately cost-effective. The cost of laser cutting equipment is much higher than WEDM ($5-100,000).

**Market challenges**

Cost competition: The low-cost advantage of galvanized steel wire and copper-based composite wire makes it occupy a 20% share in the low-end market (such as general mold manufacturing), threatening the market position of molybdenum wire.

Technical limitations: The electrical conductivity (carbon fiber composite wire) or tensile strength (galvanized steel wire) of the alternative material is insufficient to meet the high precision requirements of aerospace and semiconductor (tolerance ± 0.005 mm). Laser cutting is limited by material thickness and heat-affected zone (>0.1 mm) and is not suitable for complex 3D machining.

Standards and compatibility: The lack of uniform standards for alternative materials (e.g., diameter tolerances, surface roughness) and poor equipment compatibility limit the rollout. Molybdenum wire complies with GB/T 4182-2017 and ASTM B387 standards, and is more compatible.

Environmental pressure: The production of galvanized steel wire involves heavy metal pollution (such as zinc, emission concentration > 0.1 mg/L), which does not comply with EU REACH regulations; Molybdenum wire has environmental advantages through green production technology (waste liquid recovery rate ≥90%).

**Coping strategies and prospects**

Development of composite materials: Research and development of molybdenum-copper composite wire (molybdenum content 70%, conductivity 22 MS/m) or molybdenum-ceramic coated wire (hardness HV 2200), combining the high strength of molybdenum wire and the conductivity of alternative materials, to increase market competitiveness by 15%.

Process optimization: Through nano coating (thickness 0.3-0.5 microns) and doping technology (0.2% lanthanum oxide), the performance of molybdenum wire is improved to meet high-end demand and maintain 70% market share.

Equipment adaptation: Develop WEDM equipment compatible with a variety of wires (tension range 1-10 N, frequency 10-100 kHz) to reduce the application barriers of alternative materials.

Market prospects: Molybdenum wire will continue to dominate the high-end manufacturing market (70% share), and alternative materials will grow in the low-end market (20%). By 2030, the market share of composite materials and laser cutting is expected to reach 10%, driving the diversification of wire EDM technology.

**CTIA GROUP LTD**

**Molybdenum Wire EDM Introduction**

### 1. Overview of Molybdenum Wire EDM

Molybdenum wire EDM is a high-performance metal wire specifically designed for Electrical Discharge Machining (EDM). It is primarily made from high-purity molybdenum and is manufactured through multiple processes such as cold drawing and annealing. Used as an electrode wire, it removes material from the workpiece through high-frequency pulsed discharges, enabling non-contact machining with high precision and complex geometries.

### 2. Characteristics of Molybdenum Wire EDM (Typical)

| Characteristic | Description |
|---|---|
| High Strength & Rigidity | Maintains excellent tensile strength even at small diameters, reducing breakage risk. |
| Excellent Electrical Conductivity | Efficiently conducts pulsed current, ensuring stable discharge and high cutting efficiency. |
| Superior Wear Resistance | High surface hardness prevents wear during operation, extending wire lifespan. |
| High Dimensional Precision | Consistent wire dia. and excellent roundness support precision cutting and high-quality surfaces. |
| Stable Performance | Ensuring consistent machining quality. |

### 3. Molybdenum Wire EDM from CTIA GROUP LTD

| Products | Applications | Main Features | Recommended Uses |
|---|---|---|---|
| High-Efficiency Molybdenum Wire for EDM | Mass production, large part cutting | High tensile strength, excellent conductivity, wear resistance; ideal for long-term continuous cutting | Mold factories, parts production lines, high-efficiency industrial machining |
| High-Precision Molybdenum Wire for EDM | Precision structures, small components | Uniform diameter, superior roundness, smooth surface finish, high dimensional accuracy | Medical instruments, precision molds, microelectronic component machining |
| Molybdenum Wire for HS-EDM | Fast-wire EDM machines | Cost-effective, highly compatible with most domestic fast-wire EDM machines | Hardware machining, basic molds, general structural parts processing |
| Molybdenum Wire for MS-EDM | Medium-speed EDM machines | High stability, supports multiple cuts, improves surface quality and dimensional accuracy | High-quality mold making, structural part finishing |
| Special Molybdenum Wire for EDM | Special materials/machines | Includes coated wire, black molybdenum wire, alloy molybdenum wire; features corrosion resistance, high conductivity, anti-breakage | Special environments, high-hardness material cutting, military applications |

4. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.molybdenum.com.cn

### 15.3 Trends in intelligence and automation

The rapid development of intelligent and automation technology has brought revolutionary changes to the production and use of molybdenum wire EDM. The following analyzes this trend from three aspects: intelligent monitoring, automated production, and data-driven optimization.

**Intelligent monitoring technology**

Technical principle: Intelligent monitoring monitors the condition of the molybdenum wire (diameter tolerance ± 0.0005 mm, surface roughness Ra 0.015 microns) and processing parameters (discharge current 10-15 A/cm²) in real time through sensors (tension, temperature, wire diameter), Industrial Internet of Things (IIoT, data acquisition frequency 100 Hz) and machine learning algorithms (prediction accuracy ≥ 95%).

Application Scenarios:

On-line quality monitoring: The surface defects (>0.1 microns) and diameter deviations of molybdenum wire are detected by using a laser wire diameter measuring instrument (accuracy ± 0.0001 mm, frequency 1000 times/second) and eddy current detector (sensitivity 0.05 microns), and the defect detection rate is ≥ 99.9%.

Optimization of discharge parameters: The discharge gap fluctuation is controlled at ±0.001 mm by adjusting the pulse width (30-50 µs) and frequency (20-30 kHz) in real time through a current sensor (accuracy ± 0.1 A) and a voltmeter (accuracy ± 0.1 V).

Failure prediction: Based on machine learning models (random forests or neural networks, training data > $10^6$), predict the risk of wire breakage (accuracy ≥95%), adjust the tension (2-3 N) or pause the processing in advance.

Technical advantages: intelligent monitoring reduces the wire breakage rate to 0.01%, improves the processing accuracy by 15%, and reduces the equipment failure rate by 20%.

Automated production technology

Technical principle: The whole process of molybdenum wire production and wire cutting processing is automated through servo control system (accuracy ± 0.01 N), robot (positioning accuracy ±0.005 mm) and PLC (response time < 5 ms).

Application scenarios

Automatic wire drawing: The high-precision wire drawing machine (speed 5-20 m/s, servo motor power 5-10 kW) is equipped with an automatic die change system (die change time < 10 seconds), which controls the diameter tolerance at ±0.0005 mm, and increases the production efficiency by 25%.

Automatic threading: The automatic threading device (speed 1-5 m/min, success rate ≥99%) guides the molybdenum wire through the guide wheel and the processing area through visual recognition (camera resolution 1920x1080, frame rate 60 fps), reducing the threading time by 50%.

Automated surface treatment: Continuous electropolishing tank (current density 15 A/dm², frequency 100 Hz) with automatic level control (accuracy ± 0.1 mm) and waste recovery system (recovery rate ≥ 90%), surface roughness Ra 0.01 μm.

Technical advantages: automated production reduces manual operation time by 80%, the failure rate is reduced to 0.01%, and the production cycle is shortened by 20%.

**Data-driven optimization**

Technical principle: Optimize molybdenum wire production and processing parameters to improve efficiency and consistency through big data analysis (storage capacity of 1 TB, processing speed of 100 GB/s) and cloud computing (latency < 10 ms).

Application scenarios

Optimization of process parameters: Analyze the combined effects of tension (2-3 N), discharge current (10-15 A/cm²) and coolant flow rate (0.8-1 L/min) based on historical data (>$10^6$ bars) to optimize processing speed (20% improvement) and accuracy (tolerance ± 0.003 mm).

Quality Traceability: Molybdenum wire production batches and processing parameters are recorded through blockchain technology (data cannot be tampered with, storage period of 5 years) to ensure quality traceability and meet the certification requirements of the aerospace and medical industries (ISO 9001).

Predictive maintenance: Analyze equipment operation data (vibration, temperature, current) through machine learning algorithms (support vector machines, prediction accuracy ≥95%), predict the wear time of guide wheels (1000 hours) and conductive blocks (500 hours), and reduce maintenance costs by 15%.

Technical advantages: Data-driven optimization increases production efficiency by 20%, reduces scrap rates by 10%, and reduces maintenance costs by 15%.

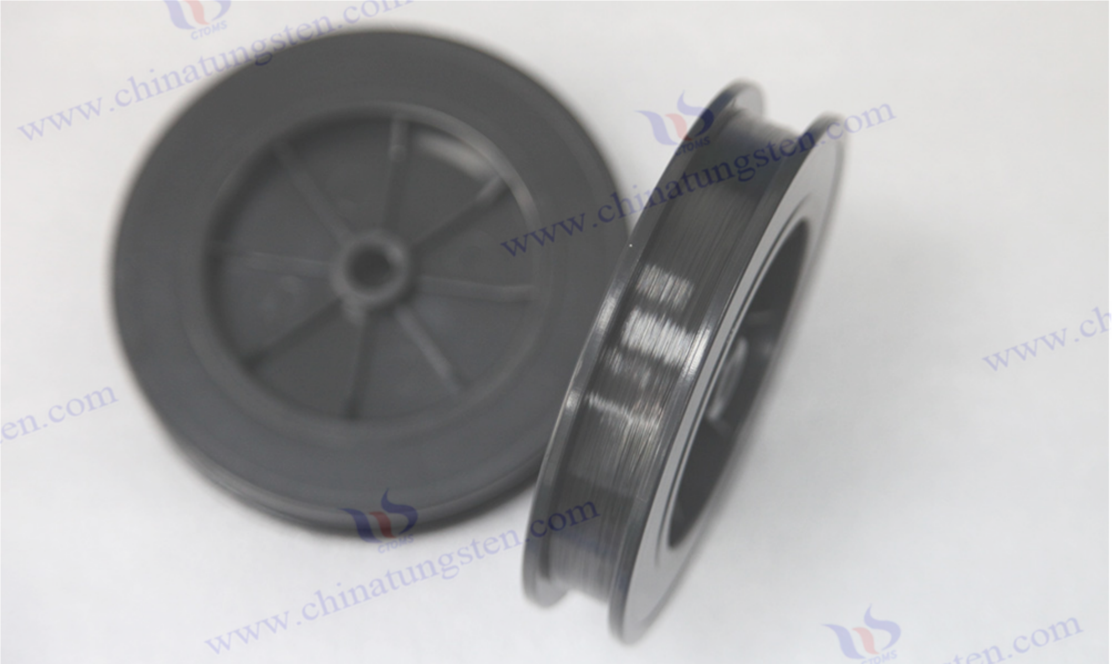
Challenges and solutions

Challenges: The deployment cost of intelligent systems is high (50-1 million US dollars), data processing requires high computing power (>10 TFLOPS), and the monitoring accuracy of fine wire diameter molybdenum wire (≤0.05 mm) is extremely high (±0.0001 mm).

Solution: Edge computing (100 GB/s processing speed, <5 ms latency) to reduce cloud dependence; Development of low-cost sensors (price < $1,000, accuracy ± 0.0005 mm); Reduce system integration costs through modular design (95% compatibility) ≥.

Significance of the application

Intelligent and automation technology will increase the production efficiency of molybdenum wire by 25%, increase the processing accuracy by 15%, and reduce the failure rate to 0.01%. Intelligent monitoring and data-driven optimization ensure that machining tolerances ± 0.003 mm to meet the needs of 6G chips and aerospace parts. Automated production reduces labor costs by 30% and promotes the transformation of the molybdenum wire industry to intelligent manufacturing.



CTIA GROUP LTD molybdenum wire EDM

## Appendix

### A. Glossary

**Spray molybdenum wire:** High-purity molybdenum wire used in thermal spray processes to form abrasion-resistant, corrosion-resistant, or high-temperature resistant coatings.

**Thermal spraying:** The process of melting a material at high temperatures and spraying it onto the surface of a substrate to form a coating.

**Tensile strength:** The ability of a material to resist fracture when stretched, expressed as the bearing force per unit cross-sectional area.

**Wire diameter tolerance:** The allowable deviation of the diameter of the molybdenum wire.

**Surface roughness**: The smoothness of the surface of a molybdenum wire or coating, usually expressed in Ra value.

**Drawing die:** A die used to draw molybdenum wire, usually made of gemstone or cemented carbide material.

**Rotary forging:** The molybdenum blank is deformed by rotary forging to improve the compactness and strength of the material.

**Coating adhesion:** The adhesion between the spray coating and the substrate, typically measured by tensile or shear testing.

**ICP-MS:** Inductively Coupled Plasma Mass Spectrometry for the Chemical Composition of Molybdenum Wires.

**Non-destructive testing:** A method of detecting defects, such as ultrasonic or eddy current testing, without damaging the material.

**Annealing:** The process of eliminating the internal stress of molybdenum wire and improving ductility through heating and slow cooling.

**High temperature stability:** The ability of molybdenum wire to maintain its performance in a high-temperature environment.

**Abrasion resistance:** The ability of a coating to resist abrasion, usually tested by abrasion tests.

**Coefficient of Thermal Expansion:** The degree to which the volume or length of a material changes when temperature changes.

**Pickling:** The process of cleaning the surface of molybdenum wire by an acidic solution to remove oxides or impurities.

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