



# Machining Molybdenum

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Pressed and sintered or recrystallized molybdenum machines very similarly to medium hard cast iron. Wrought molybdenum machines very similarly to stainless steel. Molybdenum can be machined with conventional tools and equipment. However, there are some ways that molybdenum differs from medium hard cast iron or cold rolled steel:

- \* It has a tendency to break out on the edges when cutting tools become dull
- \* It is very abrasive. This causes tools to wear much quicker than steel is cut

## Turning and Milling

For inside and outside turning, tools should be ground to angles and rakes similar to those used for cast iron. Speeds up to 200 feet per minute, with depths of cut up to 1/8", are fine for rough turning. The feed should be .015 i.p.r. For finishing work, speeds up to 400 feet per minute, with a depth cut of .005" to .015", and a feed of .005" to .010" should be used. It is extremely important, when turning, that the depth of the cut always be greater than .005". If the depth is less, tool wear will be excessive. Sulphur based cutting oil may be used as a lubricant for roughing cuts, and kerosene or sulphur based cutting oil can be used for finishing work. If lubricants are not used, tool wear will be excessive. Sulphur based oils cannot be used for electronic parts. Chlorinated oil and solvents are excellent as a machining lubricant. Molybdenum tends to chip when being machined, so care must be taken to prevent this. Work should be tightly chucked, tools rigidly supported and machines should be sufficiently strong and free from chatter or backlash. Plenty of coolant is essential. Face milling in general is not recommended. However, it can be done when necessary. Carbide tipped cutters must be used. The speeds and depth of the cut should be similar to those used in lathe turning, except that the depth of cut should not exceed .050". Molybdenum plates can be edge machined. It is recommended that plates greater than .050" should be edge machined rather than sheared to your finished dimensions. This can be done either on a shaper or a milling machine, and the machining should be done along the edge, rather than across the edge. The molybdenum should be clamped between steel plates while being machined to avoid chipping.

## Drilling, Tapping and Threading

Molybdenum can be drilled with high speed steel drills. However, carbide drills are recommended for deep drilling. Workpiece should be backed up to prevent breakout of the material at the hole exit point. When using high speed steel drills, the speed should be 30 to 50 feet per minute with a feed of .003 i.p.r. Cutting oils should be used for all tapping, drilling and threading operations. When threading, the thread depth should not be more than 50 to 60 percent because molybdenum tends to chip. Turning or chasing is the preferred method of threading. Molybdenum can be rolled threaded, but this method is slow. The molybdenum material and the die should be heated to approximately 325 degrees F. Molybdenum can be heated to 325 degrees F in air without the danger of oxidation. However, molybdenum must not be heated to temperatures above 500 degrees F except in hydrogen or other protective atmospheres. EDM is also an acceptable, but slow method for drilling, tapping, and threading.

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## **Sawing**

Molybdenum saws easily with power band saws and hacksaws. Approximately 1/8" should be allowed for kerf and 3/16" for the camber of heavier sections. Molybdenum may also be abrasive saw cut. The most effective blades are high speed steel with only the tooth area hardened. No coolant is required, but may be used, if desired.

## **EDM & ECM**

Both of these processes work well when working with molybdenum. Stock removal rates of up to .5 in<sup>3</sup>/min and +/- .0005" tolerances have been achieved with EDM. EDM wire cutting is used for intricate shapes. Electrochemical machining is normally capable of approximately 1 in<sup>3</sup>/min stock removal at 10,000 amps. ECM is especially effective for producing ultra-fine finishes.

## **Grinding**

Primarily for surface finishing, not stock removal. Conventional equipment, speeds, and feeds are adequate. Some surface checking can occur, so sharply dressed wheels of a soft grade are recommended.

## **Bending**

Heated properly molybdenum can be formed into complex shapes. Sheets under .020 inches thick can usually take a 180 degree bend at room temperature.

## **Punching, Shearing, & Drawing**

Conventional equipment is satisfactory for these operations. Tools should be sharp and clearances kept around 5% of sheet thickness. Deep draw grades of molybdenum are available. Heating can be employed, if necessary.

## **Welding**

Pure molybdenum is handled in much the same way as tungsten. It really should be joined in a high purity atmosphere after an involved chemical cleaning process. If it is to be TIG welded, run-off tabs should be utilized to prevent crater cracking at the end of each pass during welding. DCEN polarity is used and heat input is kept to a minimum. After welding, the material can be stress relieved to restore ductility. Post grinding to remove bead ripples and surface contaminants will also help restore ductility. If pure molybdenum is welded out in the open atmosphere, nitrogen and oxygen can be absorbed in quantities sufficient to cause brittleness in the HAZ and subsequent joint failure.

## **Cleaning**

Molybdenum can be cleaned in a solution consisting of 50% (by volume) nitric acid plus about 10% (by volume) hydrofluoric acid (from ASM Handbook Series, Volume 5). The solution should be heated in the range of 120-150F. A mixture of these acids will not only remove the oxides, but will also clean off any residual copper that is picked up from the EDM process. Parts should be rinsed well in water after cleaning (possibly deionized water as a final process step).