future alloys

MOLYBDENUM – DATASHEET

SUMMARY PROPERTIES

Property	Value
Name	Molybdenum
Type	Corrosion Resistant Refractory Metal
Chemical Symbol	Mo
Atomic Weight	95.94
Density (gm/cm3)	10.14
Melting Point	2610 +/- 10 ˚C
Recrystallisation Temp	100%
Recrystallisation	1000 to 1100 ˚C
Brittle / Ductile	-100 to 100 ˚C

COMPOSITION - MOLYBDENUM

Substance	Symbol	%
Molybdenum	Mo	99.9 (min)
Potassium	K	0.0007
Aluminium	Al	0.0005
Silicon	Si	0.0050
Iron	Fe	0.0040
Nickel	Ni	0.0030
Copper	Cu	0.0001
Chromium	Cr	0.0001
Sodium	Na	0.0001
Tungsten	W	0.0020

COEFFICIENT OF LINEAR THERMAL EXPANSION

Range (˚C)	Value C(-1)
20	5.3 x 10(-6)
20 - 1000	5.8 x 10(-6)
20 - 1500	1.0 x 10(-6)

THERMAL CONDUCTIVITY - MOLYBDENUM

Range (˚C)	Value (cal/cm/s/ C)
20	0.34
1000	0.25
1500	.22
2200	0.17

SPECIFIC HEAT - MOLYBDENUM

Range (˚C)	Value (X10(-2) cal/gm/ ˚C)
20	6.2
1000	7.4
2000	10.0

VAPOUR PRESSURE - MOLYBDENUM

Range (˚C)	Value (mm Hg)
1500	6.4 x 10(-9)
2000	4.0 x 10(-5)
2500	1.0 x 10(-2)

RESISTIVITY - MOLYBDENUM

Range (˚C)	Value (ohm-cm)
20	5.3 x 10 (-6)
1000	3.2 x 10 (-5)
2200	6.1 x 10 (-5)

TEMPERATURE COEFFICIENT OF RESISTIVITY - MOLYBDENUM

Range (˚C)	Value C(-1)
20 to 100	4.5 x 10 (-3)

TENSILE STRENGTH / YIELD STRENGTH / HARDNESS - MOLYBDENUM

Format	Tensile Strength (KPSI)	Yield Strength - 0.2% Offset (KPSI)	Hardness (DPH)
Sheet	50 to 115	40 to 95	220 to 240
Rod	60 to 110	90	200 to 220
Wire	90 to 350	75 to 300	250 to 300

MACHINING - MOLYBDENUM

Molybdenum Overview
Pressed and sintered (recrystallised) molybdenum has high machinability and is similar to medium hard cast iron. The machinability of wrought molybdenum is comparable to stainless steel and can be worked with conventional machine shop equipment.
However, unlike when machining cold rolled steel or medium hard cast iron, dull cutting tools cause the edges of molybdenum material to break out during machining. Its also very abrasive and reduces tool life through increased wear.

Turning and Milling
Similar to cast iron machining, molybdenum tools should be ground to rakes and angles during inside and outside turning. For rough turning the ideal feed is 0.015 inches per rotation, although a feed speed up to 200 feet per minute with a depth of up to 1/8" is acceptable.

Finishing work requires speeds of up to 400 feet per minute, having a depth cut of 0.005" to 0.015", and a feed rate of 0.005" to 0.010". During turning, cut depth needs to be higher than 0.005". A depth less than 0.005" will increase wear and reduce tool life. Sulphur based cutting oils may be used for lubricants for the roughing cut phase, and either sulphur or kerosene cutting oils are suitable lubricants for the finishing phase. However avoid using these lubricants with electronic applications to prevent contamination. Chlorinated oils are ideal as a machining lubricant, as molybdenum has a tendency to chip when being machined.

Use plenty of coolant, and if possible avoid face-milling, or use carbide tip cutting tools if unavoidable.

Drilling, Threading and Tapping
Ideally use high speed steel drills, or carbide drills for deep drilling, in conjunction with cutting oils. Ensure to back up the workpiece to avoid breakout at the exit hole. The ideal drill speed for machining moly is around 30 to 50 feet per minute with a feed of 0.003 inches per revolution. Molybdenum tends to to chip, threading depth should not be greater than 50% to 60%.

Molybdenum can be rolled threaded, but this technique is slow. A quicker method is turning or chasing.
Heat the molybdenum and the die to around 162˚C for best results. Molybdenum can be heated to 162˚C in air without it oxidisation, but should not be heated above 260˚C unless in a protective atmosphere. Electrical Discharge Machining (EDM) can be used as an alternative to molybdenum drilling, tapping, or threading but this process is slower.

Sawing
High speed steel blades with a hardened tooth area are ideal for sawing molybdenum. Power band saws, hack saws, or abrasive saws are all effective. Coolant can be used but is not required.

EDM & ECM
Molybdenum is very compatible with both Electrical Discharge Machining (EDM) and Electrochemical Machining (ECM) methods. Using EDM, machinists can achieve removal rates of up to 0.5 inches cubed per minute and +/- 0.0005 inch tolerances.

ECM is normally capable of removal at approximately 1 inch cubed per minute at 10,000 amps. While EDM is the preferred method for complex shapes, ECM is very effective for producing ultra-fine finishing.

Grinding
Traditional machining equipment can be used for grinding molybdenum.

Bending
Molybdenum can be formed into intricate shapes when heated. Moly sheets under 0.020 inches thick can usually be bent at a 180˚ angle at room temperature.

Punching, Shearing, & Drawing
Conventional equipment can be used for punching, drawing and shearing molybdenum. Tools must be sharp with equipment clearances around 5% of sheet thickness. Application of heat will make the material more pliable and help the process.

Welding
The best way to weld molybdenum is to first chemically clean it to remove impurities, then perform welding in a vacuum. During TIG welding, utilise run-off tabs to avoid crater cracking at the end of each pass. Use DCEN polarity and ensure that heat input is kept to a minimum to avoid oxidation. Following welding, you can restore some of the materials ductility using stress relieving techniques, or by grinding the material to remove any surface contaminants. Avoid welding pure molybdenum in the open atmosphere as there is a risk of absorbing the oxygen and nitrogen, hence causing oxidation and causing brittleness.

Cleaning
Molybdenum can be cleaned by using a solution consisting of 50% nitric acid mixed with approximately 10% hydrofluoric acid, heated to 50 – 65˚C. This ensures that the mixture will not only remove any oxides, but will also clean off any residual copper that is accumulated during the EDM process. Finish by dousing the parts in water and allow them to dry.