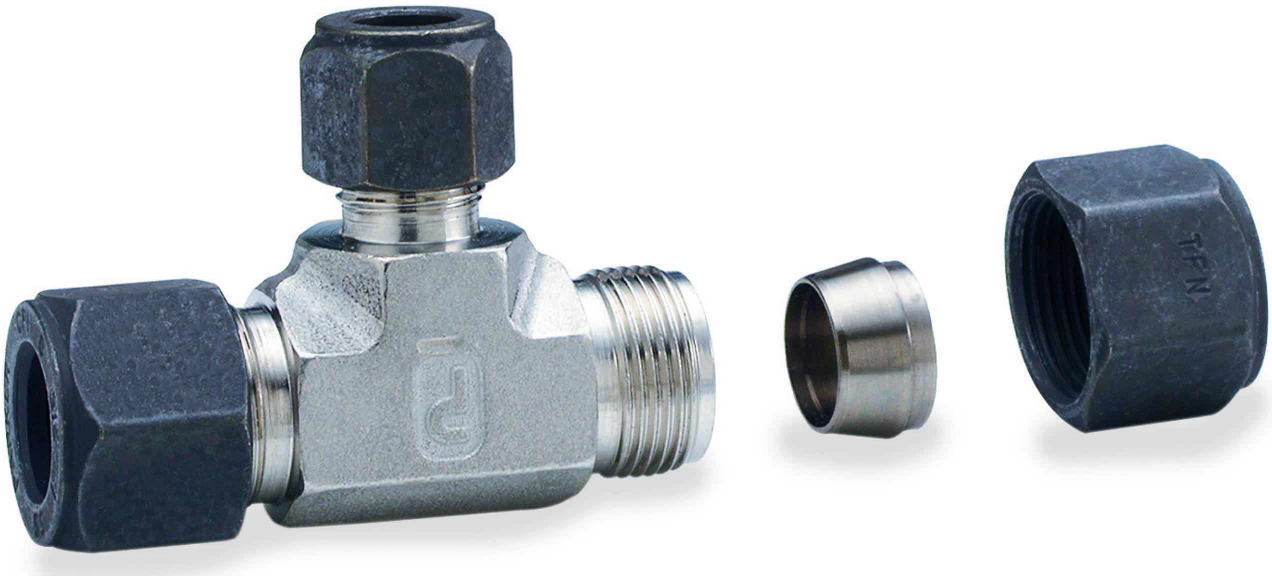


Molybdenum Disulfide - The Ideal Solid Lubricant and Anti-Galling Material

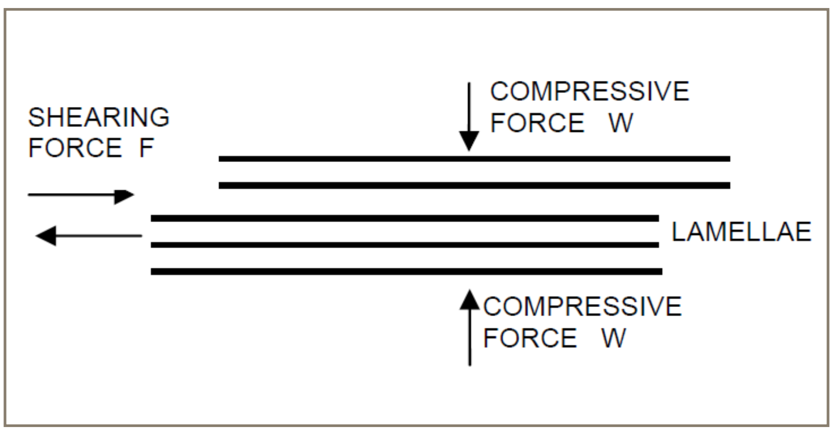
White Paper

ENGINEERING YOUR SUCCESS.

History

Molybdenum disulfide is a naturally occurring black-colored solid compound that feels slippery to the touch. It readily transfers and adheres to other solid surfaces with which it comes into contact. Its mineral form – called molybdenite – was commonly confused with graphite until late in the 1700's. Both were used for lubrication and as a writing material for centuries. Wider use of molybdenite as a lubricant was impeded by naturally occurring impurities that significantly reduced its lubricating properties. Methods of purifying molybdenum disulfide and extracting molybdenum were developed late in the 19th century, and the value of molybdenum as an alloying addition to steel was quickly recognized. The demand for a domestic source of molybdenum during World War I resulted in the development of the Climax mine in Colorado, which started production in 1918 and continued into the 1990's[1,2]. The availability of high purity molybdenum disulfide spurred extensive investigations into its lubrication properties in various environments during the late 30's and 40's. These investigations demonstrated its superior lubrication properties and stability under extreme contact pressures and in vacuum environments. The United States National Advisory Committee for Aeronautics, the precursor to NASA, the National Aeronautics and Space Administration, initiated research on aerospace uses of molybdenum disulfide in 1946. These investigations resulted in extensive applications in spacecraft[3], including the extendible legs on the Apollo Lunar Module[4,5]. Applications continue to expand as new technologies evolve requiring reliable lubrication and resistance to galling under increasingly stringent conditions of temperature, pressure, vacuum, corrosive environments, process sensitivity to contamination, product life, and maintenance requirements.

Technical



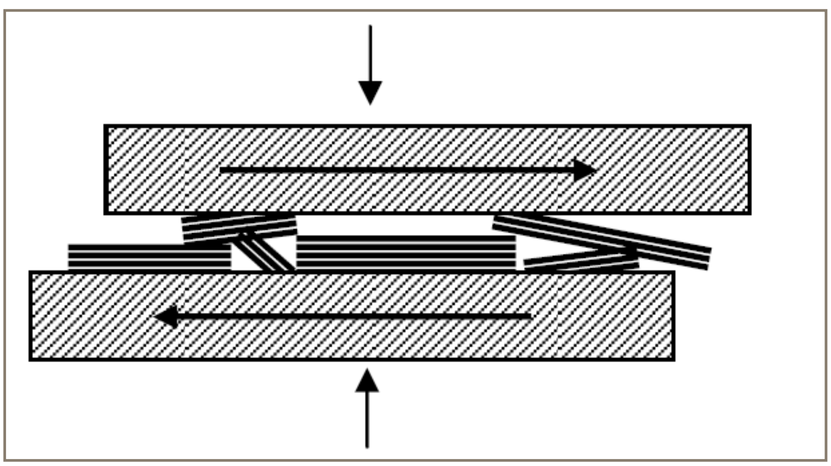


Fig 2. Lamellae align and adhere to sliding surfaces.

Molybdenum disulfide's exceptional lubricity is a consequence of its unique crystal structure, which is made up of very weakly bonded lamellae. These lamellae can slide across each other, "shear", under very low force, providing the lubrication effect. This shearing force required to overcome the weak bonding between the lamellae, F, is related to the compressive force, W, perpendicular to the lamellae by the equation

$$\mathbf{F = \mu W}$$

where μ is a constant termed the "Coefficient of Friction". The coefficient of friction for molybdenum disulfide crystals shearing along their lamella is approximately 0.025, among the lowest known for any material[6].

The lamellae tend to align and adhere to contact surfaces, particularly under conditions of sliding and pressure, as shown in Fig 2. This "burnishing in" of the molybdenum disulfide gives it its exceptional performance life.

Fig 2 – Lamellae align and adhere to sliding surfaces.

Since molybdenum disulfide is a solid phase, it is not “squeezed out” like liquid lubricants under conditions of extreme pressure. The lamellae are very “hard” to forces perpendicular to them. This combination of properties provides a very effective “boundary layer” to prevent the lubricated surfaces from contacting each other.

The surfaces of objects are generally rough on a microscopic scale. When two objects are in contact with each other, they actually “touch” at very small regions of contact (i.e. asperities), as shown in Fig 3.

These contact regions have considerably less area than the bulk surface area, typically in the range 0.5 to 0.001 percent of the bulk area for a machined metal surface[7], and consequently the stresses at these contact points are considerably higher than the stresses calculated for the bulk surface area. When these objects slide relative to each other the frictional forces add to the stresses at the contact points, and the resultant stresses may be sufficient to cause deformation of the contact points, as shown in Fig 4.

When stainless steel objects slide against each other under high load, they will “gall” or “seize” due to the deformation at the contact points. The objects will actually “cold weld” themselves to each other, which is indicated by transfer of material from one object to the other on the sliding surfaces. This causes a very rapid increase in friction, quickly to the point that further sliding is impossible without damage to the objects. In order to prevent this it is necessary to introduce an “anti-galling” or “anti-seizing” agent between the surfaces. This is a substance that is capable of maintaining separation of the surface asperities under high compressive loads – that is, to provide a “boundary layer” between the surfaces. Anti-galling materials are generally very thick grease-like substances or solid materials in powder or plated layer form. Molybdenum disulfide is an ideal anti-galling compound because of its combination of high compressive strength and its adherence (ability to fill or level) to the sliding surfaces.

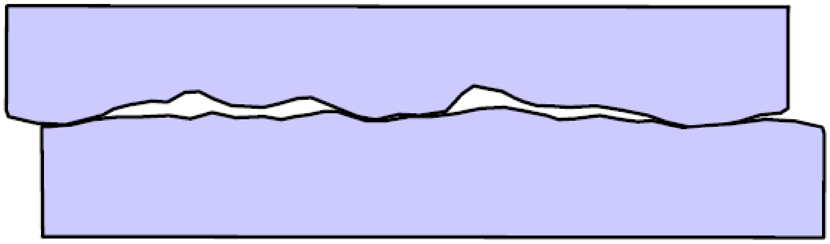


Fig 3. Surfaces are in contact at small regions.

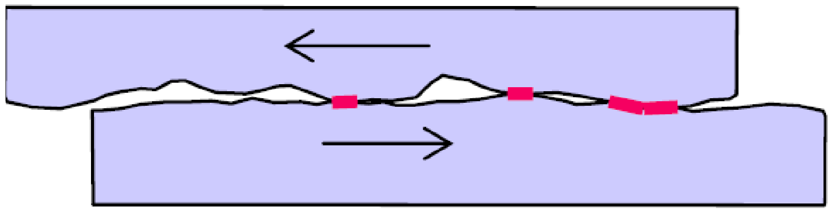


Fig 4. Sliding surfaces cause deformation of contact regions.

There are many methods of applying molybdenum disulfide to a surface, from “high tech” techniques such as vacuum sputtering, to simply dropping loose powder between sliding surfaces. The most versatile technique is application of the powder mixed with a binder and a carrier to form a bonded coating. The binder may be a polymeric material or a number of other compounds, and the carrier may be water or a volatile organic. The characteristics of the molybdenum disulfide powder, the binder, the carrier, and particularly the application process must be carefully developed and controlled to optimize the performance in a specific product. A properly developed bonded coating of molybdenum disulfide is capable of providing exceptional lubrication performance over a temperature range up to approximately 500°C, under very high pressure and corrosive exposure conditions for extensive lifetimes. There are many such formulations available commercially. These are discussed extensively in Lansdown[8].

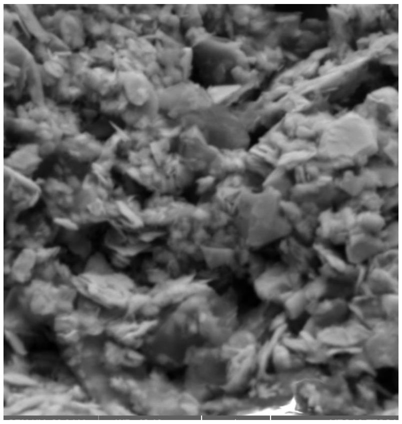


Fig 5. Molybdenum Disulphide particles on scanning electron microscope.

Molybdenum Disulfide in Compression Fittings

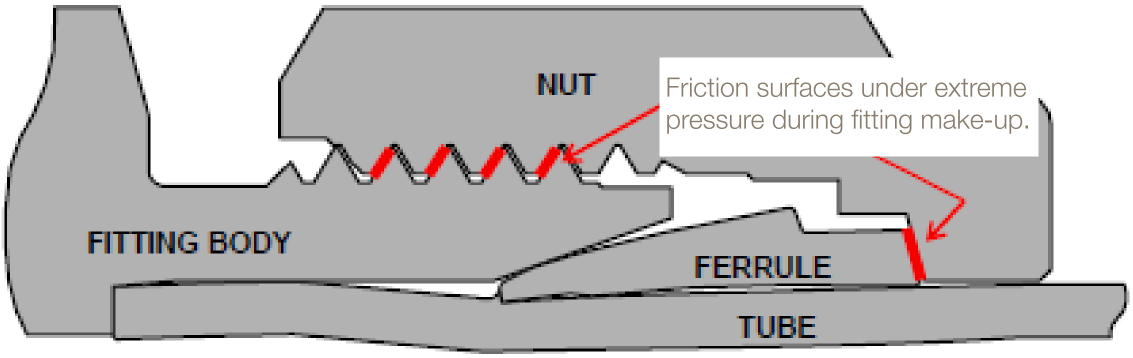


Figure 5. Half-section of Parker CPI™ single ferrule fitting showing areas of friction under very high pressure during make-up.

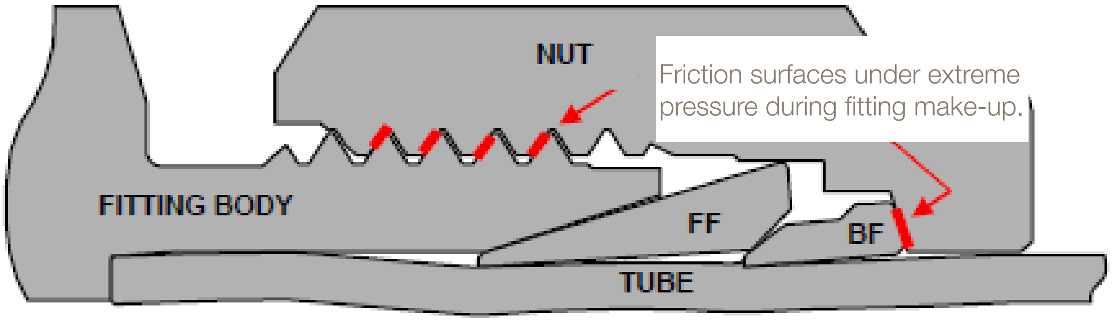


Figure 6. Half-section of Parker A-LOK® two ferrule fitting showing areas of friction under very high pressure during make-up.

Half-section diagrams of a Parker CPI™ single ferrule compression tube fitting and a Parker A-LOK® two ferrule compression fitting are shown in Fig 5 and 6.

During fitting make-up the ferrule(s) are driven forward into the body seat and tubing surface as the nut is turned per the make-up instructions. The ferrules seal at contact points with the fitting body seat and tubing surface. The fitting is carefully engineered such that the ferrule and tubing do not rotate with the nut, moving only in the axial direction. This is critical to forming a high integrity leak-free tubing connection during the first make-up and subsequent remakes. Therefore all of the sliding takes place between the back of the ferrule and the flange of the nut under very high pressure. This region of contact between the nut and the ferrule must have excellent lubrication for the proper action to occur during make-up to ensure ease of assembly, low make up torques and optimum fitting function. The nut is "pulled" against the ferrule during make-up by the threads, which are also sliding under very high pressure and also require high performance lubrication. Stainless steel compression fittings have the additional problem of preventing galling in these areas of sliding under very high contact pressures. This requires a "boundary layer material" – a substance that maintains separation of the surfaces during sliding.

The Instrumentation Products Division (IPD) of Parker Hannifin has developed and used a bonded molybdenum disulfide coating on the nuts of its premium CPI™ compression fitting products for 30+ years. These fittings are readily recognized in the field by the "black nut" – the molybdenum disulfide coated nut, and have been providing exceptional service in many demanding applications.

The molybdenum disulfide coating has been carefully formulated and processed to optimize the performance of the CPI™ compression fitting. This fitting, with its single ferrule and the molybdenum disulfide coated nut, has easy initial make-up with very low torque, consistent remake, and exceptional, leak-tight performance under demanding applications including pressure, temperature, corrosion exposure, and vibration.

One Product, Multiple Applications

The Instrumentation Products Division of Parker Hannifin also offers "Moly Inside" nut for use with the Parker CPI™ and A-LOK® compression fittings. This is an optional version of its premium compression fitting products with the molybdenum disulfide coating only where it is needed, on the inside surfaces of the nuts. This offers the same low make-up torque and consistent remake-ability of the standard CPI™ compression fitting in both the CPI™ and A-LOK® versions due to the use of molybdenum disulfide on the critical mating surfaces of the interior threads and flange of the nut, but without the molybdenum disulfide on the external surfaces to rub off onto hands, gloves, or other equipment for industries requiring a "clean" appearance.

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[8] Lansdown, p 179 – 206.

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