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Features of molybdenum disulfide friction

In the general problem of reliability, accuracy and durability of machines, mechanisms and devices the basic place belongs to questions of friction, lubricating action, wear of surfaces of details and working bodies which are among themselves in very difficult correlation dependences.

One of the current problems of modern science is the rational use of lubricants, which in many cases determines the efficiency and durability of machines and mechanisms. Difficult operating conditions of modern machines have dramatically increased the requirements for lubricants. As a result, the theory of lubricating action was further developed, especially at extreme friction. There is a need for in-depth study of the mechanisms and patterns of mechanical and physicochemical effects of lubricants with different composition under different friction conditions.

An effective way to reduce friction and wear rate of machine parts is to use lubricants of different types and nature. Among the lubricants a special place is occupied by materials containing molybdenum disulfide.

The work aims to analyse of the structure, tribological properties and rational applications of lubricants containing molybdenum disulfide.

Lubrication between two surfaces in conditions of dry or extreme friction is provided by solid lubricants [1-2].

The main types of solid lubricants are graphite, molybdenum and tungsten disulfides, hexagonal boron nitride, tin and cadmium bromides, silver sulfate, bismuth iodides, nickel and cadmium, selenides and tellurides of tungsten, titanium, polytetrafluoroethylene (teflon). The most widely used among solid lubricants are graphite, molybdenum disulfide, polytetrafluoroethylene.

The antifriction properties of molybdenum disulfide (MoS_2) were discovered in 1744. However, for a long time this discovery was unnecessary. And only in 1940 the development of lubricants based on MoS_2 began, and the production of lubricants based on MoS_2 was organized in 1948 by Alpha Molykote (USA).

The chemical, molybdenum disulfide, used in industry has the number CAS-1317-33-5 according to the international classification.

Molybdenum disulfide (MoS_2) is a soft bluish-gray powder with a metallic luster of natural or synthetic origin.

According to the classification proposed by Campbell, molybdenum disulfide as well as graphite, mica, talc, boron nitride, zinc stearate belongs to the group of solid lubricants, the crystal lattice of which has a layered structure.

Molybdenum disulfide MoS_2 has a layered molecular structure that is similar to the structure of graphite. Molybdenum atoms are covalently joined into regular hexagons, and sulfur atoms, when combined with molybdenum atoms, form a branched three-dimensional structure, separating the layers of molybdenum atoms from each other (Fig. 1). Separate atomic planes consist either of pure molybdenum or of pure sulfur. Crystal lattice parameters: width 3.26 Å, height 12.3 Å, thickness of one elementary layer MoS_2 is equal to 6.25 Å. Neighboring layers of sulfur interact through Van der Waals forces. The bond strength between them is relatively low, that provides low shear resistance of this material. At the same time, the film of this lubricant can withstand relatively high loads and retain its antifriction properties up to a pressure of $3 \cdot 10^3$ MPa, which corresponds to the tensile strength of most metals.

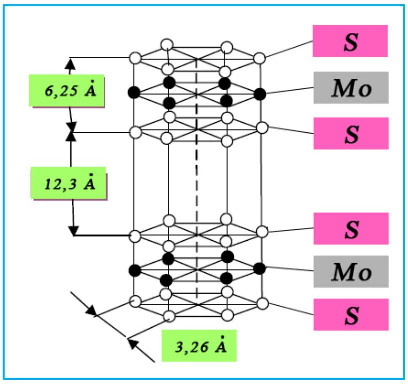

Figure 1 – Crystal lattice of molybdenum disulfide

The layered structure of the crystals and the strong polarization of sulfur atoms during friction determine the lubricating ability of molybdenum disulfide. The high adhesion of molybdenum disulfide to metals is due to the strong molecular bonds formed by sulfur atoms with the metal. The film of molybdenum disulfide with a thickness of 0.025 μm consists of 40 layers with 38 sliding planes between them. The film of molybdenum disulfide with a thickness of 1 μm contains 1631 sliding surface. The presence of layers of two different atoms in the structure of molybdenum disulfide creates conditions for easy sliding of the plates.

The density of molybdenum disulfide is 4800 kg/m^3, Mohs hardness 1…1.5, oxidation temperature in air 400 °C, decomposition temperature in vacuum 1100 °C, melting point 1185 °C. Molybdenum disulfide has good adsorption capacity against most ferrous and nonferrous metals. The friction coefficient of molybdenum disulfide is in the range of 0.03…0.05. In contrast to graphite, with increasing load and temperature, the friction coefficient of molybdenum disulfide decreases.

Molybdenum disulfide’s friction coefficient in vacuum differs little from the air one, even at temperatures up to 800 °C (Fig. 2) [1].

The bearing capacity of the limiting lubricating film of molybdenum disulfide is higher than that of any lubricating oils. High bearing capacity (up to 2800 MPa), high radiation resistance and thermal conductivity, preservation of antifriction properties in vacuum up to 800 °C made molybdenum disulfide one of the main materials of the friction units of space technology.

The disadvantages of molybdenum disulfide include:

1. High chemical activity. Molybdenum disulfide reacts relatively easily with water and oxygen. In a humid atmosphere there is a reaction

$$2MoS_2 + 9O_2 + 4H_2O = 2MoO_3 + 4H_2SO_4.$$

For MoO_3 the friction coefficient is 0.6, it is much harder than MoS_2. Thus, intense abrasive wear of the friction surface in the presence of sulfuric acid begins. With this in mind, when in contact with air, the maximum allowable temperature is not more than 450 °C.

2. At temperatures above 500 °C it is oxidized with the release of sulfur dioxide (SO_2).

3. At temperatures above 800 ° C, molybdenum disulfide almost decomposes.

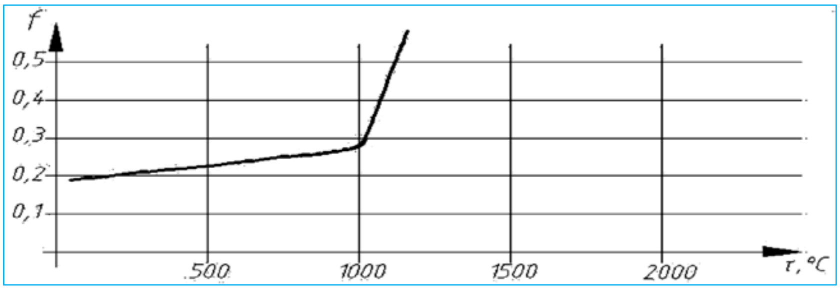

Figure 2 – Dependence of the friction coefficient of molybdenum disulfide on the temperature in vacuum

Molybdenum disulfide is used in the form of a powder, which is added to the carrier material: a plastic mixture consisting of 40...70 % MoS_2 in a semi-liquid environment, aerosol dispersion sprays.

The second method of use is the introduction of molybdenum disulfide into the composition of sintered metal parts. The brushes of the electric motor, made with MoS_2 - silver, have the intensity of wear 2...3 times less than the graphite ones.

Comparison of MoS_2 characteristics (0.5 % MoS_2; 2 % MoS_2; 5 % MoS_2; 10 % MoS_2) and other additives (0.5 % graphite; 5 % graphite; 10 % graphite; Si + 5 % MoS_2; 0.5 % ZnO; 10 % ZnO) in mineral oil at low sliding velocities allows us to conclude that only molybdenum disulfide has the ability to suppress the abrupt increase in friction [1]. In addition, the concentration of graphite above 5 % is less effective in reducing wear than the concentration of 0.5 % MoS_2 (Fig. 3). Not surprisingly, molybdenum disulfide is now a promising material for friction and slip joints.

In 1992, due to the discovery of fullerene-like particles of molybdenum disulfide (Reshef Tenne), the study of the tribological properties of lubricants with nanostructured MoS_2 began.

The introduction of nanocrystalline MoS_2 additives improves tribotechnical characteristics in comparison with similar additives of micron MoS_2 powder [3-4]. Examples of lubricants containing nanostructured MoS_2 and being manufactured are Nano Grease UNIVERSAL M-00 Grease Nano Black, Nano Grease UNIVERSAL M-0 Grease Nano Black, Nano Grease UNIVERSAL M-1 Grease Nano Black, Nano Grease UNIVERSAL M Grease Nano Black, low-temperature Nano Grease NOFROST AEP 2 Grease -60 °C.

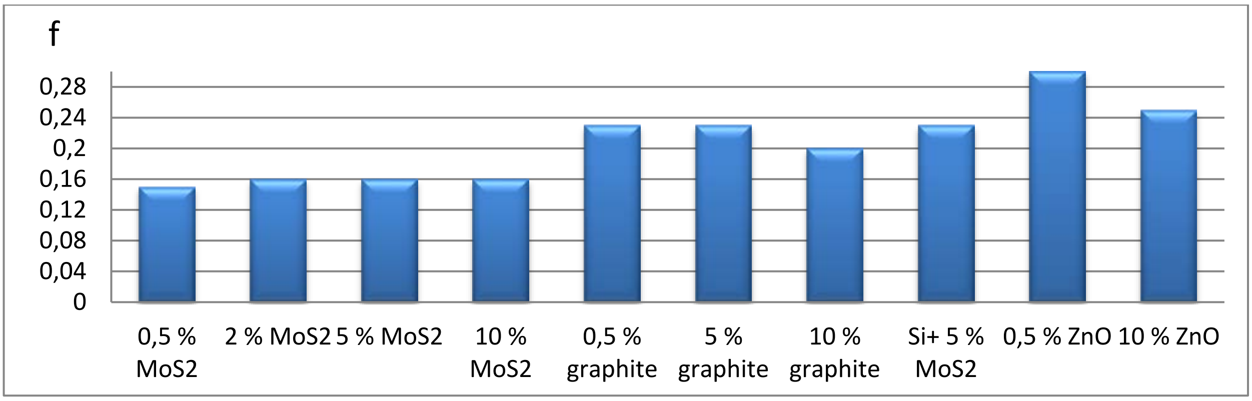

Figure 3 – Comparison of the friction coefficient of molybdenum disulfide and other additives to mineral oil:
0.5 % MoS_2; 2 % MoS_2; 5 % MoS_2; 10 % MoS_2; 0.5 % graphite; 5 % graphite; 10 % graphite; Si + 5 % MoS_2; 0.5 % ZnO; 10 % ZnO

As a solid lubricant, molybdenum disulfide is successfully used in internal combustion engines that operate without lubrication, roller chain drives, presses and oil pipelines fans. The characteristics of MoS_2 exceed the characteristics of graphite and fluoroplastic, and, in addition to traditional use (in the form of powder, grease or dispersion), it can also be applied by plasma spraying.

The low friction coefficient of molybdenum disulfide in vacuum allows using it in space technology.

Thus, molybdenum disulfide is a promising material for tribodes.

The analysis of composition, structure, tribological properties and rational areas of application of lubricants containing molybdenum disulfide is made. Specifics of molybdenum disulfide friction are considered. Promising areas of molybdenum disulfide use are shown. The content of the article can be used by students majoring in 274 Automotive engineering in the study of disciplines "Structural and operational materials in the automotive industry", "Fundamentals of technology for the production and repair of cars".

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