Influence of different environement on the tribological behavior of molybdenum disulfide MoS_2

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***Abstract*—Plastic materials are more and more important in our life. This article measure the thermal properties of some typical plastics materials by using the TMA Q400 machine. By comparision of their results and their chemical formulas will show their properties.**

The tribological properties of molybdenite or molybdenum disulphide MoS_2 depend on the relative humidity of gases surrounding the tribocontact. In high vacuum environments and in inert gases, the friction coefficient μ of molybdenum disulphide MoS_2 is very low about μ=0,02 and in humid environments, the friction coefficient increases to μ = 0,18.

The objective of this study is to present the experimental results of the tribological properties of molybdenum disulfide MoS_2 against steel XC48 in different gaseous environments (in high vacuum and ambient air). We calculate the potential energy between the gaseous molecules and the surface of adsorption or between these adsorbed gaseous molecules. We also try to estimate the interactions between the adsorbed gaseous molecules of the gap between the two consecutive layers of the crystal molybdenum disulfide MoS_2. We discuss the effect of these interactions on the tribological characteristics of molybdenite MoS_2.

Keywords—molybdenum disulphide, water vapor, polarisation, ionization energy, lubrification, friction coefficient

I. INTRODUCTION

Molybdenum disulfide MoS_2 crystal is a hexagonal structure. It is a solid lubricant lamellar structure of alternating layers: layer of sulfur / molybdenum layer / layer of sulfur ... layer of sulfur / molybdenum layer / layer of sulfur ... (S / Mo / S ... S / Mo / S ...). Its low friction coefficient μ = 0.02 obtained in high vacuum around tribocontact is due to the weak bonds Van der Waals [1-15] between two layers of sulfur. However, this low coefficient of friction can vary and increase to μ = 0.18 in air ambient around the tribocontact [1-15].

In the previous time, we did not attribute the variation of friction coefficient molybdenum disulfide MoS_2 in the environment around tribocontact [19]. Since 1976, it demonstrates with the notion of "time stop effect" that there is an influence of water vapor, gases or other contamination on the friction coefficient. In this paper, we present the experimental results obtained in four tribological different gas environments. Then we discuss the reasons which change the friction coefficient in the different gaseous environments.

II. DESCRIPTION OF EXPERIMENTAL TESTS

Tribological tests were done by using one pin-on-disc type tribometer as shown in the figure 1. The pin is hemispherical shape with diameter of 5 mm and length of 15 mm. The disc diameter is 70 mm which is covered by a thin layer of molybdenum disulphide MoS_2. Both of them are made of steel XC 48 and they are localised in the chamber of tribometer.

The different gaseous types used for the experimental tests such as dry ambient air. The temperature is nearly stable about 25° C. The relative sliding speed is 0,4 m/s. The normal load N is 4,625 N applied with the mass on the arm carrying the pin.

To prepare the experimental in high vacuum, the air of the closed chamber is evacuated by a system of pumps. A primary pump can descend to a pressure of 10^{-1} Pa. A second turbo pump continues descend down to 10^{-5} Pa in 24 hours. Once the high vacuum reached, we can start the friction tests in high vacuum.

The friction force is recorded by a gauge. The various sensors are connected to a central acquisition of multichannel data. The analog signal is amplified and converted by a conditioner Labview 7.1.

Fig. 1 : The general view of tribometer pion-disc type (disc support, chamber, vacuum pump)

III. RESULTS AND DISCUSSIONS

All the gaseous contamination in the molybdenum disulfide produced an increase in friction coefficient compared with the value obtained in high vacuum. Indeed, it has been shown experimentally in several publications [1,15].

The contamination by the vapors is probably inherently an impact on the structure of molybdenum disulfide MoS_2 and produces an increase of friction coefficient rather than the one in high vacuum. In fact, it has been demonstrated experimentally in a wide range of publications reported that it increases the friction coefficient when the two consecutive layers of molybdenum disulfide sliding parallel with the basal planes of the crystallites.

For each experiment, we must change the new pin and the new disc.

A. Tribological behavior of molybdenum disulfide in high vacuum (10^{-5} Pa)

Once the contact pin of steel / molybdenum disulfide / steel disc is established is placed, the chamber is pumped by a primary pump for an hour until the residual pressure $P = 10^{-1}$ Pa and then the secondary pump descends the residual pressure 10^{-5} Pa in 24 hours.

Our test of the tribological contact steel / MoS_2 / steel carried out in high vacuum ($P = 10^{-5}$ Pa) lead to a friction coefficient $\mu = 0.018$ in steady state (Figure 2).

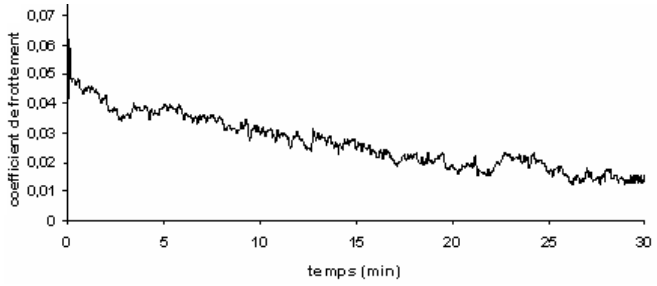

Fig. 2 : Evolution of friction coefficient of the steel / molybdenum disulfide / steel in high vacuum (v = 0.4 m / s, T = 25 ° C, load = 4.6 N)

B. Tribological behavior of molybdenum disulfide in ambiant air

Under the influence of a mixture of several gases such as ambient air, the coefficient of friction is not stable (Figure 3). It varies between the value $\mu = 0.18$ at the start of the test and $\mu = 0.12$ at steady state and depends on the concentration or percentage of the gases in the mixture.

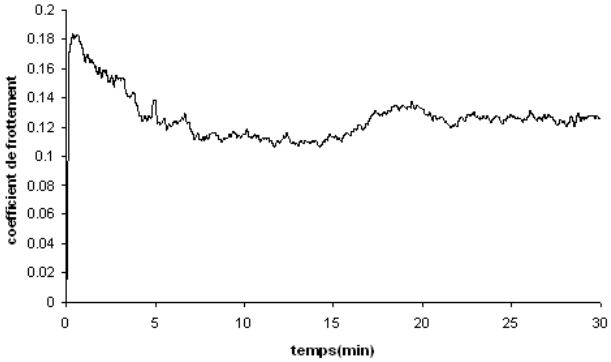

Fig. 3: Evolution of friction coefficient of the steel / molybdenum disulfide / steel in ambiant air (v = 0.4 m / s, T = 25 ° C, load = 4.6 N)

IV. DISCUSSION

A. Study of the Van der Waals forces between the molybdenum disulfide and gas

The forces of Van der Waals interactions between low dipole atoms, molecules, or between a molecule and a crystal. It is possible to describe these interactions by considering the dipolar forces are present between all pairs of electric charges which form the atoms and molecules. The effect of the strength of Van der Waals (in $1/R^6$) is very important if the distance r is very low, which corresponds to the case of adsorption of gas in the molybdenum disulfide MoS_2

These between molybdenum disulfide and the surrounding gases are dipolar interactions: dipole dipole MoS_2 and gas. In fact, each atom has a permanent dipole moment more or less strong due to the separation of the positive charge of the nucleus and the negatively charged electron and a dipole moment snapshot that comes from quantum fluctuations of the instantaneous charge density of valence. Moreover, the inter-plane in the crystal of molybdenum disulfide MoS_2 is about 3.08 A° (less than 5 A°) and the attraction of van der Waals force between the gas and the dipoles MoS_2 is strong enough in this case (Figure 4).

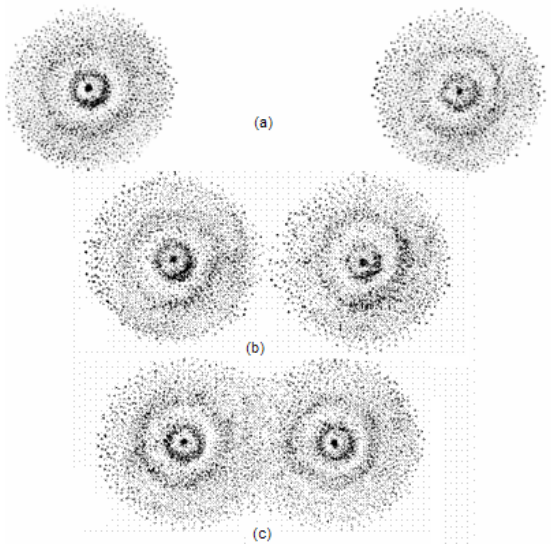

Fig. 4 : *Diagrams showing the van der Waals attraction and repulsion from the electronic distribution between two argon atoms*
(a) Weak Van der Waals attraction (10 A°)
(b) Very strong attraction of van der Waals distance 5 A °
(c) van der Waals attraction just balanced by the repulsive forces due to interlocking outer electron shells at a distance about 4 A °

B. Study of the influence of The Van der Waals forces and the evolution of friction

Molybdenum disulfide MoS_2 has a lamellar structure as graphite but each layer is composed of either sulfur or molybdenum. Molybdenum disulfide is a hybridization sd^4p [5]. Each molybdenum atom is surrounded by six sulfur atoms in a hexagonal shape. The valences are all saturated. The hexagonal form of molybdenum disulfide MoS_2 is symmetrical and is autoequilibrium (Figure 5). This structure allows the material to have a low coefficient of friction.
Molybdenum disulfide MoS_2 is considered a microporous material capable of adsorbing gases. In the adsorption, the gas molecules under dipole attraction molybdenum disulphide potential energy U.

The total potential energy is the sum of all the potential energy components. In this process, the adsorbed amount is influenced by several parameters such as the partial pressure of gas, the reactivity of gas molecules etc.. On the surface, the freedom of rotation and vibration of the adsorbed molecules is usually limited and these molecules could also be desorbed under the influence of temperature

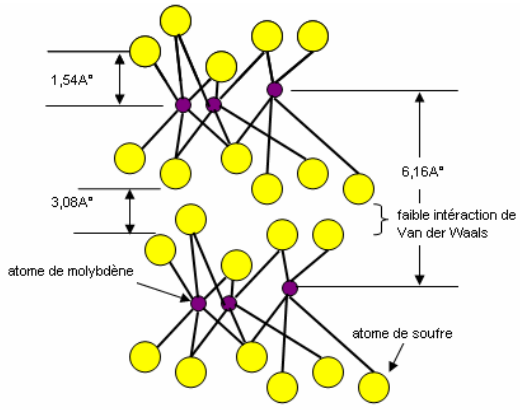

Fig. 5 *The structure of molybdenum disulphide MoS_2*

The description of the interaction of a gas molecule with the surface is approximately the sum of the interaction of a gas particle with the surface of each atom [17]

$$U_{surface} = \sum_{i=1}^{n} u_{(r_i)}$$

And $$u\ (r_i) = 4\varepsilon_{gs}\left[\left(\frac{\sigma_{gs}}{r_i}\right)^{12} - \left(\frac{\sigma_{gs}}{r_i}\right)^{6}\right]$$

Where u (r_i) is the Lennard-Jones potential describing the interactions and r_i is the distance between gas particles and the surface interaction

εgs = (εgg εss) and σgs = (σgg σss) 1 / 2 / 2 εgg σgg and are the depth of potential wells and the diameter of hard sphere collision. Gg indices indicate the parameters determined for the gas molecules interactions. The indices indicate settings ss solid atoms.

V. CONCLUSION

Our tests conducted on the tribological couple acier/MoS_2/acier in high vacuum (P = 10^{-5} Pa), and in ambiant air that illustrate the influence of environment around the tribo-contact tribological behavior of MoS_2 :
- Tests under high vacuum demonstrate clearly the intrinsic nature of self-lubricating molybdenum disulfide μ = 0.02. Disulfide behaves almost as well as a lubricant fluid.

- The tests carried out under ambient air clearly show the influence of the dipolar character of different gases on the tribological molybdenum disulfide MoS_2.
- It is interesting to perform tribological tests in mixtures of gases (argon + oxygen), (nitrogen + oxygen) ..., (nitrogen + oxygen + water vapor) to determine the partial pressures at critical transition (low friction / friction severe).

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