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Experimental Investigation on Effect of Particle Sizes of Molybdenum Disulphide on Wear Under Heavy Load and Slow Speed Conditions

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ABSTRACT: *In the present work, experimental investigation has been carried out to identify the effectiveness of employing three different particle sizes of MoS2 (Nano-particles: 40 nm size, Technical superfine grade: 1.75 µm size and Technical grade: 53 µm size) in varying quantities (0.5, 1.0 and 1.5% by weight) on the wear of the sliding surfaces. The experiments were conducted on a conformal block and disk test setup. The running-in distance required to achieve steady state wear was determined experimentally. The wear of the block is measured as its weight loss after the test. The results of the experiments are reported.*

Keywords: *Molybdenum disulphide, Nano-particles, wear, running-in wear, steady wear.*

I. Introduction

The molybdenum disulphide (MoS_2) had been in use for quite a long time as a solid lubricant additive in oils [1] for effectively reducing the wear between contacting sliding surfaces. Under extreme operating conditions of heavy loads and low sliding velocities, the asperities of the sliding surfaces interact with each other and results in wear which may eventually cause the surface degradation/failure. Recent advancements in the technology of synthesizing nano-sized molybdenum disulphide (MoS_2) particles [2] have accelerated their use as anti-wear additive in lubricants. The molybdenum disulphide nano-particles when used as lubricant additive also enhances the load carrying capacity of the base oil in addition to reducing wear [3]. The nano-particles are shown to have superior properties than micro-sized MoS_2 particles due to high specific surface area [4], which is also the cause of their agglomeration [5]. The lubricating property of nano-sized molybdenum disulphide (MoS_2) is attributed to its layered crystal structure (as a result of strong polarization of sulfur atoms) providing easy sliding of its lamellae [6]. The amount of wear reduction is dependent on the particle size of molybdenum disulphide (MoS_2). Hu et al. [7] investigated the effect of particle size of molybdenum disulphide (MoS_2) in liquid paraffin and proved that nano-sized particles were more effective in reducing wear and friction as compared to micro-sized particles [7]. However, if the nano-particles are not properly dispersed in the lubricant they may agglomerate and cause excessive wear due to three body abrasion. Muzakkir et al [8] have proposed a lubricant containing Zinc as antiwear additive that is able to minimize wear under heavy load and slow speed conditions. In another study Muzakkir et al [9] showed that for bearings subjected to extreme operating conditions, use of a high viscosity lubricant with anti-wear additives reduces the wear and also the probability of failures.

In the present work, experimental investigations have been carried out to determine the effect of size and quantity of molybdenum disulphide (MoS_2) particles on the wear of the sliding surfaces. Three different particle sizes of molybdenum disulphide (MoS_2) namely, Nano-particles: 40 nm size, Technical superfine grade: 1.75 µm size and Technical grade: 53 µm size, were considered as additive in a commercial lubricant in varying quantities ranging from 0.5% to 1.5% by weight. In order to achieve a distinct performance, the wear during the initial running-in period was segregated from the steady state wear. The running-in distance required to achieve the steady state wear is determined experimentally. The experiments were conducted on a conformal block of phosphorus bronze material sliding against a steel disk. The wear of the block is measured as its weight loss after the test. The results of the experiments are reported.

II. Experimental Details

In the present work, wear tests were carried out on a conformal block-on-disk test setup. The photograph and schematic diagram of the conformal block-on-disk test setup is shown in fig. 1(a) and 1(b).

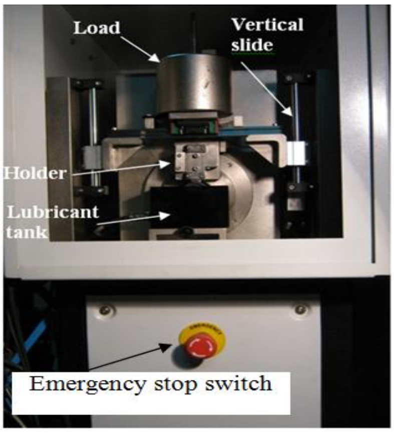

Figure 1(a) Photograph of conformal block and disk test setup

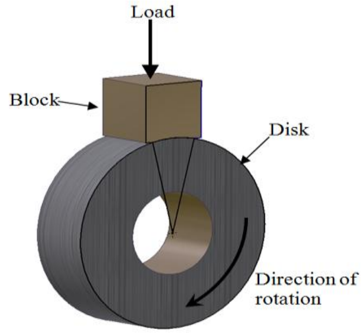

Figure 1(b) Schematic diagram

The test setup employs a conformal block (made of phosphorus bronze material) on hardened steel disk (diameter = 40 mm, width = 15mm), which is driven by induction motor. Half of the steel disk is immersed in the lubricant tank. The lubricant inside the tank is maintained at the desired temperature by the help of heaters and thermal cut-off switch. The static load is applied on the platform on which the block is fixed.

The tests were conducted at a load of 50N generating a pressure of 4.6×10^5 N/m^2 corresponding to the contact area of 1.085×10^{-4} N/m^2 of conformal block for a disk of 40 mm diameter. The disk was rotated at a speed of 25 rpm corresponding to a sliding speed of 5.23×10^{-2} N/m^2. For running-in tests, the disk was rotated at 50 rpm at a load of 50N and the wear was recorded after every 125m sliding distance corresponding to test duration of 20 minutes. The lubricant samples were prepared by dispersing the molybdenum disulphide (MoS_2) particles in a commercial lubricant with lithium stearate as a surfactant by ultrasonic homogenization for duration of one hour.

III. Results and Discussion

Initial experiments were conducted to determine the minimum sliding distance required to complete the running-in process. The experimental wear values were obtained after every 125m sliding distance corresponding to test duration of 20 minutes and are shown in fig. 2.

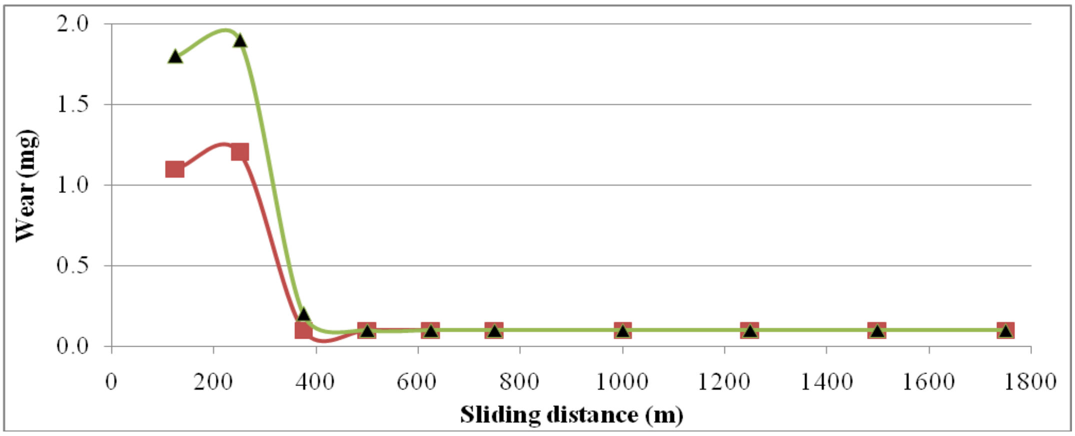

Figure 2 Wear Vs sliding distance of the conformal block during the running-in test

It is observed from figure 2 that the minimum sliding distance required to achieve the steady state wear is about 500m. Therefore, to be conservative, a value of 750m (corresponding to a test duration of 2 hours) may be taken as the minimum sliding distance for the completion of the running-in process. All the subsequent wear tests of 6 hours duration were then conducted after completing the running-in of the conformal blocks. The results of the normal tests with lubricant 1 are shown in fig. 3.

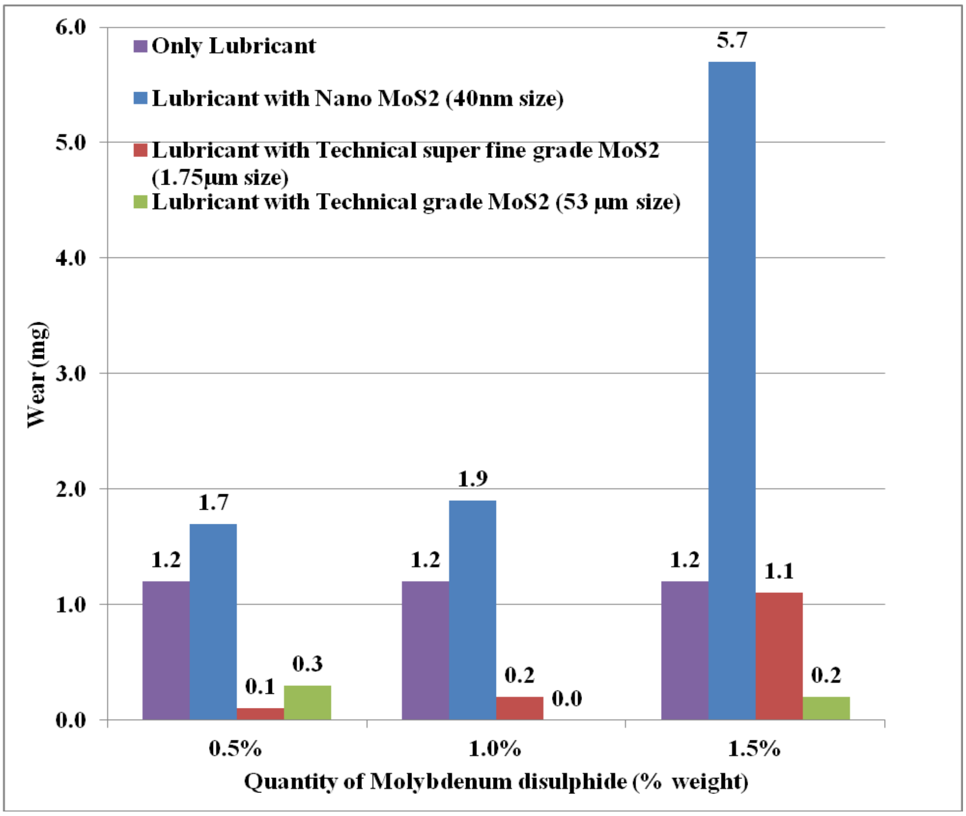

Figure 3 Wear of the conformal block after the normal test of 6 hours

It is observed from the experimental results that the wear during the normal test is highest for the MoS_2 nano-particles as compared to other particle sizes and increases with the increase in the nano-particle quantity, being the maximum when MoS_2 nano-particle quantity is 1.5%. It is observed from the experimental results that the addition of MoS_2 nano-particles results in higher wear even when compared with only oil. The wear increases with the increase in the quantity of MoS_2 nano-particles. The possible reason could be the agglomeration of nano-particles to bigger size with sharp edges. The size of the resulting nano-particles agglomerate is larger by an order of magnitude. This might have resulted in three body abrasion causing increased wear. The minimum wear was observed with the technical grade particles. In order to ascertain the reasons for increased wear with the use of MoS_2 nano-particles, the SEM images of the three molybdenum disulphide (MoS_2) particles were obtained. These SEM images of the molybdenum disulphide (MoS_2) particles are given in fig. 4, 5, and 6.

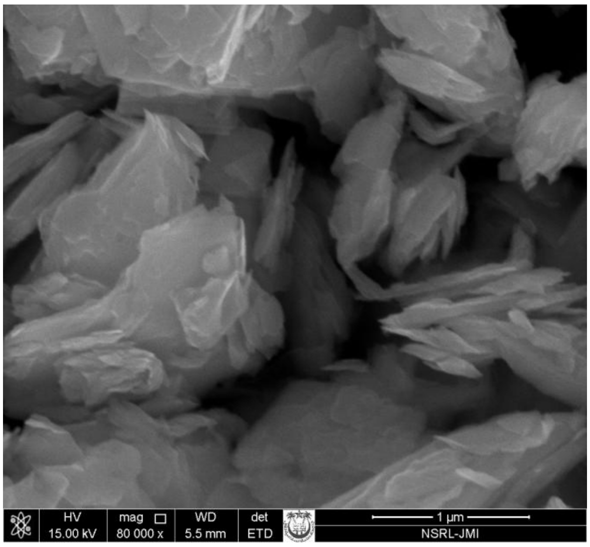

Figure 4 SEM image of MoS_2 Nano-particles

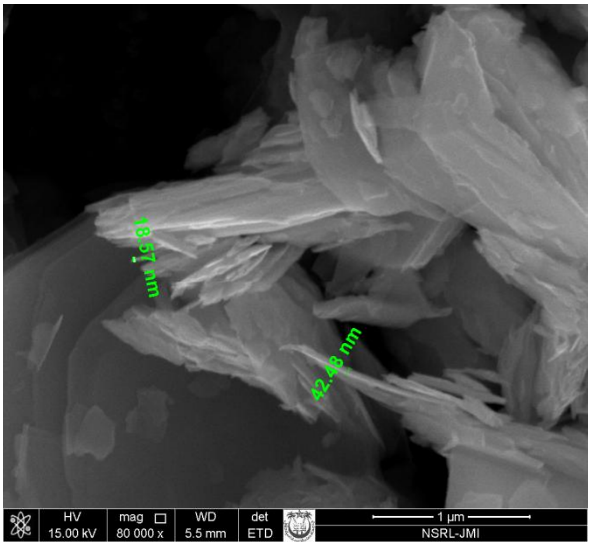

Figure 5 SEM image of MoS_2 Tech. Superfine grade particles

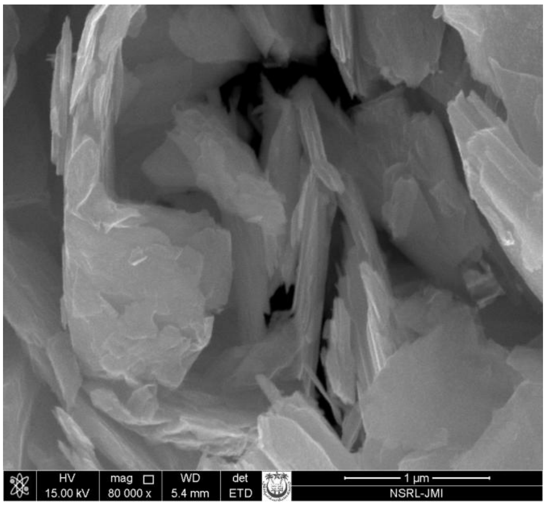

Figure 6 SEM image of MoS_2 Technical grade particles

It is observed from the SEM images that the molybdenum disulphide (MoS_2) particles are in a predominantly slices form with a distinct layered structure which is responsible for easy sliding of its lamellae that contributes in wear and friction reduction. Since nano-particles are very active, therefore there is increased adhesion of the nano-slices with each other.

IV. Conclusion

Based on the observations of the experimental studies, following conclusions are drawn:

- The wear of the sliding surfaces subjected to heavy load and slow speeds is reduced by using molybdenum disulphide (MoS_2) particles as additive in lubricant.
- The molybdenum disulphide (MoS_2) nano-particles were actually found to be detrimental to the surface as they caused increased wear.
- The increase in wear was observed with increase in nano-particles percentage in the lubricant. This could be possibly due to agglomeration of nano-particles to bigger size with sharp edges resulting in three body abrasion causing increased wear.
- The technical grade molybdenum disulphide (MoS_2) particles were found to reduce wear to the minimum.
- The reduction in wear increases with the increase in the percentage of technical grade molybdenum disulphide (MoS_2) in the lubricant. The technical grade MoS_2 particles have lower tendency to agglomerate.
- The reduction in wear was observed with technical superfine grade molybdenum disulphide (MoS_2) compared with MoS_2 nano-particles. The wear increased with the increase in the percentage of technical superfine grade MoS_2 in the lubricant.
- Further theoretical studies are needed to identify the reasons of increased wear with the use of molybdenum disulphide (MoS_2) nano-particles.

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