Effect of Nanoparticles Morphology on Friction Behavior of Lubricants

Muhammad Hamid[1], Mubashir Gulzar[1], Amar Ul Hassan Khawaja[1], Ahmed Usman U[1], Haris Bin Hamid[1]

[1]Department of Mechanical Engineering, University of Engineering and Technology Taxila, Punjab, Pakistan

*Corresponding Author

*chaudryhamid04@gmail.com
*amar.hassan@uettaxila.edu.pk

ABSTRACT

The emergence of nanomaterial-based lubrication systems, the development of which lubricating system, has broadened the scope of modern tribology. Nanotechnology has made significant advances in recent years Lubricant additives have an important influence on the performance of lubricants. These additives are active ingredients which can be added during a blending process to base oils in order either to enhance the existing performance of the base fluids or to impart new properties that the base fluids lack. The effect of ZrO_2 and CuO nanoparticles morphology on friction behavior of lubricants is investigated. The lubricating oil used is SAE20. The method of preparation of ZrO_2 and CuO nanoparticles also discussed. Sample preparation and a ring disc tester for investigating of spinning friction are described. The microstructure, friction coefficient, wear surface and vibration tests investigated in detail. The results shows that tribological properties are improved significantly, with the friction coefficient and wear diameter decrease, and wear surface is smooth and fine. This is due mostly to the synergistic action of the lamellar thickener structure of ZrO_2 and the CuO nanoparticles. Furthermore, addition of ZrO_2 and the CuO nanoparticles has a clear inhibitory influence on bearing vibration.

Keywords: Nanoparticles, friction, Bearing Vibration, Tribological performance, Microstructure

1. INTRODUCTION:

Since most of the existing lubricants have reached their performance limits, one of the significant scientific tasks is to develop new lubricant formulations that can achieve energy efficiency across various fields and when used under increasingly severe conditions. This quest of energy efficiency has led to the development of novel materials, rather than old materials, for use as lubricant additives. Various types of nanomaterials are now being researched as lubricant-additives. Nanolubricants typically consist of base oils or fully formulated lubricants with colloidal solid particles suspended within them. There are usually three components in a nanolubricant; the lubricant/base oil solvent, the nanoparticles that act as antiwear (AW)/extreme pressure (EP) additive or friction modifier (FM), and the surfactant that inhabits the interface area between the lubricating oil and the particles. There are many reasons for use of nanoparticles as a lubricant additive [1]. The most important feature is their tiny size that enables the nanoparticles to enter the contact area, resulting in a positive lubrication effect. five potential advantages of using nanoparticles as lubricant additives: (1) insolubility in nonpolar base oils; (2) low reactivity with other additives in the lubricant; (3) high possibility of film formation on many different types of surfaces; (4) more durability; and (5) high nonvolatility to withstand high temperatures. Nanoparticles are also versatile, and many researchers have reported that a single type of nanoparticle served multiple purposes as antiwear AW, antiwear EP additive as well as friction modifier FM. Due to the various types, sizes, and morphology of nanoparticles, the combinations of nanoparticles and lubricants can result in several nano-lubricants. Although various studies have shown remarkable tribological improvement in lubricants dispersed with different types of nanoparticles, it is still difficult to select the suitable nanoparticle additive [2]. The effectiveness of nanoparticles depends on various factors, including their compatibility with base oil/lubricant, their sizes and morphologies, as well as their concentrations.

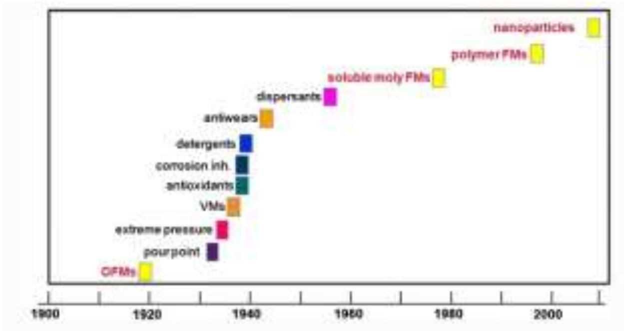

Figure 1: Development of lubricant additives

Keeping in view the nanoparticle–lubricant compatibility in terms of stability and the role of nanoparticles morphology and concentration in tribological performance, the present article aims to consolidate relevant studies in an organized and apprehensible manner. This paper also provides a summary of the relevant material properties, lubricant types, tribo-test conditions, and characterization techniques provided in different experimental studies.

1.2 Classification of nanoparticles

Nanoparticles can be categorized into different types based on their applications. Since this review considered studies related to the tribological performance of nanoparticles, the classification has been provided on the basis of widely used nanoparticles for tribological performance. Figure 2 shows the three major types of nanoparticles in which engineered nanoparticles have been further classified into nine major types by the authors on the basis of their vast use in lubricants [3].

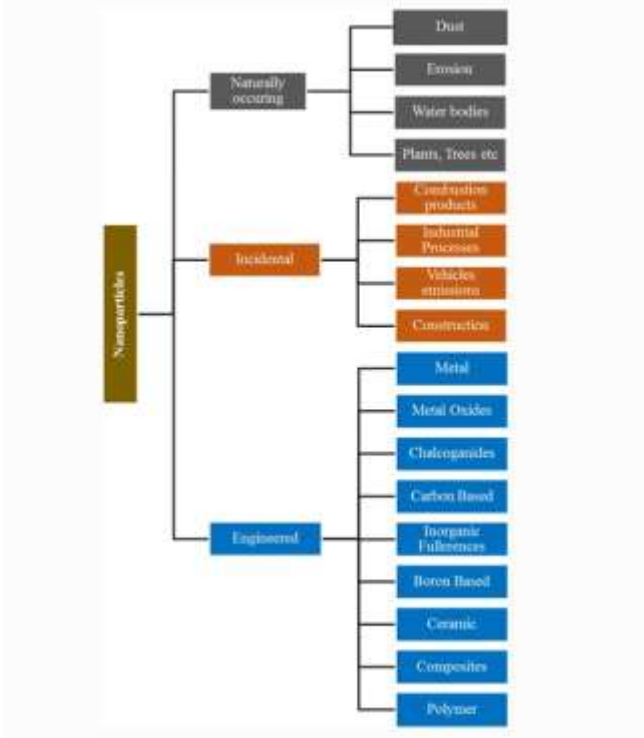

Figure 2: Classification of nanoparticles

The nanoparticles can be further subdivided on the basis of morphology, size, and their source. In the majority of research studies, researchers have synthesized the nanoparticles while some other studies have also used commercially available nanoparticles. The morphology of nanoparticles is characterized using Field Emission Scanning Electron Microscopy (FESEM) and High-resolution Transmission Electron Microscopy (HRTEM). The effectiveness of nanoparticles depends on various factors, including their compatibility with base oil/lubricant, their sizes and morphologies, as well as their concentrations. In order to determine a suitable nanoparticle and lubricant combination, it is required to address all these parameters while focusing on their tribological test conditions and related lubrication mechanisms [4].

2.Methodology

The methodology of this research is such that, he rings nanoparticles are produced from the mineral raw material. The F-VC 200 High Energy Ball Mill is used to pulverize the mineral raw material, with intermittent milling of the mineral particles. Each milling process was composed of 60 s milling and 40 s cooling, and the cumulative ball-milled time is 10 h. The zirconia ball-milled jars with 2 mm diameter zirconia grinding balls are used, and oleic acid is used as the solvent. The mass ratio of grinding balls, mineral raw material, and the solvent is 8:2:1 based on previous studies. The synthetic nanoparticles are provided. The shape of the ball-milled and synthetic particles under SEM is shown in Figure 1. The lubricating used is SAE20. The particles of ball-milled serpentine and kaolin are large and unevenly distributed, with a maximum particle diameter of about 1000 nm and a minimum particle diameter of about 200 nm. The sharp edge of the ball-milled serpentine and kaolin is more obvious compared with the synthetic particles. The synthetic serpentine particles are more rounded and have a uniform particle size of around 300–400 nm. Synthetic kaolin has the smallest particle size and some of the particles are agglomerated. The smallest particle size is about 100 nm, and the agglomerated large particles are about 500 nm [5].

Figure 3: Nanoparticles Preparation

2.1. Experimental Apparatus

Tribological performance was tested using a block-ring tribological test rig, as shown in Figure 4. During the test, the friction ring was mounted on the end of a rotating shaft, which driven by a servo motor. The friction force between the ring and block was detected by a tensile force sensor. The oil bath with a temperature control device installed at the bottom of the friction ring. The detailed working principle of the test rig can be found. During the rotation of the friction ring, the lubricant will entrain into the friction surface. The temperature of the lubricant entrained in the contact surface was difficult to detect. Therefore, the temperature of the oil bath represents the test temperature in this paper.

The friction ring and block are made of bearing steel. The friction ring has an inner diameter of 45 mm and an outer diameter of 50 mm. The friction block is cylindrical with a diameter of 10 mm and a height of 10 mm. The hardness of the friction ring and the block is 751.0 HV, and the surface roughness of the friction ring and the block is 0.06 mm and 0.02 mm [6].

Figure 4: Test Rig

Before the test, the friction ring and block installed, and lubricant added to the oil bath. The test lubricant temperatures 50 °C, 70 °C, 90 °C, 110 °C, 130 °C, and 150 °C. The speed of the friction ring was controlled at 100 r/min, the test load was 150 N, and the test time was 12 h. Each set of friction experiments was repeated four times. After that, the friction specimens were cleaned ultrasonically with petroleum ether and anhydrous ethanol respectively. After the test, the optical images of the friction surface were observed by a ZEISS Axio Observer optical microscope, and the width of the wear scar was measured. The elemental compositions of the friction surface analyzed by a JEOL JSM-7610F scanning electron microscope (SEM) [7].

3.Results and Discussions

In order to deeply explore the effect of thickener and nano-CuO particles on the properties of lubricant, Fig. 5 shows the low and high magnification SEM images of the three deoiled grease. It appears to consist of several fibrous structures that are highly concentrated and dense. These also present coiled helices shape, but are relatively short. This helical fiber is composed of semi-crystalline material. The weak mesh structure could result in softer lubricant and make it difficult to maintain the base oil in thelubricantmatrix.

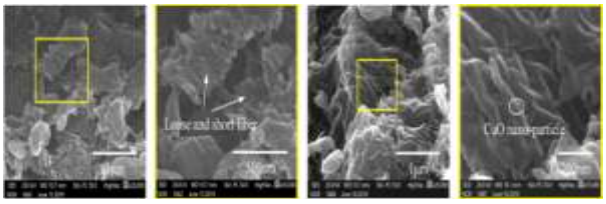

Figure5: SEM images of CuO

Friction enhancement of the nanolubricants is investigated through direct friction coefficient analysis and viscosity measurements. Figure 3(a) presents the results of the tests for the control sample which is a 10%wt solution of dodecane in the blended base oil and several concentrations of nanolubricants. Each test is repeated three times [8].

Results indicate that the nanoparticles decrease the coefficient of friction. The effect of nanoparticles is more influential at higher loads and nanoparticle concentrations. The system works at the boundary lubrication regime which refers to the case where the lubricant film thickness between surfaces is smaller than the surface RMS roughness. In this lubrication regime, there is substantial contact between surfaces but also some parts of the surfaces are separated by the lubricant film. Therefore, an increase in the normal load would squeeze more lubricant out of the contact region which reduces the lubricant film thickness between surfaces.

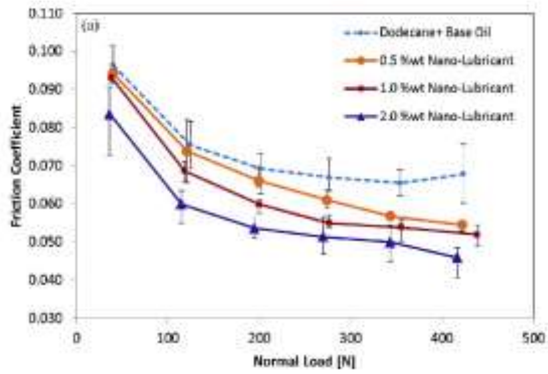

Figure 6: Effect of nanoparticles on Friction

Figure 6 shows the steady state temperature of the lubricant at the end of the experiment. In the case of nano-lubricants, a lower friction coefficient results in less heat production and consequently the final temperature is less. As mentioned, the CuO nanoparticles also have proven to affect the thermal properties of the solution (such as conduction) which could result in better heat dissipation. Therefore, the combination of these effects appears to result in a significant reduction in the temperature in comparison to the lubricant without nanoparticles [9].

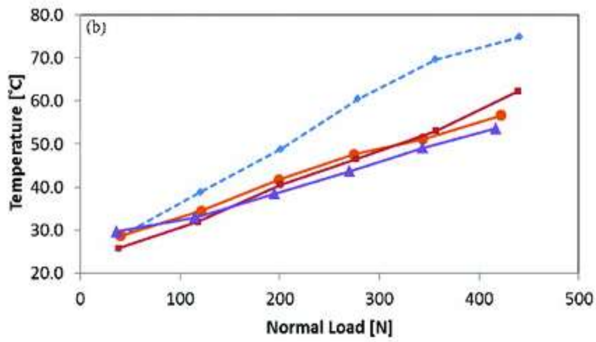

Figure 7: Effect of nanoparticles on Temperature

After testing the surfaces are analyzed using a Veeco Dektak 150 stylus profilometer and three-dimensional profiles of the surfaces are obtained. The 3D surface profiles show clear evidence for surface contact and wear grooves which prove that the system is working in the boundary lubrication regime [10].

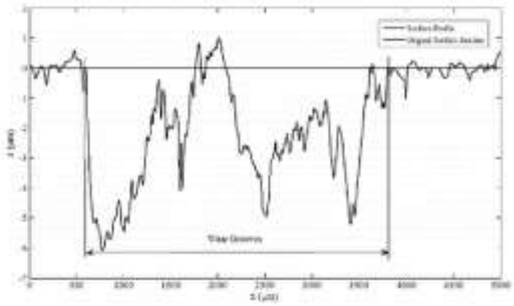

Figure 8: Wear Analysis

4.Conclusion

The study's outcomes suggest various potential enhancement mechanisms, with a focus on proposing a dominant mechanism for CuO particles—specifically, the reduction of the real area of contact. This proposed mechanism aligns with observed friction and wear experimental results. However, further investigations are essential to fully substantiate this suggested mechanism and deepen our understanding of its implications in lubrication processes.

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