IMPROVING THE TRIBOLOGICAL PROPERTIES OF THE LUBRICANT USING ZnS NANOPARTICLES AS LUBRICANT ADDITIVES

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ABSTRACT
One of the main causes of mechanical parts failure is wear and friction between bearing surfaces. There is a lot of interest in the search for novel additives with excellent tribological characteristics. During this paper, the friction and wear of steel surfaces are discussed. zinc sulphide nano particles dispersing paraffin oil were used as lubricating substance. ZnS addition is aimed to reduce the impact friction between metal elements, on friction coefficient and wear of steel test specimens. The experiment was conducted using a cross-pin tester. The device consists, mainly, of rotating and stationary pins of 18 mm diameter and 130 mm long. (10, 15 and 20 N) normal loads are applied by means of weights attached to a loading lever. The rotating specimens are oiled with several percentage of zinc sulphide nano-additives (0, 0.2, 0.4, 0.6, 0.8, 1.0 wt. %) dispersing in paraffin base oil before the test and further oil is carried out every 30 sec. during the test. The test time is 5 min. The friction force is measured via a digital screen that connects to the load cell. Under an optical microscope, the scar's diameter is measured to indicate wear, and the coefficient of friction is computed by dividing the friction force by the normal load. Experiments were carried out at 25 °C using paraffin based oil dispersed by the solid additives of zinc sulphide nano particles. Experimental results show that 0.4 wt. % Zinc sulphide nano filler added to paraffin oil gives the best anti-friction and wear resistance performance.

KEYWORDS
Friction. Wear, zinc sulphide additive, lubricant, paraffin oil.

INTRODUCTION
In engineering and manufacturing applications, lubricants are widely and frequently used to avoid wear between moving parts. An earlier goal in the design and development of "novel lubricating substances" for lubricants was to identify useful "additives" that improve lubricant performance and efficiency for benefits to the environment, economy, and sustainability, [1, 2]. Additives are essential components of lubricants because they can enhance the lubricant's ability to reduce friction.
Traditional lubricant additives come in a variety of kinds, including organic sulphides, organophosphorus compounds, borate ester, boric acid salt, and organic metal compounds. Nanoscale materials have drawn a lot of attention from researchers in a wide range of sectors due to their unique physical and chemical characteristics, such as their high surface energy and chemical activity.

Certain nanomaterials, such as sulphides, [3–9], (ZnS, CuS, MoS2 etc.), oxides, [10–13], (CuO, SiO2, ZnO, etc.), rare earth compounds, [14–17], (CeF3, LaF3, etc.), borate, [18, 19], and metals, [20–24], (Cu, Co, Ni, etc.), have been shown to have significant promise for use as lubricants. Among these metal sulfides, zinc sulfide (ZnS) has been investigated in tribology under a variety of operating conditions. When dialkyldithiophosphate-coated ZnS nanoparticles were added to liquid paraffin, Liu's group found that they could support a greater weight than liquid paraffin and significantly reduced wear, [25, 26].

Octadecylamine's frictional characteristics altered. Under humidity conditions, ZnS nanorods and nanowires dispersed in dodecane were investigated; the coefficient of friction was sensitive to traces of water, [27]. As and addition in PEG-400, Wang et al. claimed that polyethylene glycol monomethyl ether dithio phosphate modified ZnS had reasonable anti-wear and friction reduction capabilities, [28]. Zhao reported on the tribological performance of the ZnS/short fibers/Polyimide hybrid composite when it was lubricated with poly-alpha-olefin (PAO) oil; the ZnS particles created a tribochemical layer during the sliding process, and the fibers provided the composite with abrasion resistance, [29].

According to other researchers, adding ZnS nanoparticles to a chemical compound can increase its carrying capacity, reduce its friction coefficient, and increase its mechanical wear resistance as well as lengthen its service life [30–33]. Furthermore, according to Kang, [34], a composite Zn/ZnS coating showed exceptional anti-wear and friction-reduction characteristics in dry environments. It was generally acknowledged that materials referred to as oil additives give the oil special properties for a range of applications, [35–38]. A variety of oil additives, including viscosity improvers, detergents, anti-rust, anti-foam, and anti-wear additives, were studied.

This work studies the use of zinc sulphide nano particles additives to enhance the tribological properties of lubricants in order to avoid the failure of mechanical components by enhancing the friction and wear resistant between bearing surfaces.

EXPERIMENTAL

A cross pins test rig, shown in Fig. 1, was used for the experiments. The test apparatus is composed of carbon steel (St. 60) revolving and stationary specimens that are 130 mm long and have an 18 mm diameter. The test rig's primary shaft had a chuck to which the rotating pin was fastened. The loading block, where the load is applied, was secured with the stationary pin. An AC motor of 560 watts and 220 volts powers the test machine's main shaft through a reduction unit. A load cell is also included in the test rig to measure the frictional force produced in the contact zone between the stationary and revolving pins. 180 revolutions per minute was the rotational speed while applied normal loads were 10, 15, and 20 N.
Prior to the test, the rotating specimens were lubricated, and during the five-minute test, further lubrication was performed every 30 seconds. Paraffin oil was used as the lubricant, and solid nano additives of zinc sulfide were added at several quantities (0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt. %) at a temperature of 25 °C. Using the Ultrasonic Get 750, USA Microprobe, 400 Watts for 15 minutes, sonication was used to guarantee a good dispersion of ZnS nano additions over paraffin oil (Fig. 2). In order to aid in the dispersion, CMC (Carboxymethylcellulose Natriumsalz) 98 granuliert was also added in a 1:1 ratio to ZnS nano-additives. The load cell supplied by digital screen was utilized to identify the friction force.

Wear is measured by measuring the scar diameters, Fig. 3, on the optical microscope (Digital E-Scope), whereas the coefficient of friction is calculated as the ratio between the friction force and normal load. The carbon steel (St. 60) used to make the test specimens had the chemical compositions shown in table 1. The trials were conducted three times.
Table 1. Chemical composition of St. 60.

<table>
<thead>
<tr>
<th>Element</th>
<th>Chemical composition [wt. %]</th>
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<tbody>
<tr>
<td>Mn</td>
<td>0.65</td>
</tr>
<tr>
<td>Si</td>
<td>0.25</td>
</tr>
<tr>
<td>C</td>
<td>0.6</td>
</tr>
<tr>
<td>P</td>
<td>0.045</td>
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<tr>
<td>S</td>
<td>0.045</td>
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RESULTS AND DISCUSSION
The impact of using ZnS nano-particles as a solid lubricant on the lubricant tribological behavior is examined at room temperature, at constant speed, and with various normal loads. It is common knowledge that the coefficient of friction and wear are the primary factors used to assess a system tribological characteristics.

The friction coefficients of paraffin oil with varying ZnS nano-particle concentrations under various loads of 10, 15, and 20 N are displayed in Fig. 4. The base paraffin oil’s COF (without additions) approached 0.28 at 10 N normal load. The friction coefficient dropped to 0.18 as the content of ZnS nano additives was increased. For normal force values of 15 and 20 N, a similar pattern was noted, with COFs falling from 0.22 and 0.19 to 0.16 and 0.15, respectively. It is clearly observed that when ZnS is added to base paraffin oil at a concentration of 0.4 weight percent, the lubricating performance was improved. A decrease in COF was seen in paraffin oil containing 0.4 weight percent ZnS over the course of the test.

Additionally, at 0.6 weight percent ZnS concentration, it is evident that the friction coefficient increased marginally. As a result, it is thought that adding ZnS nano additives at a concentration of (0.6 wt%) is not quite helpful in enhancing friction qualities. Conversely, an excess of addition (0.8 and 1.0 wt%) also somewhat enhanced the lubricating abilities. After three testing, the average friction values of the lubricant containing 0.8 wt.% ZnS nano additions were 0.2, 0.18, and 0.16 at 10, 15, and 20 N normal load, respectively. As the normal load increased, the friction coefficient values fell. Since Zn and S are the main triboactive elements involved in tribofilm production [39], the ZnS enhanced the lubrication performance.

Fig. 4 Friction coefficients of paraffin oil with varying ZnS nanoparticle concentrations.
The wear scar diameter variations of the steel sample at varying ZnS nano additives concentrations at 10, 15, and 20 N loads in paraffin oil are displayed in Fig. 5. The ZnS additions have the potential to greatly enhance base oil resistance to wear, as demonstrated in Fig. When adding 0.4 weight percent of ZnS additive at 10, 15, and 20 N, respectively, the wear scar diameter drops from 0.6 mm to 0.53 mm, 0.73 mm to 0.56 mm, and 0.77 mm to 0.59 mm. As the additive concentration rises to 0.50–0.75 weight percent, the anti-wear performances improved. It might be because of the protective films produced during the friction process by an arrangement of tribochemical processes,[40]. These protective layers shield the two rubbing surfaces from direct contact since they are pliable. ZnS additives concentration is optimum at 0.4 weight percent. The wear scar diameters increased due to the corrosive wear of the additives when the concentrations of the additives increased to 0.6 weight percent. Additionally noted is the impact of applied load on anti-wear performance at various ZnS additive concentrations. The wear resistance decreases as the applied load increases. This can be because protective films become unstable under high loads.

Figure 6 exhibits SEM images of the worn surfaces of carbon steel (St. 60) samples that were lubricated with paraffin oil and solid nano-additives of ZnS at 0.8 and 1.0 wt. %. It is evident that scratching may be the primary wear process of the steel in the lubricated conditions described above. Additionally, it is evident that protective layers, which are comparatively homogenous and dense, form on the worn surfaces.

The elemental analysis and EDS mapping of the worn surfaces following lubrication testing with base oil (paraffin) and 0.8 weight percent ZnS are shown in Fig. 7. The EDS mapping is significant in this context because it offers a clearer understanding of the process underlying the role of additives, Fe, C, and Cr make up the majority of the components in both situations, as can be shown. The weight percentage of zinc (0.77) on the worn surface, or around 95 % of the Zn additives, was also revealed by
mapping analysis. This suggests that the additive has formed a protective film on the lubricated plate.

Fig. 6 SEM images of the worn surfaces of carbon steel (St. 60) samples lubricated with paraffin oil and solid nano-additives of ZnS at (a) 0.8 and (b) 1.0 wt. %.

Fig. 7 EDS mapping of the worn surfaces of carbon steel (St. 60) samples lubricated with paraffin oil and solid nano-additives of ZnS at 0.8 wt. %.
CONCLUSIONS

The addition of ZnS nanoparticles at a concentration of 0.4 weight percent to paraffin oil improves its lubricating performance by reducing the coefficient of friction. However, higher concentrations of ZnS additives do not provide significant benefits and may even increase friction. The wear resistance of the lubricant is also enhanced with the addition of ZnS nanoparticles, with optimal performance observed at 0.4 weight percent concentration. The protective films formed by the additives contribute to the reduction in wear. The analysis of worn surfaces confirms the presence of these protective films and the role of ZnS additives in enhancing lubrication.

REFERENCES


