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INFLUENCE OF DISPERSING OIL BY ABRASIVE NANO AND MICROPARTICLES ON THE FRICTION AND WEAR DURING SCRATCH TEST

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ABSTRACT
The present study discusses the influence of dispersing lubricating oil by aluminium oxide (Al_2O_3), silicon oxide (SiO_2) and silicon carbide (SiC) nano and microparticles on the friction coefficient and wear displayed by the scratch of copper sheet.

The experimental results showed that clean oil showed the highest friction coefficient and wear values followed by oil dispersed by nano and microparticles of SiO_2, Al_2O_3 and SiC. As the normal load increased, friction coefficient and wear remarkably increased. The reduction of both wear and friction coefficient observed for dispersed oil with the tested nano and microparticles may be from the embedment of nano and microparticles in the surface of substrate and forming a protective layer on the substrate. It was observed that nanoparticles showed higher friction and wear values than that detected for microparticles due to their agglomeration in the contact area and increasing the shear stress between the stylus and substrate as well as the particles themselves. Besides, nanoparticles polish the asperities of the scratched substrate.

KEYWORDS
Micro and nanoparticles, aluminium oxide, silicon oxide, silicon carbide, scratch, friction coefficient and wear.

INTRODUCTION
The lubricating properties of greases are enhanced by solid lubricants, [1, 2], that adhere into the sliding surfaces. Some of the solid lubricants are hard polymers that roll on the sliding surfaces and decrease. Certain nanomaterials, such as sulphides, [3 - 5], zinc sulphide (ZnS), copper sulphide (CuS) and molybdenum sulphide (MoS_2), copper oxide (CuO), silicon oxide (SiO_2) and zinc oxide (ZnO), [7, 8], and metals, [9], proved to have significant improvement in operation.

It was generally acknowledged that materials referred to as oil additives give the oil special properties for a range of applications, [11 - 13]. A variety of oil additives, including viscosity improvers, detergents, anti-rust, anti-foam, and anti-wear additives, were studied.

Lithium grease was dispersed by aluminum oxide (Al_2O_3) nanoparticles and carbon nanotubes (CNT), [14, 15]. It was observed that friction coefficient displayed by the grease dispersed by CNT and Al_2O_3 showed the highest values, while wear values drastically decreased. Zinc sulphide nano particles dispersed paraffin reduced the friction and wear of metallic surfaces, [16].

The present study discusses the effect of dispersing lubricating oil by Al_2O_3, SiO_2 and SiC nanoparticles on the friction coefficient and wear displayed by the scratch of copper sheet.

EXPERIMENTAL

Experiments were conducted by the scratch tester, Fig. 1. It consists of 90° apex angle steel stylus assembled in the loading lever. Load was applied by weights of 2, 4, 6, 8 and 10 N weights. The scratch (friction) force was measured by load cell by means of digital monitor. The scratch test was carried out by scratching copper sheet lubricated by oil dispersed by Al_2O_3, SiO_2 and SiC nanoparticles of 0.5 wt. % content. Friction coefficient was calculated by measuring the scratch force. Wear scar width was measured of an accuracy of ± 1.0 μm by optical microscope.

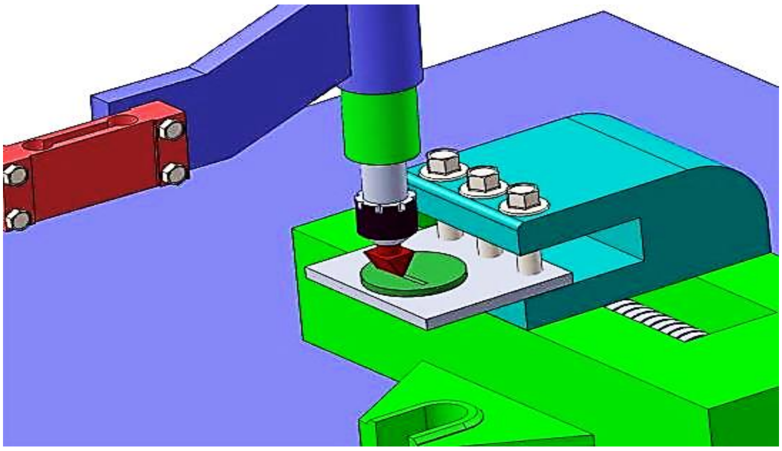

Fig. 1 Arrangement of scratch test rig.

RESULTS AND DISCUSSION

Friction coefficient displayed by the scratch in the presence of clean oil showed the highest values followed by oil dispersed by microparticles of SiO_2, Al_2O_3 and SiC, Fig. 2. Friction coefficient significantly increased with increasing normal load. Figure 3 illustrates the action of the microparticles in the surface of substrate. Because the tested particles have higher hardness than the copper substrate, it is expected that the particles are embedded in the copper substrate forming a protective layer that withstand the abrasion of the stylus. Based on the observations in Fig. 2, it seems that the embedment of SiC microparticles was much pronounced than that displayed by SiO_2 and Al_2O_3. Because the hardness of the stylus is relatively higher than the hardness of the substrate, the particles will embed in the substrate.

Dispersing the oil by nanoparticles of the tested abrasive showed relatively higher friction values than that observed for microparticles, Fig. 4. That behavior may be from the agglomeration of the nanoparticles that increased their layers and consequently shear stress between these layers increased, Fig. 5. Al_2O_3 showed relatively higher friction than that recorded for SiO_2 and SiC. The size of the nanoparticles enables them to interact with the asperities of scratched substrate and abrade them or they enter into and adsorb on the asperities of the substrate. It is suggested that, the presence of the nanoparticles combines the sliding with rolling friction. Because the embedment of nanoparticles into the contact surfaces is low compared to that of microparticles, they tend to roll and decrease the shear force acting on the asperities. It can be suggested that the mechanism of action of the nanoparticles depend on their adsorption into the sliding surface, where they form protective layer and prevent the contact between the asperities of the two sliding surfaces.

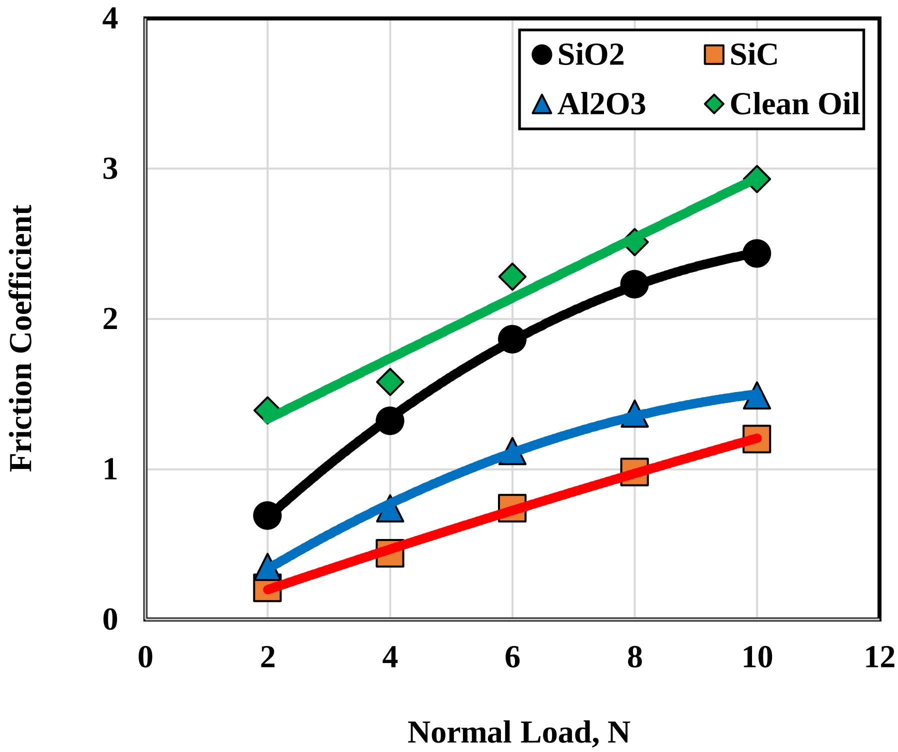

Fig. 2 Friction coefficient displayed by scratching in presence of oil dispersed by abrasive microparticles.

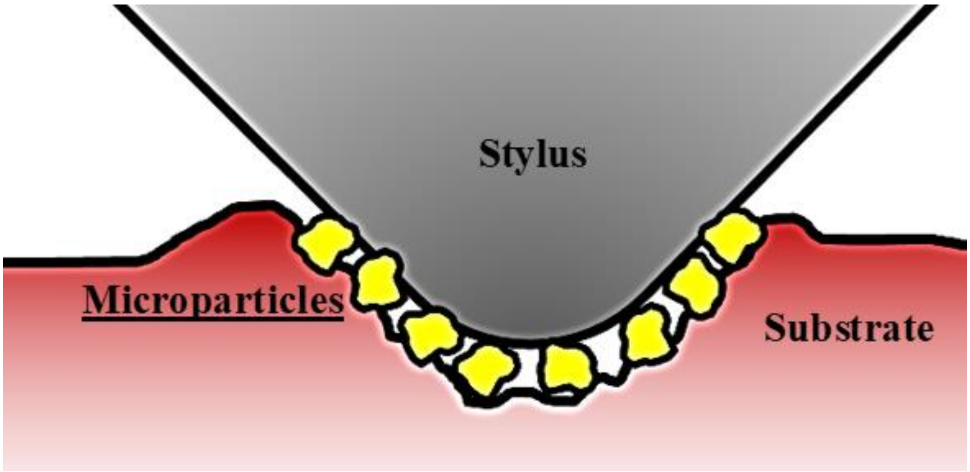

Fig. 3 Illustration of the action of the microparticles in the surface of substrate.

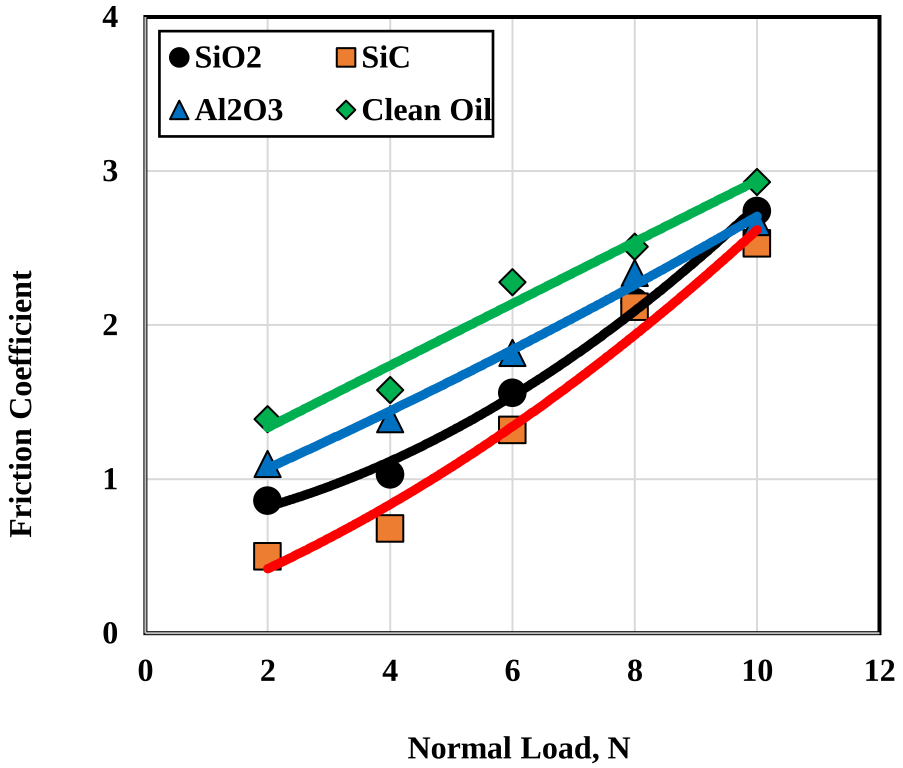

Fig. 4 Friction coefficient displayed by scratching in presence of oil dispersed by abrasive nanoparticles.

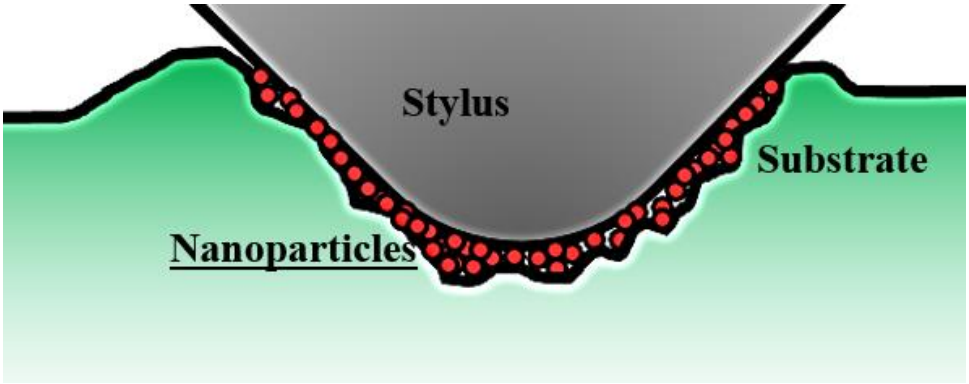

Fig. 5 Illustration of the action of the nanoparticles in the surface of substrate.

Wear of the test specimen was evaluated by the wear scar width. It was noticed that wear showed the same trend observed for friction. Clean oil displayed the highest wear values. When the oil was dispersed by microparticles, Fig. 6, Al_2O_3 pronounced the highest wear compared to SiC and SiO_2. The contaminated oil showed lower wear than clean oil. It seems that the microparticles act as rolling bearings, where separate the two contact surfaces. As the load increases, they suffer from fracture retarding the rolling action, [17 – 21]. Wear scar width displayed by scratching in presence of oil dispersed by abrasive nanoparticles is illustrated in Fig. 7, where nanoparticles showed slight wear increase due to their polishing the asperities of the substrate.

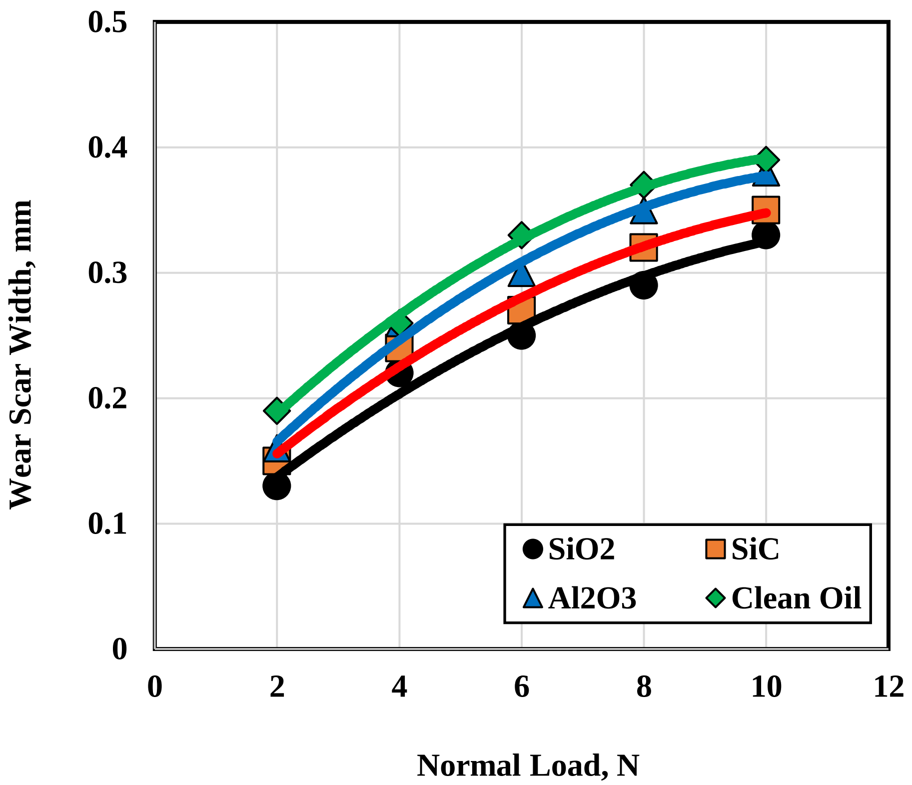

Fig. 6 Wear scar width displayed by scratching in presence of oil dispersed by abrasive microparticles.

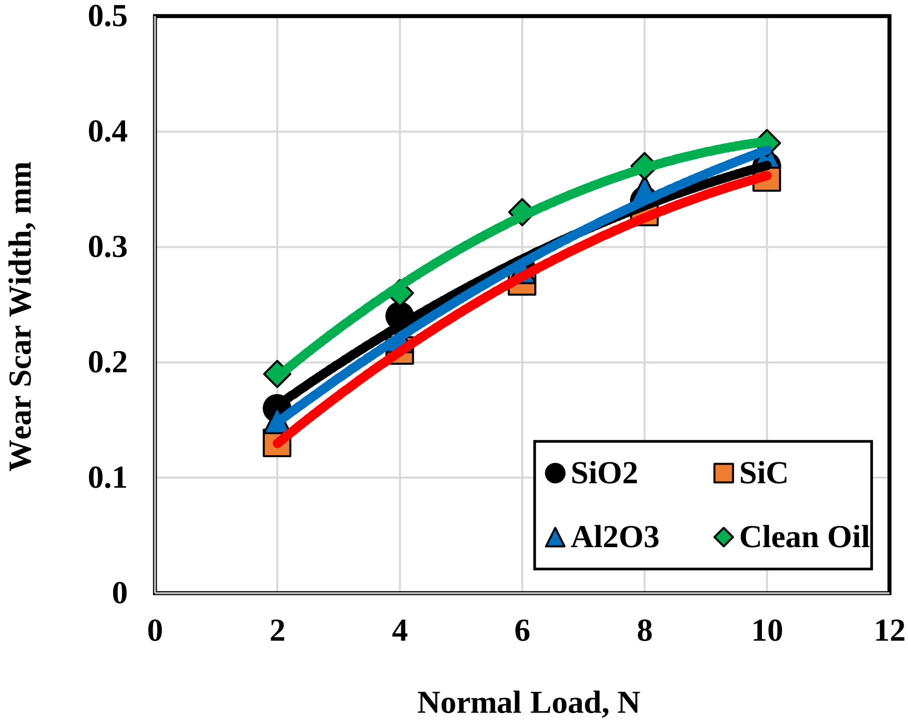

Fig. 7 Wear scar width displayed by scratching in presence of oil dispersed by abrasive nanoparticles.

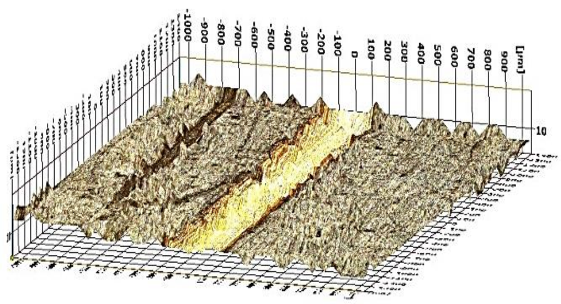

Fig. 8 Photomicrograph of scrath at 4 N load.

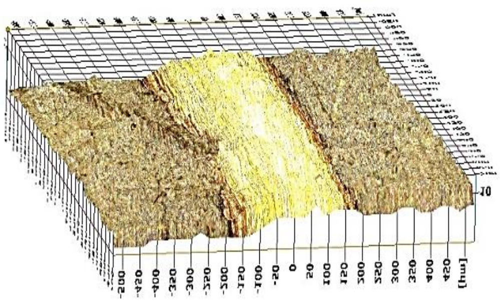

Fig. 9 Photomicrograph of scrath at 8 N load.

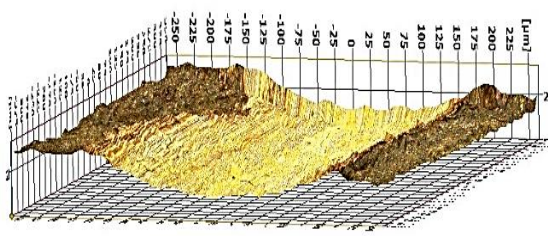

Fig. 10 Photomicrograph of scrath at 10 N load.

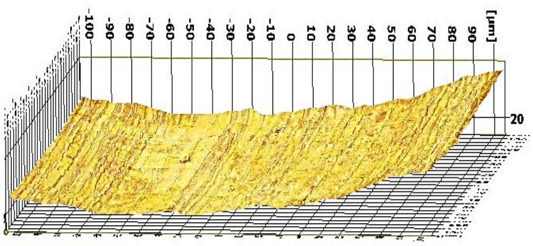

Fig. 11 Photomicrograph of the surface texture of the wear scar.

The improvement of the wear resistance offered by micro and nano particles dispersed in the oil is attributed to the action of the hard particles presented between

the sliding surfaces that prevented their direct contact, [22 - 24]. Al_2O_3 plastically deformed the contact surface, where Al_2O_3 nanoparticles slide, roll and polish the asperities of the sliding surfaces. The rolling of the nanoparticles decreased the formation of the transfer layer and wear, [25, 26]. Their nanosize of the tested particles enables them to enter into and adsorb on the asperities of the rubbing surfaces. Besides, the nanomaterials form thin plastic layer on the sliding surface.

The rolling of the nano and microparticles is defined as ball bearing mechanism that offers reduction of friction and wear. Added to that, the tested particles polish the asperities and improve the texture of the contact surfaces. The photomicrographs of the wear scar are shown in Figs. 8 – 11. The surface texture at 4, 8 and 10 N load when the oil was dispersed by Al_2O_3 microparticles is illustrated in Figs. 8, 9 and 10 respectively. The polishing process conducted by Al_2O_3 nanoparticles is shown in Fig. 11, where their agglomeration is responsible for that behavior.

CONCLUSIONS

1. Clean oil showed the highest wear and friction coefficient values followed by oil dispersed by nano and microparticles of SiO_2, Al_2O_3 and SiC, where friction coefficient and wear remarkably increased with the increase of the normal load.
2. Embedment of nano and microparticles in the surface of substrate influences the frictional behavior through forming a protective film on the substrate.
3. Embedment of SiC microparticles was much higher than that displayed by SiO_2 and Al_2O_3.
4. Nanoparticles dispersing the oil displayed higher friction values than that recrded for microparticles. This is due to the agglomeration of the nanoparticles increasing the shear stress between these particles.
5. The nanoparticles can interact and polish the asperities of the scratched substrate.
6. The highest wear values were displayed by clean oil. While contaminated oil showed lower wear. It seems that the nano and microparticles work as rolling bearings that separate the two contact surfaces.
7. Nanoparticles showed higher wear due to their polishing the asperities of the substrate.

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