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EFFECT OF DISPERSING LITHIUM GREASE BY ALUMINUM OXIDE NANOPARTICLES AND CARBON NANOTUBES

Badran A.[1], EL-Abden S. Z.[1], Ali W. Y.[1] and Elzayady N.[2]

[1]Department of Production Engineering and Mechanical Design, Faculty of Engineering, Minia University, El-Minia, EGYPT.
[2]Mechanical and Aerospace Department, Institute of Aviation Engineering and Technology, Giza, EGYPT.

ABSTRACT
The effect of dispersing lithium grease by aluminum oxide (Al_2O_3) nanoparticles and carbon nanotubes (CNT) on the lubricating properties is discussed. Friction coefficient and wear displayed by the reciprocating sliding of bearing steel ball on aluminum (Al) sheet lubricated by lithium grease dispersed by Al_2O_3 nanoparticles and CNT.

It was found that friction coefficient displayed by the grease dispersed by CNT displayed the highest values followed by Al_2O_3, while CNT/Al_2O_3 showed the lowest values. Minimum values were observed at 0.4 – 0.6 wt. % of nanomaterial content. Minimum wear values were displayed by grease dispersed by CNT/Al_2O_3 of 0.4 wt. % content. Further increase in Al_2O_3 content significantly increased wear due to their abrasive action. It was observed that combination of CNT/Al_2O_3 significantly reduced of friction and wear. That can be explained on the bases that agglomeration of CNT increased their layers and shear stress. Al_2O_3 showed relatively lower increase in friction due to the ball bearing effect of the nanoparticles. The enhancing effect of CNT/Al_2O_3 may be attributed to the easy rolling of Al_2O_3 nanoparticles by the help of the low shear CNT.

KEYWORDS
Aluminum oxide nanoparticles, carbon nanotubes, lithium grease.

INTRODUCTION
Solid lubricants are extensively used to increase the efficiency of greases in different application. Polymeric particles dispersed in grease was proposed, [1, 2]. Their function is to adhere into the sliding surfaces, where the adhesion force depends on their deformed contact area that increases for soft polymers. Relatively harder polymers roll on the sliding surfaces decreasing friction and. Intensive care should be considered in selecting the solid lubricants suitable for dispersing greases. Rolling contact wear is familiar for rolling bearings, [3 - 5]. Increasing load carrying capacity of journal bearing running

under mixed lubricating condition is to apply extreme pressure (EP) additives. Polytetrafluoroethylene (PTFE) was dispersing grease.

Type of the lubricants mainly influences the lubrication of sliding surfaces, [6 - 9]. In metal forming, the relative movement between the tools and the work piece is accompanied by friction that controls the surface quality. Applying the proper lubricants can reduce the drawbacks of the friction. Friction was measured by sensors during metal forming process, [10 – 12]. It was found that engineering materials are sensitive to the contact pressure. The possibilities to evaluate friction were discussed, [13, 14]. Recently, it was found that friction coefficient displayed by the grease dispersed by multiwall carbon nanotubes (MWCNT) showed lower values than that dispersed by silica nanoparticles, [15]. Wear resistance provided by silica nanoparticles was superior to that observed for MWCNT.

The present work discusses the effect of dispersing lithium grease by Al_2O_3 nanoparticles and CNT on friction coefficient and wear displayed by the sliding of bearing steel ball on aluminum sheet.

EXPERIMENTAL

The test rig used in the present experiments consists of bearing steel ball sliding on aluminum sheet in multiple passes under different load values, Figs. 1 and 2. Experiments were carried out to investigate the effect of the tested nanomaterials dispersing lithium grease on friction coefficient and wear. Weights of 2, 4, 6, 8, 10 and 12 N were vertically applied. Wear scar width was measured using optical microscope of ± 0.01 mm accuracy. The test was conducted manually under dry condition at room temperature. The stroke was 20 mm and repeated 10 times.

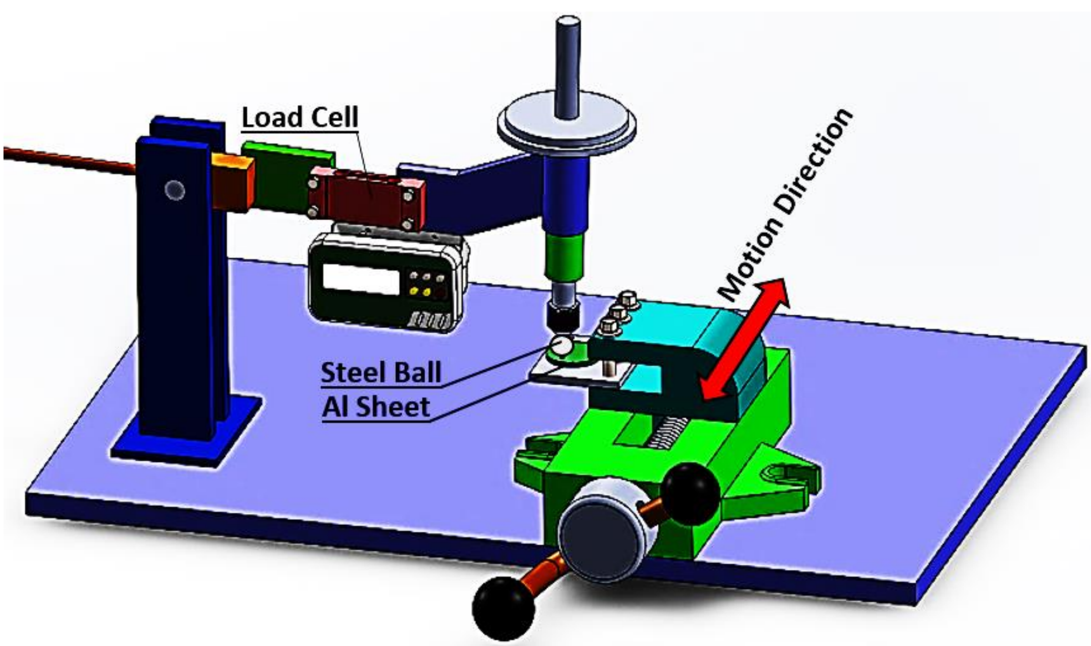

Fig. 1 Arrangement of the test rig.

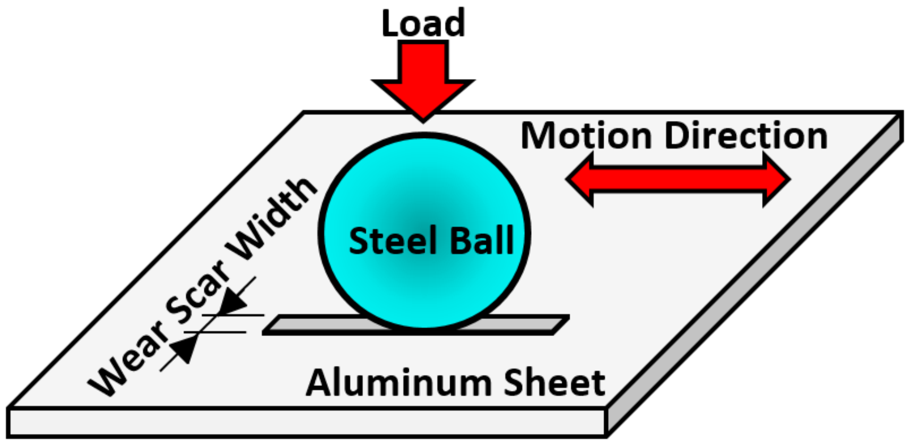

Fig. 2 Details of the test process.

The dispersing additives used were Al_2O_3 nanoparticles of 30 – 50 ηm particle size and CNT of 10-30 µm length. The nanomaterials were added in different contents of 0.2, 0.4, 0.6, 0.8 and 1.0 wt. %.

RESULTS AND DISCUSSION

Friction coefficient displayed by the grease dispersed by CNT displayed the highest values followed by Al_2O_3, while CNT/Al_2O_3 dispersing the grease showed the lowest values, Fig. 3. Friction coefficient slightly decreased down to minimum then increased with increasing nanomaterial content. Minimum values were observed at 0.4 – 0.6 wt. % of nanomaterial content. Further increase in nanomaterial content increased friction coefficient up to values higher than that recorded for grease free of nanomaterial. That behavior was more pronounced for CNT. It seems that agglomeration of CNT increased their layers and consequently shear stress increased.

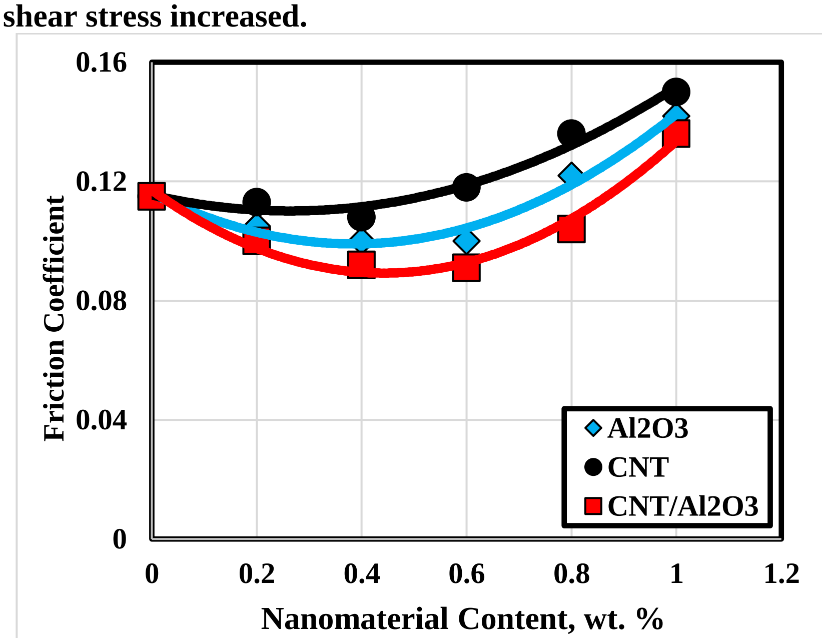

Fig. 3 Friction coefficient displayed by the tested nanomaterials dispersed in grease.

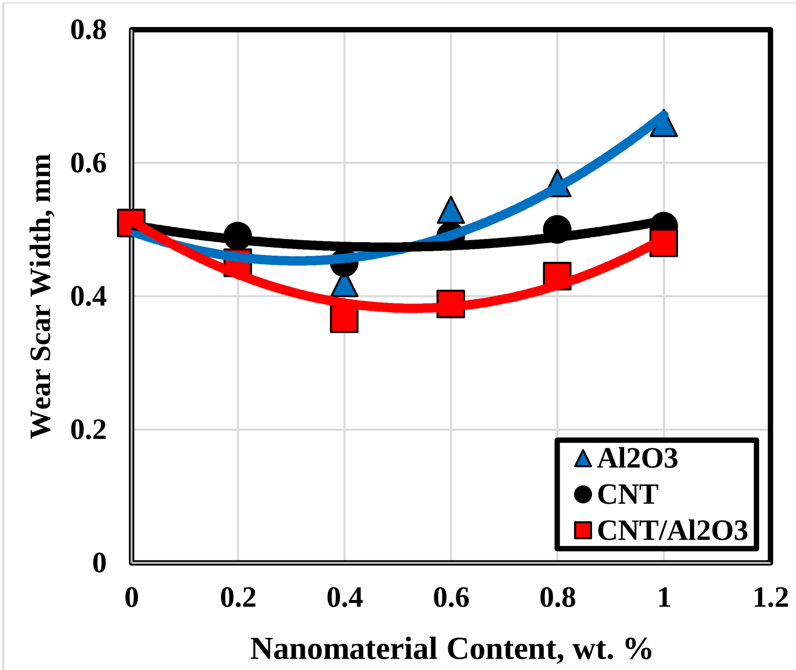

Fig. 4 Wear displayed by the tested nanomaterials dispersed in grease.

Al_2O_3 showed relatively lower increase in friction due to the ball bearing effect of the nanoparticles. The enhancing effect of CNT/Al_2O_3 may be attributed to the easy rolling of Al_2O_3 nanoparticles by the help of the low shear CNT.

Wear of the test specimen measured by the wear scar width, Fig. 4, showed the same trend observed for friction. Minimum values were displayed by grease dispersed by CNT/Al_2O_3 of 0.4 wt. % content. Further increase in Al_2O_3 content significantly increased wear due to their abrasive action.

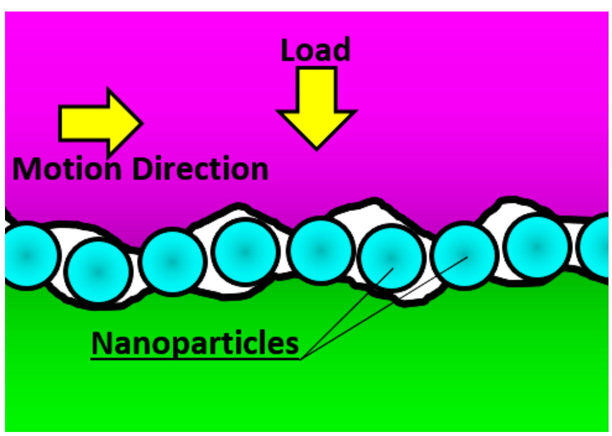

Fig. 1 Effect of ball bearing mechanism.

The mechanism of ball bearing depends on the size of the particles that should be bigger than the minimum film thickness to support the load, Fig. 1. Besides, the hardness of the

particles should be higher than the hardness of the two sliding surfaces. In the presence of nanoparticles, that mechanism can be valid for the very fine surfaces. In extreme pressure, nanoparticles can perform better due to their interaction with the asperities of surface roughness. Further increase of Al_2O_3 nanoparticles increased wear as result of the increased abrasiveness. They act as rolling bearings separating the two contact surfaces, where metal to metal contact is prevented. The drawback is their fracture when the load is increased and the rolling action is retarded, [16 – 20].

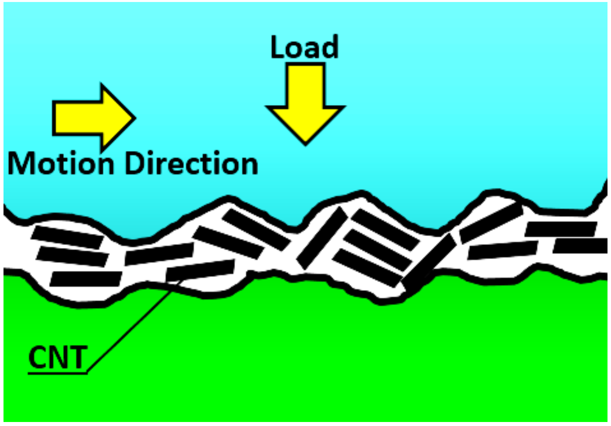

Fig. 2 Carbon nanotubes dispersed in grease.

The enhancement of the wear resistance offered by CNT might be attributed to the fact that CNT is quite good solid lubricant. The lubrication mechanism of CNT depends on their nature as cylinders. Their nanosize enables them entering into and adsorbing on the asperities of the rubbing surfaces, Fig. 2. It was found that their carbon content displayed significant reduction in friction due to the carbon formation on the friction surface of low shear strength film that protected from further friction and wear.

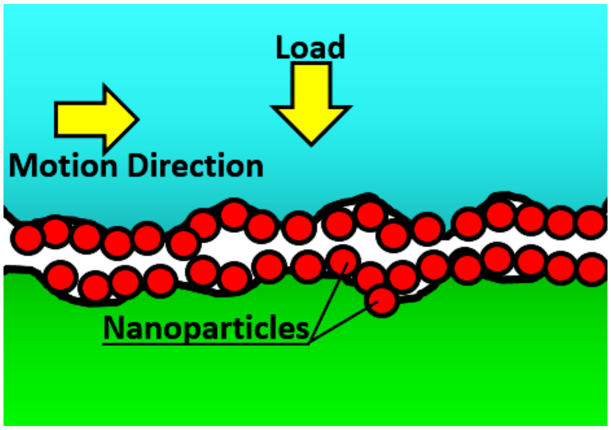

Fig. 3. Adhesion of Al_2O_3 into the sliding surfaces.

CNT can be adsorbed onto the sliding surfaces forming physical adsorption film, Fig. 6. They can provide the surface by chemical reaction film and enhance the wear resistance [21 - 23]. The nanomaterials forms thin layer of high plasticity on the sliding surface. The extremely plastic film works as a viscous lubricant. It was revealed that, presence of the

transmitted film when formed from a material softer than the substrate, prevents seizure and tearing in depth.

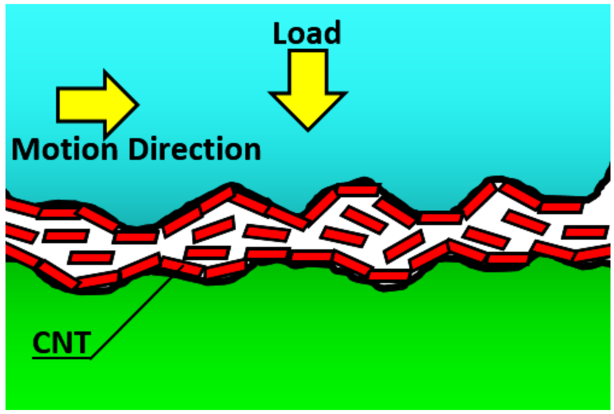

Fig. 4 Adhesion of CNT into the sliding surfaces.

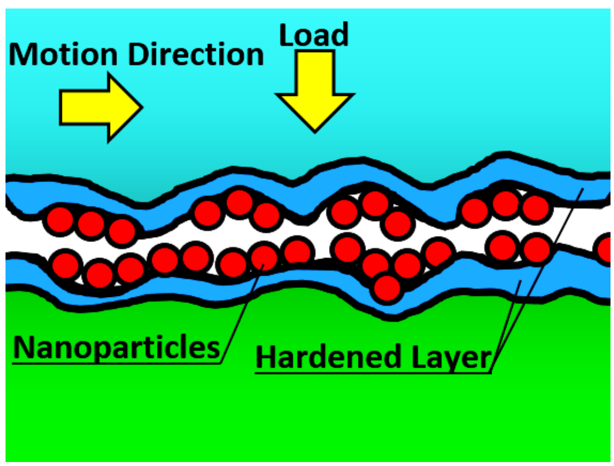

Fig. 5 Formation of hardened layers.

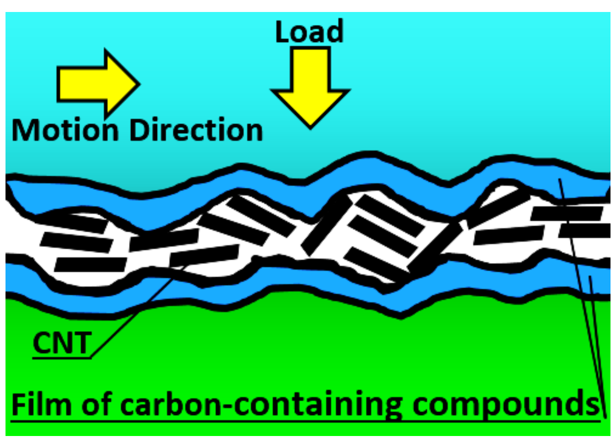

Fig. 6 Formation of carbon-containing compounds.

The presence of hard nanoparticles between the sliding surfaces prevented their direct contact, [26 - 28]. CNT deformed under the load, while Al_2O_3 caused severe plastic deformation on test specimen and the scratch depth increased, Fig. 7. Al_2O_3 nanoparticles acted as ball bearings sliding and rolling on the sliding surfaces accompanied by polishing effect. The ball bearing effect decreased the formation of the transfer layer, [27 - 30]. It was revealed that the friction of Al_2O_3 nanoparticles reduce wear rate and enhance the morphology of the worn surface. The ball bearing mechanism offers wear and friction reduction by hard nanoparticles, where Al_2O_3 nanoparticles roll between the rubbing surfaces. In addition to that, Al_2O_3 nanoparticles polish the asperities and penetrate the contact area improving the morphology of the rough surface.

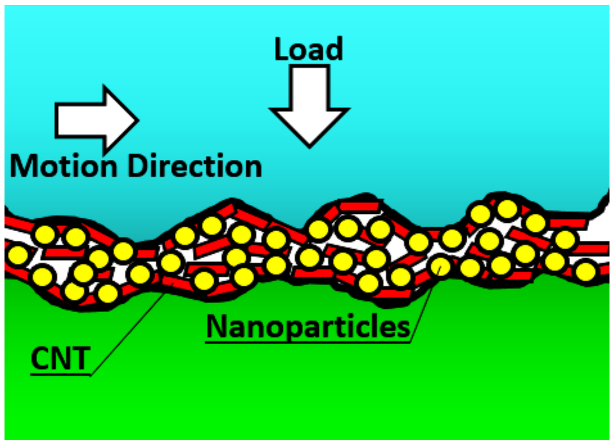

Fig. 7 CNT and Al_2O_3 dispersed in grease.

In the present experiments, the friction coefficient and wear of CNT/Al_2O_3 nanoparticles were studied. It is expected that the surface is adhered by film of carbon-containing compounds. It seems that CNT/Al_2O_3 are transferred onto the surface. Based on that, nanoparticles change sliding friction into a combination of sliding friction as result of CNT and rolling friction because of Al_2O_3 nanoparticles.

The mechanism of action of CNT/Al_2O_3 depend on the fact that they enter the friction surfaces and form the third body that bear the shear force acting on the surface asperities. CNT dispersed in lithium is absorbed onto the sliding surface. They form protective film and prevent the direct contact between the asperities of the two surfaces. Besides, their relatively low shear strength causes interlayer sliding of relatively low friction. It is known that agglomeration of nanoparticles increases friction due to the reduced shear and ball bearing effects.

The shape of nanomaterial influences its performance in lubrication process. This can be explained on the bases of the nature of the contact between the nanoparticles and the contact area. Spherical nanoparticles have high load carrying capacity and EP properties due to their ball bearing effect, [31]. They have point contact with the sliding surfaces, while the line contact is resulted from interaction of CNT with the sliding surfaces. The morphology of nanoparticles is much affected by their internal nanostructure, [32]. The structure of CNT has a tendency to form tribo-films on the sliding surfaces and can withstand severe working conditions. It can be concluded that combination of CNT/Al_2O_3

results in significant improvement in the reduction of friction and wear. It seems that the agglomeration of nanoparticles decreased allowing the nanomaterial to behave in efficient way.

CONCLUSIONS

1. Friction coefficient displayed by the grease dispersed by CNT displayed the highest values followed by Al_2O_3, while CNT/Al_2O_3 dispersing the grease showed the lowest values.
2. Friction coefficient slightly decreased down to minimum then increased with increasing nanomaterial content. Minimum values were observed at 0.4 – 0.6 wt. % of nanomaterial content.
3. Minimum wear values were displayed by grease dispersed by CNT/Al_2O_3 of 0.4 wt. % content. Further increase in Al_2O_3 content significantly increased wear due to their abrasive action.
4. The lubrication mechanism of CNT depends on the carbon formation of low shear strength film on the friction surface that protected from further friction and wear, while Al_2O_3 nanoparticles act as ball bearing and offer wear and friction reduction, where Al_2O_3 nanoparticles roll between the rubbing surfaces. Besides, Al_2O_3 nanoparticles polish the asperities and penetrate the contact area improving the morphology of the rough surface.
5. Further increase of Al_2O_3 nanoparticles increased wear as result of the increased abrasion.
6. Combination of CNT/Al_2O_3 significantly reduced friction and wear.

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