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TRIBOLOGICAL PERFORMANCE OF LITHIUM GREASE DISPERSED BY SILCA NANO PARTICLES AND CARBON NANOTUBES

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ABSTRACT
The present study deals to evaluate the effect of mixing lithium grease by paraffin oil that dispersed with silicon dioxide (SiO_2) nanoparticles and carbon nanotubes (CNT) on the lubricating properties of deep drawing process. Friction and wear tests were conducted by the reciprocating sliding of bearing steel ball on aluminum (Al) sheet lubricated by the mixture. It was found that friction coefficient displayed by the grease dispersed by CNT/ SiO2 displayed the highest values followed by SiO_2. Minimum values were observed when carbon nanotubes were added at 0.4 and 0.6 wt. %. The morphology of worn surface is analyzed by optical microscopy for measuring the wear scare width as an indication for the wear rate. Minimum wear values were displayed by grease mixed by 50 % wight content of paraffin oil. Further increase in SiO_2 content significantly increased wear due to their abrasive action. It was observed that combination of CNT/ SiO_2 significantly increases of friction and wear. That can be explained on the bases that agglomeration of CNT increased their layers and shear stress. SiO_2 showed relatively lower increase in friction due to the ball bearing effect of the nanoparticles.

KEYWORDS
Silicon dioxide nanoparticles, carbon nanotubes, lithium grease, Paraffin oil, Friction, Wear scar width.

INTRODUCTION
Grease is a semi-solid material contains lubricating oil and thickening agent. Grease is extensively used in different serious conditions like intense pressure, elevated speed, and temperature. The achievement of grease is largely controlled by the concentration percentage of the thickening assistant in addition to base oil type viscosity, [1 - 3]. The addition of nano particles into grease lead to improve its tribological properties during services. In recent, nanoparticles as an additive in the grease have attracted the scientist because of its attractive tribological and physical properties. Different types of nanoparticles have been explored for tribological performances. Among the described nanoparticles, silica nanoparticles are one of the best materials for tribological applications, [4, 5].

The effect of nanoparticles is dependent on its size, shape, roughness, and homogeny with base grease. There has been large interest to perform convenient dispersion of

nanoparticles in grease, [6 - 8]. In the last decade, hybrid composite nanoparticles were integrated as an additive material in the base grease to increase tribological properties, [9 - 11].

Tribological properties of silica nanoparticles has been discussed as a lubricant additive in grease [12]. The size effects of silica nanoparticles was investigated on the tribological action of paraffin oil, and the results showed that surface modification for silica nanoparticles with acid have improved the tribological performance of the paraffin [13]. The tribological properties of titanium greases mixing with nano particles of silica and TiO_2 was studied and the results showed an attractive frictional properties and antiwear properties [14, 15].

It is obvious that nano silica particles has an important role for improving the tribological performance for grease. On the other hand, it has been found that the tribological characteristics of silica nanoparticles of different sizes was doped in the applicable lithium grease in the market. It is essential to take in our consideration that the available grease in market have many fillers and additives to enhancing its tribological characteristics. It is hard to confirm the actual trend of nanoparticles on a lubrication action when the grease was already mixed with various additives. The main objective of this study was to evaluate the tribological characteristics of grease mixed with paraffin oil and adding silica and CNT as an additive. The pure grease without adding any additives was used as a standard to compare the tribological properties of silica and CNT dispersed grease. Also, another objective of this article was to explore the optimal percentage of additives in the grease and paraffin mixture for determining the best tribological characteristics.

The present work investigates the effect of mixing lithium grease by paraffin oil and dispersed with silicon dioxide (SiO_2) nanoparticles as well as carbon nanotubes (CNT) on the friction and wear caused by the sliding of bearing steel ball on aluminum (Al) sheet simulating the deep drawing process.

EXPERIMENTAL WORK

The test rig as shown in Figs.1 and 2 used in the present work consists of bearing steel ball sliding on aluminum sheet in dimensions of 40 × 40 mm and 3 mm thickness for multiple passes under different normal loads values. Load cell is connected through Arduino circuit and load cell amplifier to record the values of friction force. Mechanical properties of the used aluminum sheet material are presented in table1.

Table 1. The mechanical properties of the aluminum sheet.

Mechanical Properties	Yield stress σ y, MPa	Max stress σ max, MPa	K MPa	n	Hardness HV
Value	55	125	137	0.26	37

Experiments were carried out to investigate the effect of the tested nanomaterials (silica and carbon nanotubes) dispersing in a mixture of lithium grease and paraffin oil on friction coefficient and scar width. The technical data for used grease and paraffin oil are displayed in Tables 2 and 3 respectively. The shape of SiO_2 nanoparticles according to supplier data sheet is almost spherical. The average particle size was found to be nearly 200 nm and size distribution was in the range between 50 and 120 nm. Different weight percentages of multi-wall carbon nanotubes (0.2, 0.4, 0.6 and 0.8 wt. %) were dispersed

in the grease mixture. The parameters of these CNTs, according to supplier information were: average diameter 10–30 nm, average length 5–15µm. The purity of CNTs was better than 95 %, the amorphous carbon content was below 3 %. The specific surface area was between 40 and 300 m^2/g. CNTs used in this study were synthesized using chemical vapor deposition (CVD).

Table 2. Lithium grease technical specifications.

Property	Value
Color	White
Density	0.794 g/cm^3 (@ 20°C)
Flash Point	< 0 °C
Vapor density	3 (@ 20°C)
Density active product	0.95 g/cm^3 (@ 20°C)

Table 3. Paraffin oil technical specifications.

Property	Value
Specific gravity	0.830 - 0.855
Viscosity kinematic at 40°C	13 - 18 mm^2/s
Dynamic viscosity at 20°C	32 mPa.s (typical)
Flash point	>120°C
Auto-ignition temperature	260 - 370°C

The testing procedures have been divided to three groups. First group has been conducted by using 2 gram of lithium grease with different weight content (10, 20, 30, 40, 50, 60, 70, 80 and 90 %) of paraffin oil. Thereafter, a selected content of paraffin oil (50, 60 and 70%) ware examined after adding 1 gram of silica Nano particles, all of which expressed as the second group. The most promising specimen (50% paraffin oil) of the perverse group regarding of coefficient and scar width were investigated after adding various weight content of carbon nanotubes (0.2, 0.4, 0.6 and 0.8%) with the same amount of 1 gram silica Nano particles.

Normal loads of 2, 4, 6, 8 and 10 N were vertically applied. Wear scar width was measured using optical microscope Olympus BX51. Images were recorded by a digital camera (Olympus DP 73) attached to the microscope using Cell Sense Imaging soft- ware (Olympus). The test was operated manually under dry condition at room temperature. The stroke length was 30 mm and repeated 20 times.

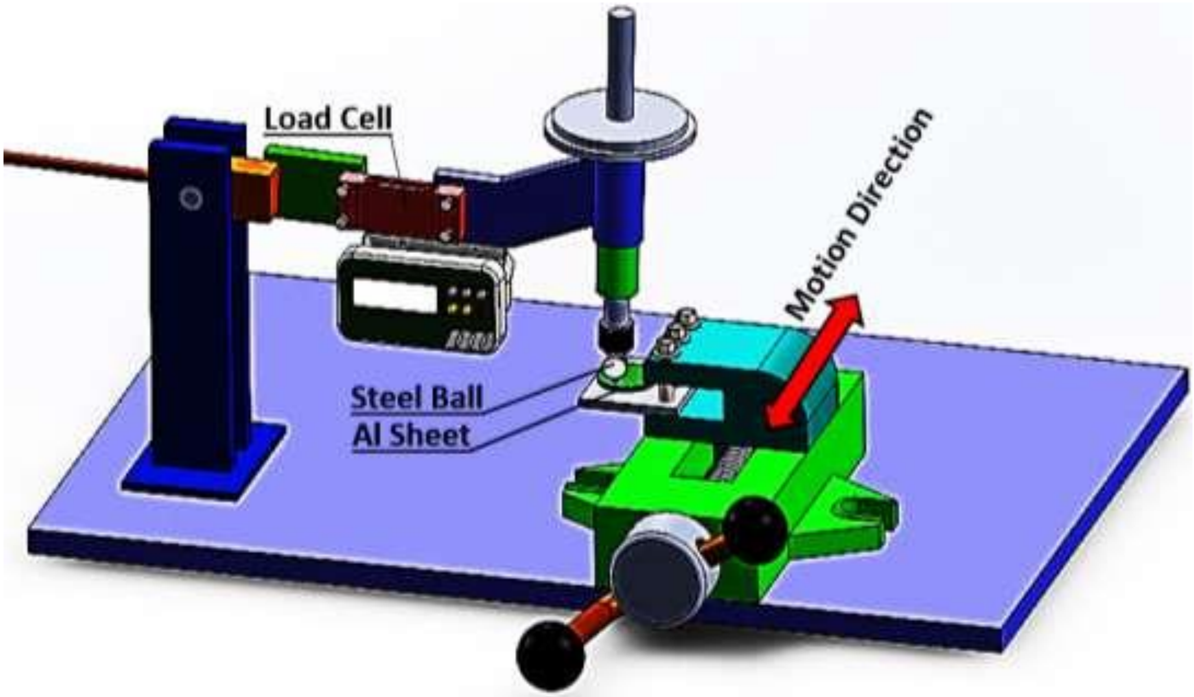

Fig. 1 Arrangement of the test rig

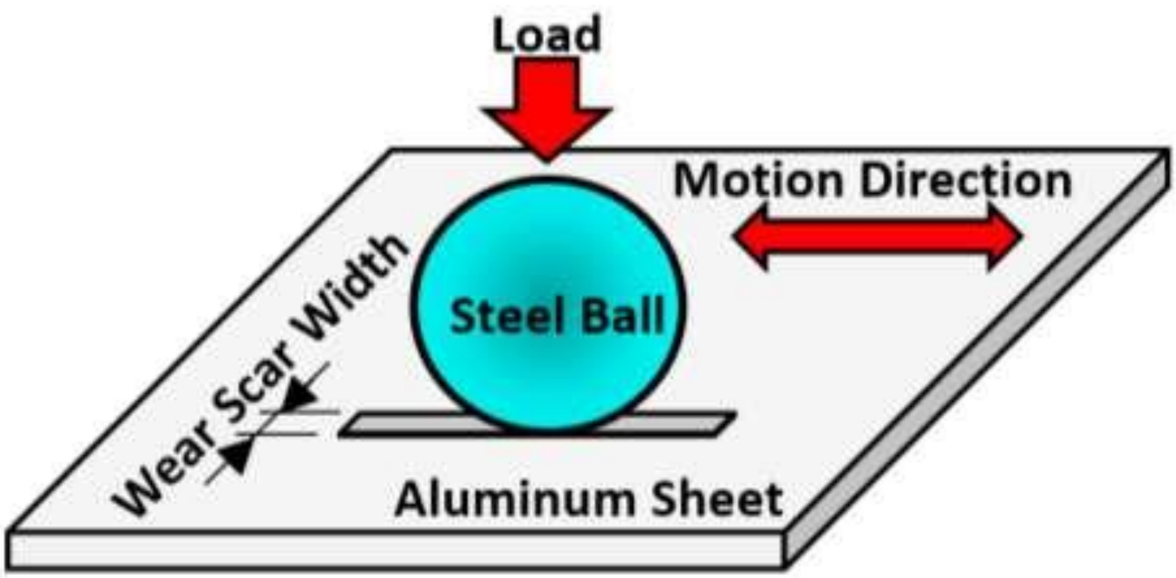

Fig. 2 Details of the test process.

RESULTS AND DISCUSSION

Friction is typically characterized by a friction coefficient which is the ratio of the frictional resistance force to the normal force which presses the surfaces together. In this case the normal force is the weight of the blocks. Normal load was applied by weights of 2, 4, 6, 8 and 10 N.

Frictional behavior for Lithium grease mixed by paraffin oil

The relationship between friction coefficient and paraffin oil content added to Lithium grease is shown in Fig.3. From the figure it can be seen that, the friction coefficient decreases with increasing oil content. This may be attributed to, oil lubricating mechanism during wear. In addition, it can also be clear that friction coefficient decreases

with increasing normal load. This may be regarded to extra heat which is generated during sliding. If the temperature is high, a layer of low shear strength material will be expected to form at the interface which should provide low values of the coefficient of friction. It is clearly seen that the best paraffin oil contents that gives minimum frictional values were 50, 60, 70 wt. % respectively.

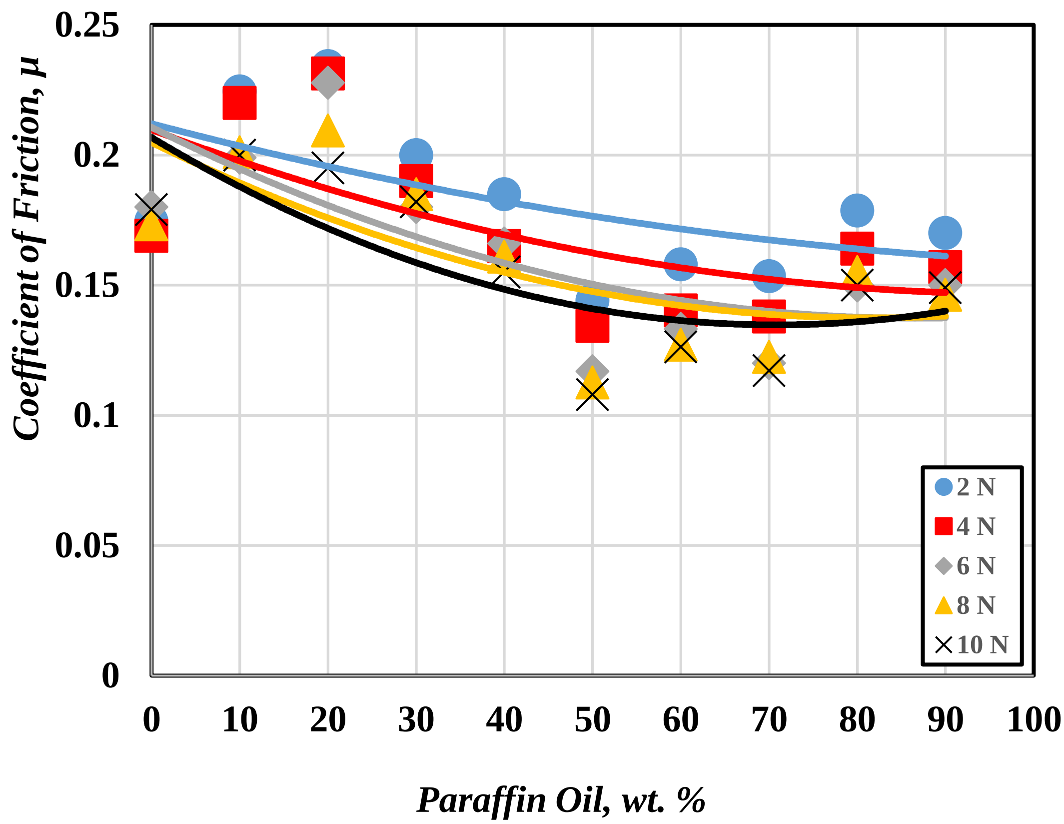

Fig. 3 Friction coefficient for Lithium grease mixed by paraffin oil.

Frictional behavior for Lithium grease mixed by paraffin oil dispersed by SiO_2 Nanoparticles

The effect of adding SiO_2 Nanoparticles to a mixture of grease and paraffin oil with 50, 60, 70 wt. % respectively on friction coefficient is shown in Fig. 4. It is clear that; the coefficient of friction values were increased compared to previous mixture. This may be referred to, the mechanism of friction for SiO_2 Nanoparticles and its abrasive action. The addition of SiO_2 Nanoparticles has a significant effect for increasing friction coefficient. There is a pronounced minimum friction coefficient around 50 wt. % paraffin oil content. Compare with the previous condition, the grease/paraffin oil/SiO_2 mixture have higher friction coefficient at the same oil content. It seems also that increasing normal load has a burnishing effect on the surface of the aluminum sheet. This effect has a major role to enhance the surface roughness which will eventually reduce the friction.

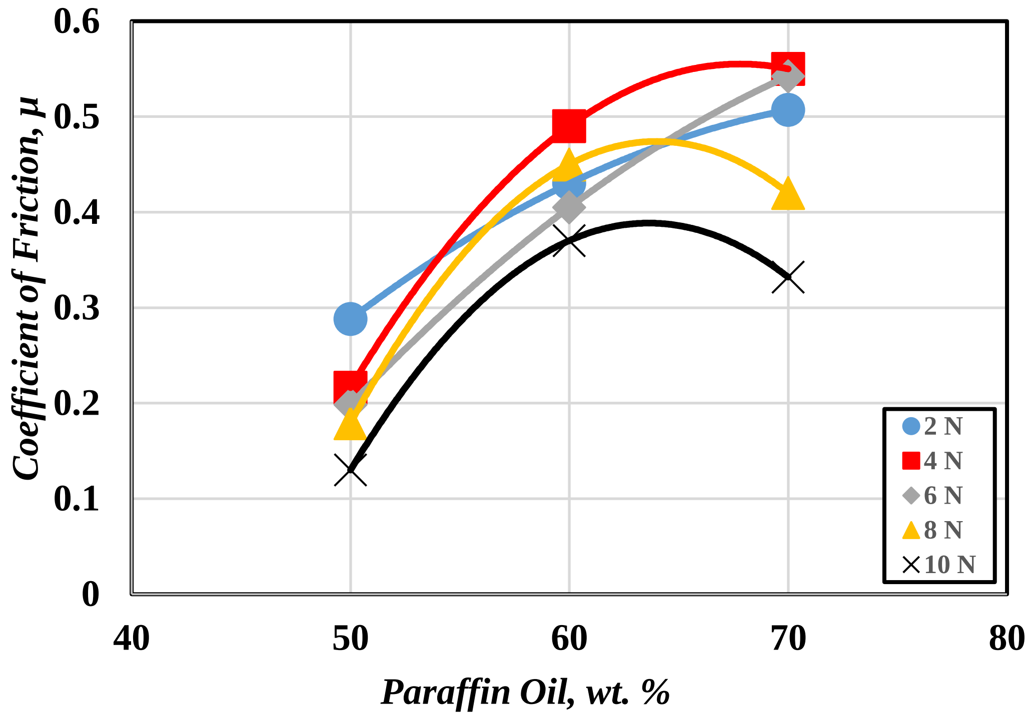

Fig. 4 Friction coefficient for Lithium grease mixed by paraffin oil and SiO_2

Frictional behavior for lithium grease mixed by paraffin oil dispersed by SiO_2 Nanoparticles and CNT

The friction coefficient values displayed by sliding of a steel ball on lithium grease mixed by paraffin oil dispersed by SiO2 Nanoparticles and CNT illustrates in Fig.5. It is clearly visible that, friction coefficient values were higher than that observes for other previous conditions. This may be refer to electrostatic characteristics for CNT.

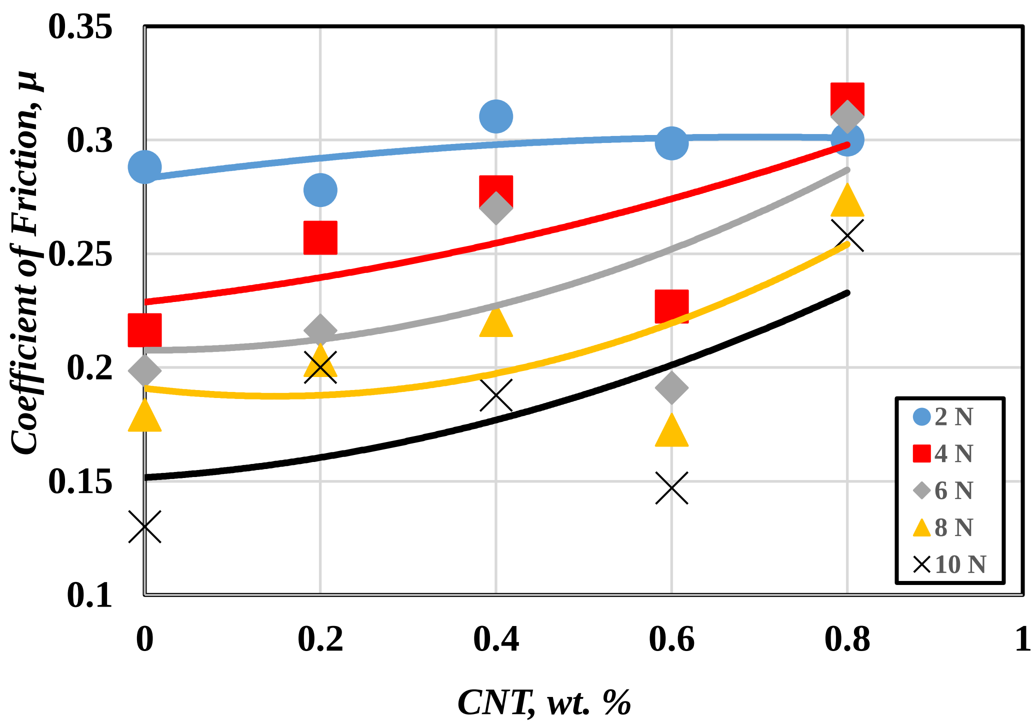

Fig. 5 Friction coefficient for Lithium grease mixed by paraffin oil, CNT and SiO_2.

Because of friction, electrical charges are generated due to static electricity, so the particles of sand acquire a positive charge, while the aluminum plate acquires a negative charge as shown in Fig.6. The particles are attracted to the surface of the aluminum plate, forming a layer of sand covering the sheet surface during friction as shown in Figs.7 and 8 respectively.

In the case of adding CNT or any electrical conductive material, the electrical charge of both the aluminum plate and the sand particles is weakened as shown in Fig.9. Thus reduces the attraction and electrical connection between them, and this causes more freedom for the particles during friction, which ultimately leads to an increase in the friction coefficient and wear as shown in Figs.10 and 11 respectively.

On the other hand, the increase of the friction coefficient that occurs with CNTs may be regarded to that CNTs can act as a third body in the wear mechanism, thus further increasing real contact surface, and production a slight increase in the friction coefficient. It is also known that agglomeration of nanoparticles increases friction due to the reduced shear and ball bearing effects.

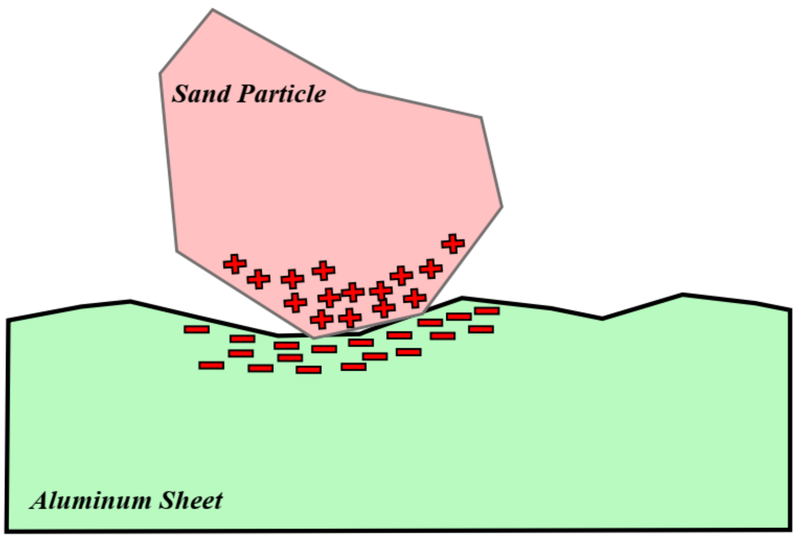

Fig. 6 Electrical charges generation due to friction.

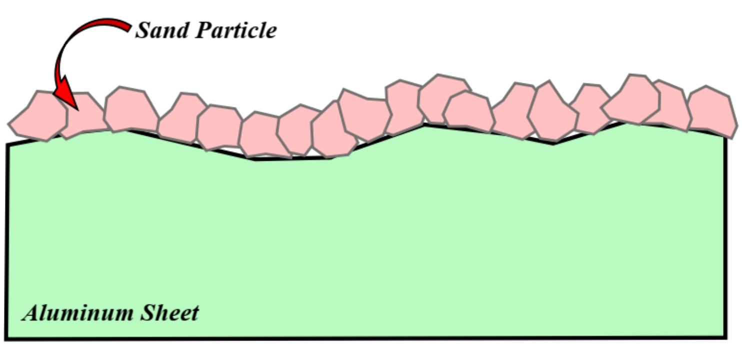

Fig. 7 Layer of sand covering the sheet surface.

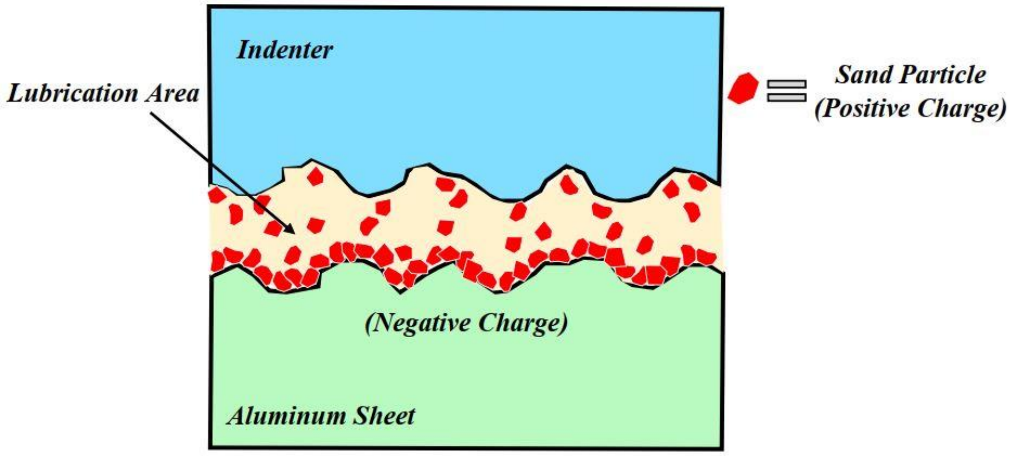

Fig. 8 Adhesion of SiO_2 into the Al Sheet.

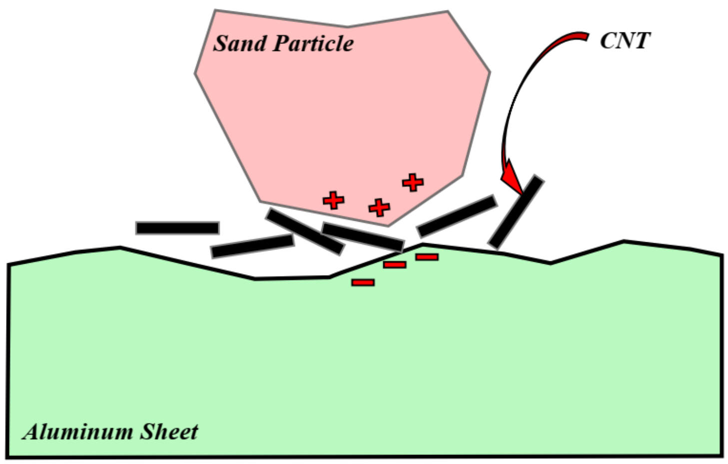

Fig. 9 Reducing electrical charge due to adding CNT.

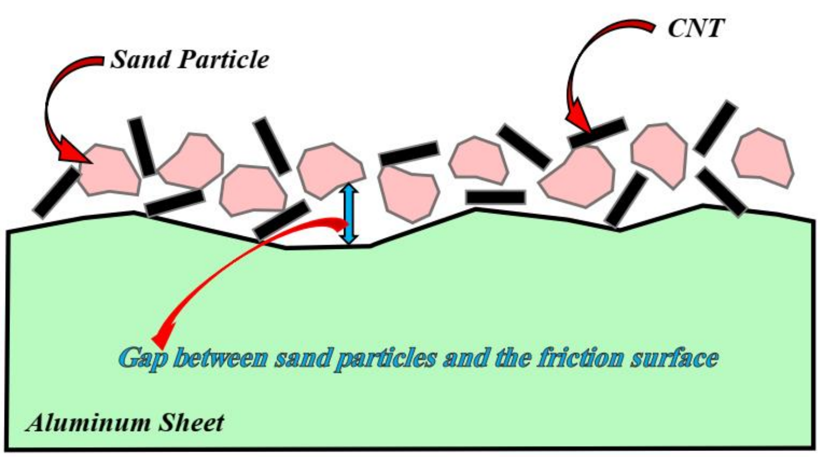

Fig. 10 The effect of adding CNT for reducing the sand particles attraction to the sheet.

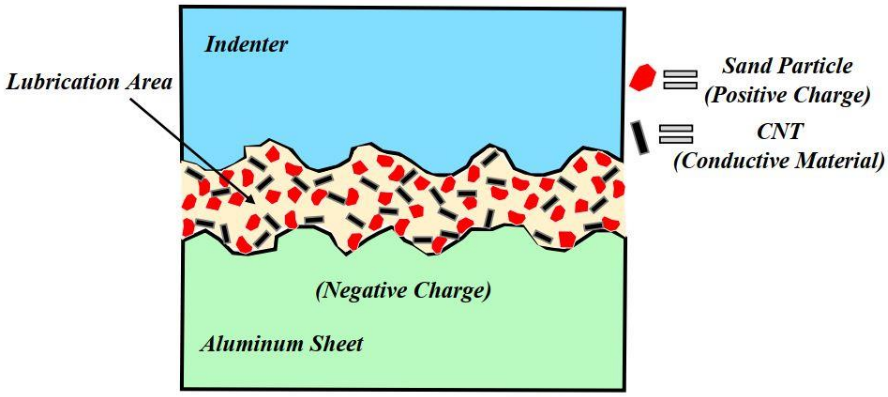

Fig. 11 CNT and SiO_2 dispersed in grease.

Wear results for Lithium grease mixed by paraffin oil

The relationship between wear scar width and paraffin oil content is shown in Fig. 12. It is noticed that, a decrease in scar width was observed with increasing the oil content up to 50 wt. % and there a slight increase beyond that percent. On the other hand it can be seen that, wear value increased with increasing normal load value.

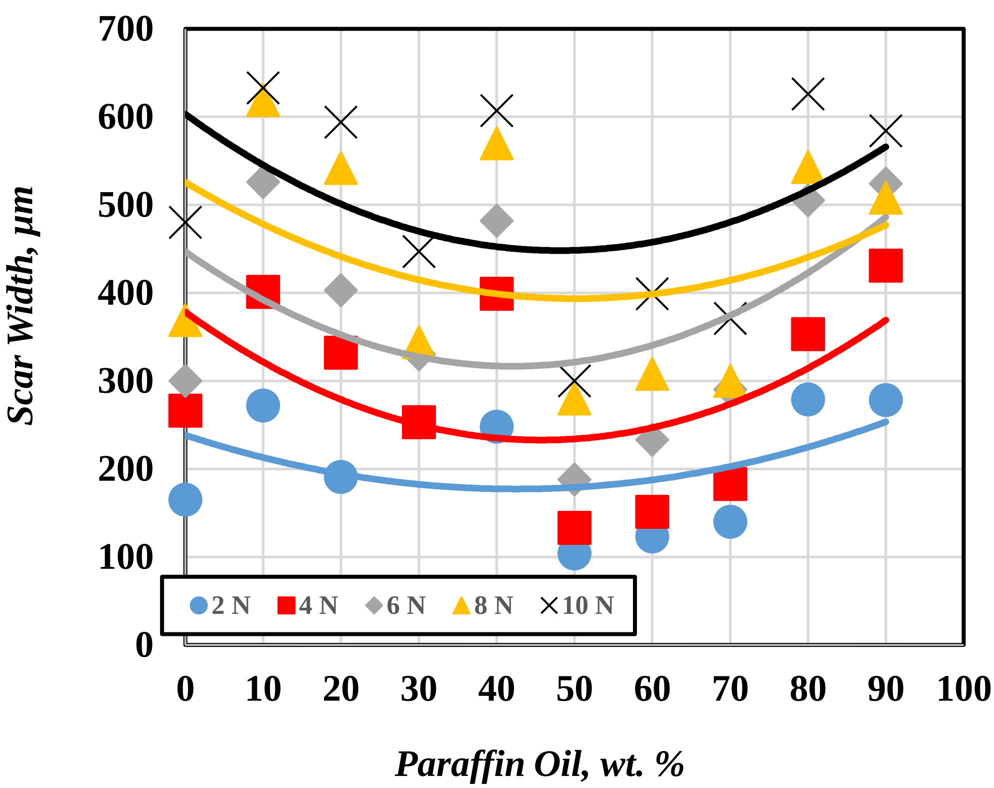

Fig. 12 Wear results for Lithium grease mixed by paraffin oil.

Wear results for Lithium grease mixed by paraffin oil and dispersed by SiO_2 Nanoparticles

Figure 13 demonstrates the wear behavior for lithium grease mixed by paraffin oil and dispersed by SiO_2 Nanoparticles. As shown from figure, the SiO_2 plays a significant role in increasing the scar width values. Adding SiO_2 nanoparticles increased wear as a result of the increased abrasiveness. The lowest values of wear were observed at 50 wt. % oil

content. It is noticed that, wear values increased with increasing applied normal load values this may be regarded to the decreasing of rolling action formed by the particles.

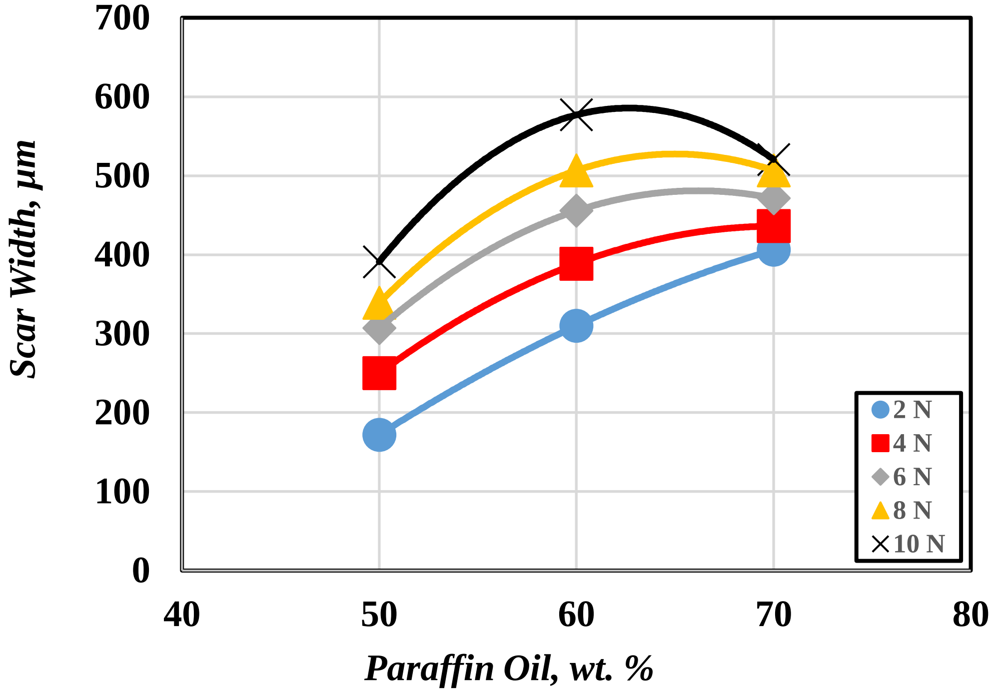

Fig. 13 Wear results for Lithium grease mixed by paraffin oil and dispersed by SiO_2.

Wear results for Lithium grease mixed by paraffin oil and dispersed by SiO_2 Nanoparticles and CNT

Results of wear for lithium grease mixed by paraffin oil and dispersed by SiO2 Nanoparticles and CNT are presented in Fig. 14. It is clear that, the scar width increased with the increase of CNTs percentage and the applied normal load.

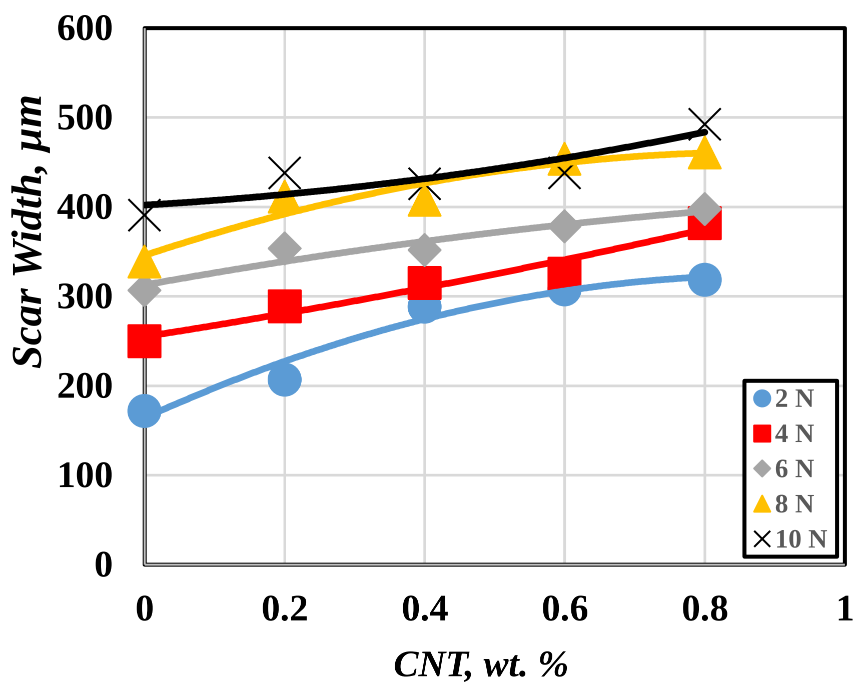

Fig.14 Wear results for Lithium grease mixed by paraffin oil and dispersed by SiO_2 and CNT.

CONCLUSIONS

From the present work, the following points can be concluded:

1. A significant decrease in friction coefficient and wear was observed with increasing paraffin oil content.

2. Paraffin and grease mixture containing 50 wt. % oil content exhibited the lowest wear and friction coefficient.

3. It can also be clear that friction coefficient decreases with increasing normal load.

4. Adding SiO_2 Nanoparticles has a significant effect for increasing friction coefficient and wear.

5. Combination of CNT/ SiO_2 slightly increase friction coefficient and wear.

6. It is clear that, the scar width increased with increasing CNTs percentage and the applied normal load.

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