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# EFFECT OF ELECTRIC CURRENT ON THE TRIBOLOGICAL PROPERTIES OF LITHIUM GREASE DISPERSED BY SILCA NANO PARTICLES AND CARBON NANOTUBES

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## ABSTRACT
**The present work discusses the effect of applying external voltage on the tribological characteristics of sliding steel ball against an aluminum sheet lubricated by lithium grease dispersed with silicon dioxide ($SiO_2$) nanoparticles and carbon nanotubes CNTs. Friction and wear tests were conducted by the reciprocating sliding of the ball on aluminum (Al) sheet lubricated by the previous mixture. The polarity of the Al sheet was positive at first then changed to negative to study the effect of polarity. It was found that the friction coefficient values for the negative Al sheet polarity was higher than positive polarity. This may be referred to the attractive force that generated between the positive sand particles and the negative aluminum sheet, which led to increasing the sand particles density on the sheet surface. In addition, it can also be clear that friction coefficient decreases with increasing DC volt value. The morphology of worn surface is analyzed by optical microscopy for measuring the wear scare width as an indication for the wear rate. The wear values decreased with increasing volt values. Minimum wear values were displayed by grease dispersed by $SiO_2$ Nano particles. It was observed that combination of CNTs/ $SiO_2$ significantly increases of friction and wear. That can be explained on the bases that agglomeration of CNTs increased their layers and shear stress.**

## KEYWORDS
**Electric current, Silicon dioxide nanoparticles, carbon nanotubes, lithium grease, Friction, Wear scar width.**

## INTRODUCTION
**It has been detected that in the friction of metals, wear rates can be altered by application of electric current, [1]. The wear of the surfaces influenced by the additives between the surfaces as each additive react differently with the current. Wear and friction of metals can be modified by applied of an electric current voltage throw the surfaces, [2]. The polarities of sliding surfaces have evident effect on friction forces during sliding of surfaces. It was noticed that in a ball and disk friction test, in the presence of conventional lubricant that used in cutting processes, that wear of anode surfaces collapsed and that of cathode surfaces expanded compared to condition where no current was applied, [3]. A vast efforts have been made by researchers in this research point, and many attractive**

**results have concluded that the tribological properties could be alternated to differing after external DC current was applied, [4].**

**It was revealed that when an electric current is applied between two sliding surfaces in the presence of engine oils, the wear behavior of the surfaces could be modified in a great matter, [5]. The wear on the anode surface increased while it was decreased on the cathode. The difference in wear rate of surfaces with and without current may be referred to the modification of the composition of surface films, [6]. It was observed that in the presence of a lubrication fluid, the wear of the anode surface decreased with a great way while the wear of the cathode surface increased in a small way, [7]. Similar conclusions were observed in face milling process where the wear of milling tool was reduced when it was the anode and expanded when the tool was the cathode.**

**The effect of electric current has also been observed to reduce friction and wear for sliding of two materials, [8]. The friction and wear behavior of a steel when an electric current was passed through the contact in the presence of engine oils was analyzed, [9]. The applied electric current alternated friction coefficient to a small degree but the wear was changed considerably. The wear changed by two to three orders of value depending on the direction of current flow. The current volte played a significant role in the value of wear observed on surfaces, [10]. The change in wear rate of surfaces with and without current may be referred to the alteration of the elemental composition of surface films shaped at the contact surfaces. High wear was realized on the anode surface and low wear on the cathode surface. This could have a significant practical implication, [11].**

## 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 as shown in Fig. 3. DC electric current of 3, 6 and 12 volts were applied to the test specimens. The polarity of the current was changed to allow the test specimen to be anode and cathode. The 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 |

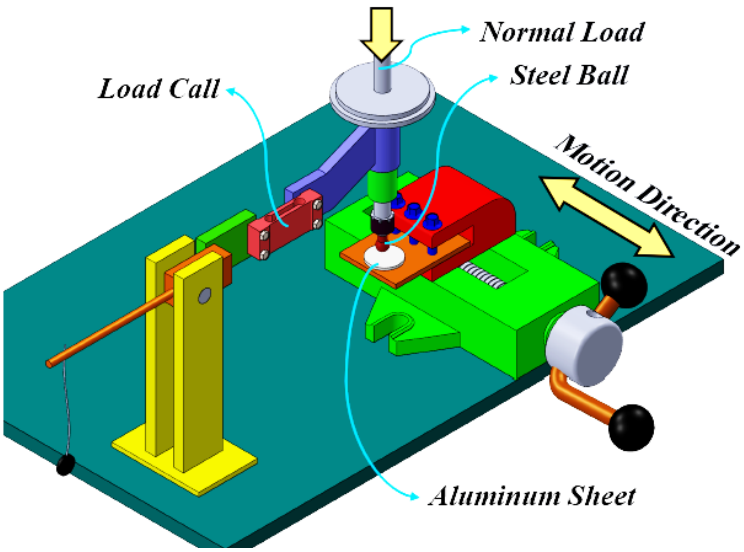



**Fig. 1 Arrangement of the test rig.**

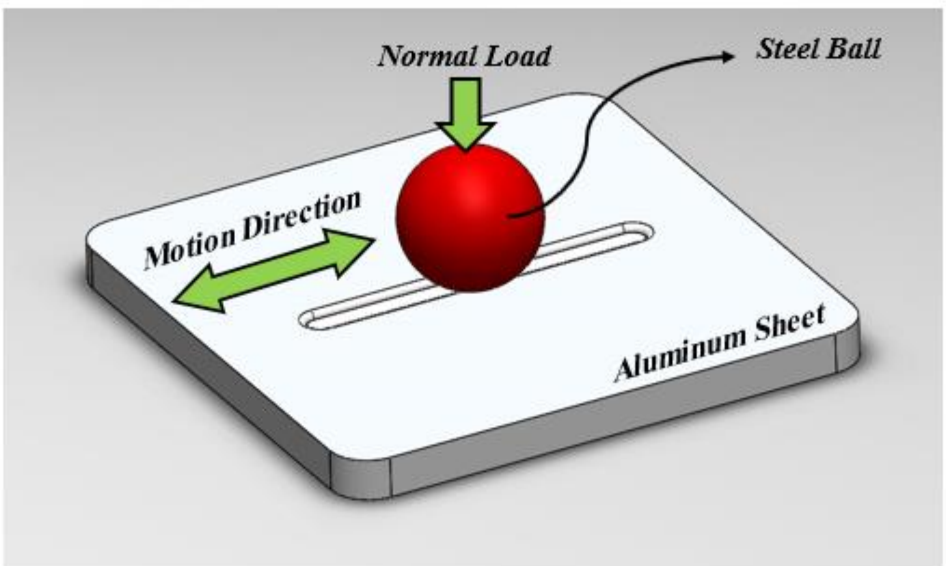



**Fig. 2 Details of the test process.**

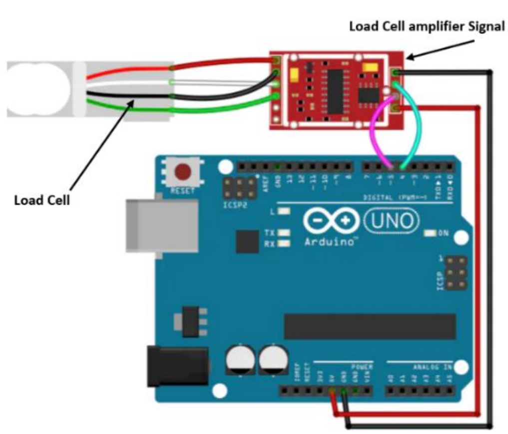



**Fig. 3 Wiring diagram for load cell Signal.**

**Experiments were carried out to investigate the effect of the tested nanomaterials (silica and carbon nanotubes) dispersing in lithium grease applying external DC Volt on friction coefficient and scar width. The technical data for used grease are displayed in Table 2. 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. The weight percentages of CNTs was 0.05 wt. % dispersed in the grease. The parameters of these CNTs, according to supplier information were: average diameter 10 – 30 nm, average length 5 –15 µm. The purity of CNTs was higher 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/cm3 (@ 20°C) |
| Flash Point | < 0 °C |
| Vapor density | 3 (@ 20°C) |
| Density active product | 0.95 g/cm3 (@ 20°C) |

**The testing procedures have been divided to three groups. First group has been conducted by using 0.01 g of Nano silica particles with applying an external 3, 6, 12 DC volts. In the second group the grease was dispersed by silica Nano particles and applying 6 and 12 DC volts, while in the final group the grease was dispersed by silica and CNTs with 6 and 12 DC volts.**

**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 at room temperature. The stroke length was 30 mm and repeated 20 times.**

**RESULTS AND DISCUSSION**

**Friction is characterized by friction coefficient that is the ratio of the frictional resistance force to the normal force that 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 silica Nano particles under several DC volts**

**The relationship between friction coefficient and normal load for different DC volts is shown in Fig.4. From the figure it can be seen that, the friction coefficient decreases with increasing normal load. This may be attributed to extra heat that is generated during sliding. If the temperature is high, a layer of low shear strength material will be expected to form at the interface that should provide low values of the coefficient of friction.**

**It is clearly seen that the friction coefficient values for the negative Al sheet polarity was higher than positive polarity. This may be referred to the electrostatic charges that generated during the motion, so the particles of sand particles acquire a positive charge.**

**Therefore an attractive force was generated between the positive sand particles and the negative aluminum sheet, which led to increasing the sand particles density on the friction surface and increasing the coefficient friction as shown in Fig. 5.**

**In the second case, as shown in fig. 6, the aluminum sheet carried a positive charge and the steel ball (indenter) carried a negative charge, a repulsion occurred between the sand particles and the surface of the aluminum sheet, and consequently the sand particles clumped around the steel ball. Because of this behavior, density of the sand particles decreases at the surface of the aluminum sheet this led to decreases in coefficient of friction. In addition, it can also be clear that friction coefficient decreases with increasing DC volt value. This may be regarded to an increase in the previously described behavior.**

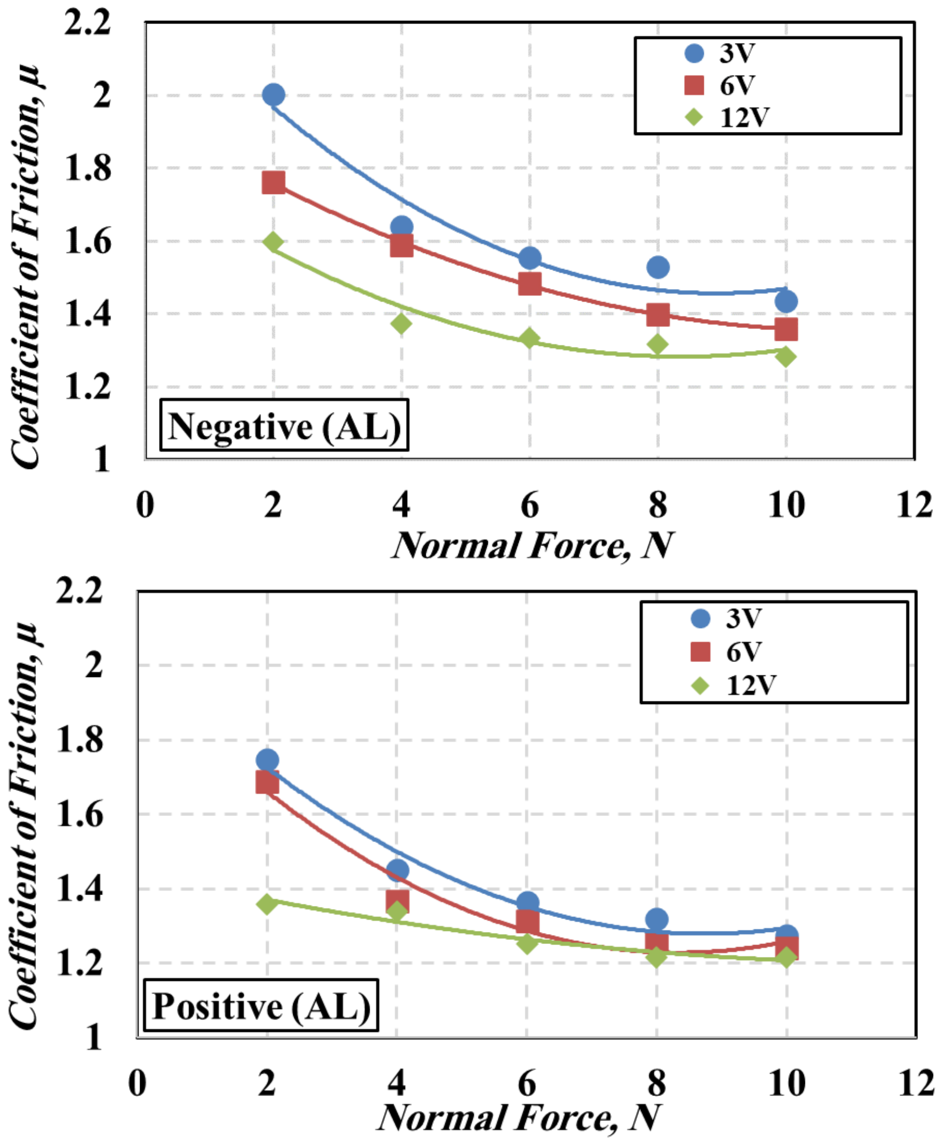



**Fig. 4 Effect of DC current volts on friction coefficient of Nano silica particles for different polarities.**

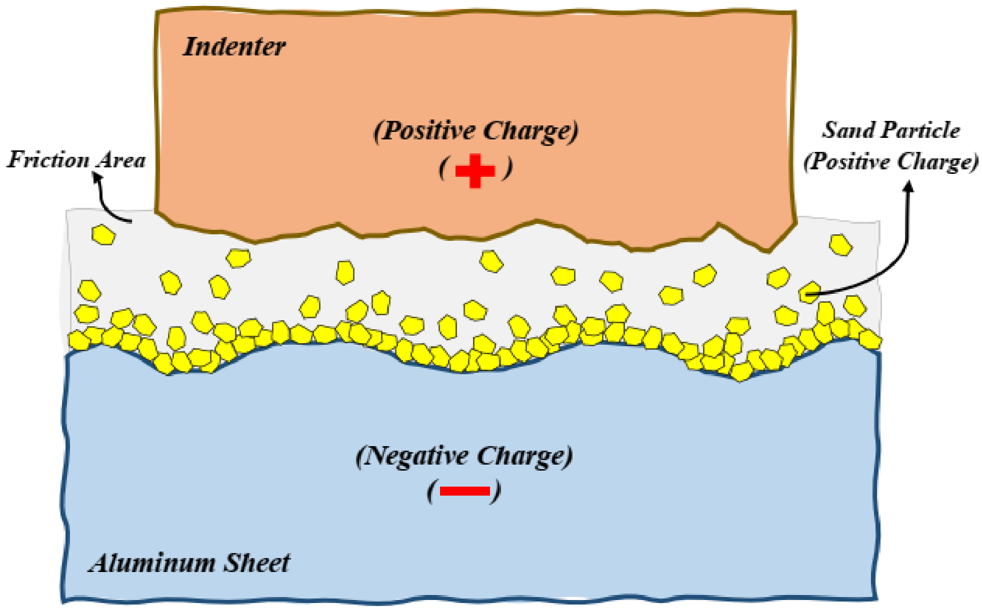



**Fig. 5 Distribution of Nano silica particles on the Al sheet surface under the applied volt. (Al sheet has a negative charge)**

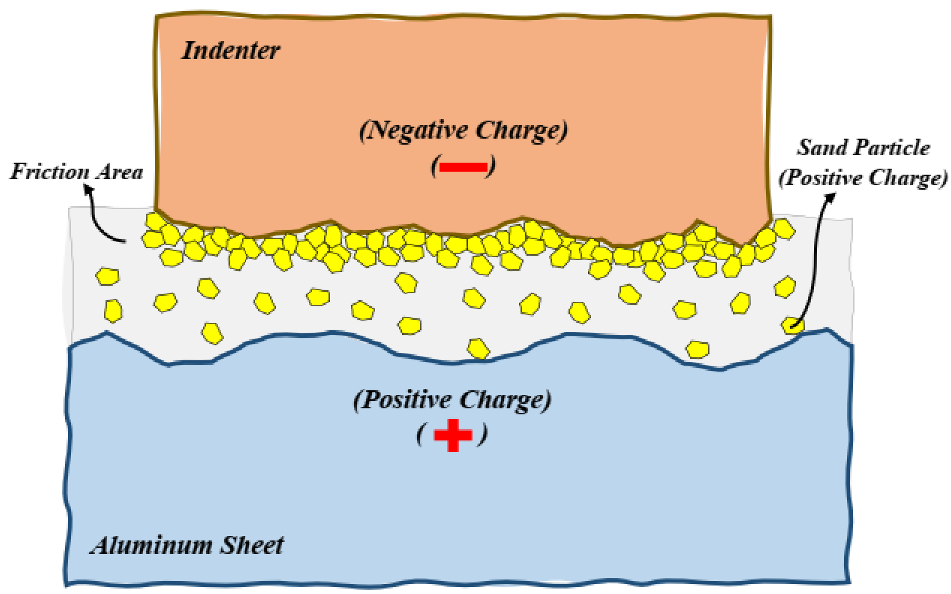
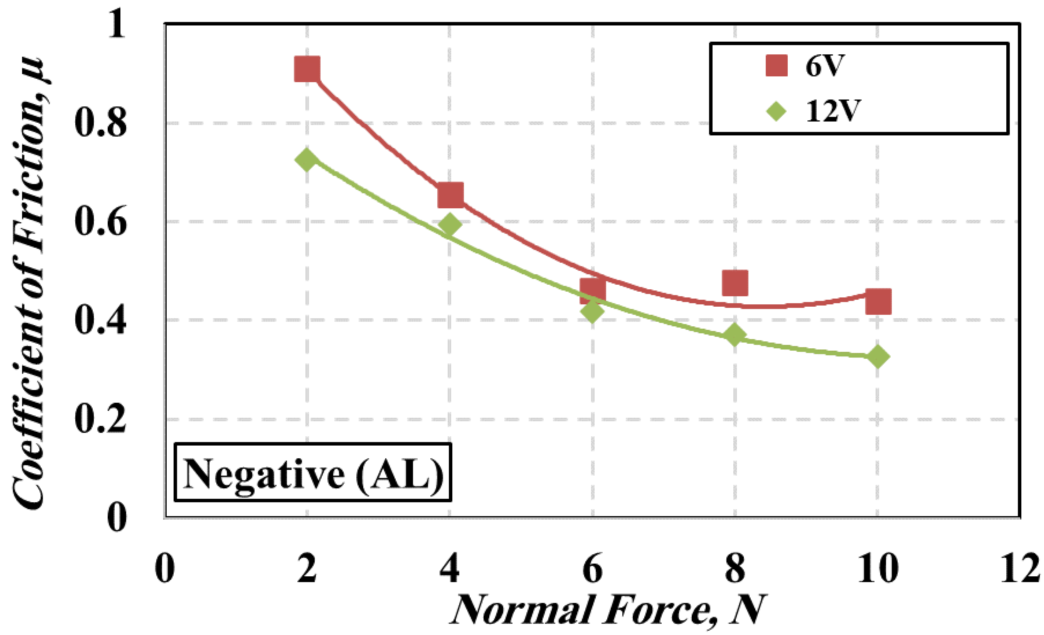



**Fig. 6 Distribution of Nano silica particles on the Al sheet surface under the applied volt. (Al sheet has a positive charge).**

**Frictional behavior for Lithium grease dispersed by silica Nanoparticles.**

**The effect of dispersing $SiO_2$ Nanoparticles in grease on friction coefficient with applying 6 and 12 DC volts is shown in Fig.7. It is clear that; the coefficient of friction values were decreased compared to previous mixture. This may be referred to the effect of grease. It is clear that increasing the volt value leads to decrease the coefficient of friction. 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. As shown the friction coefficient values for negative polarity were higher than positive polarity.**



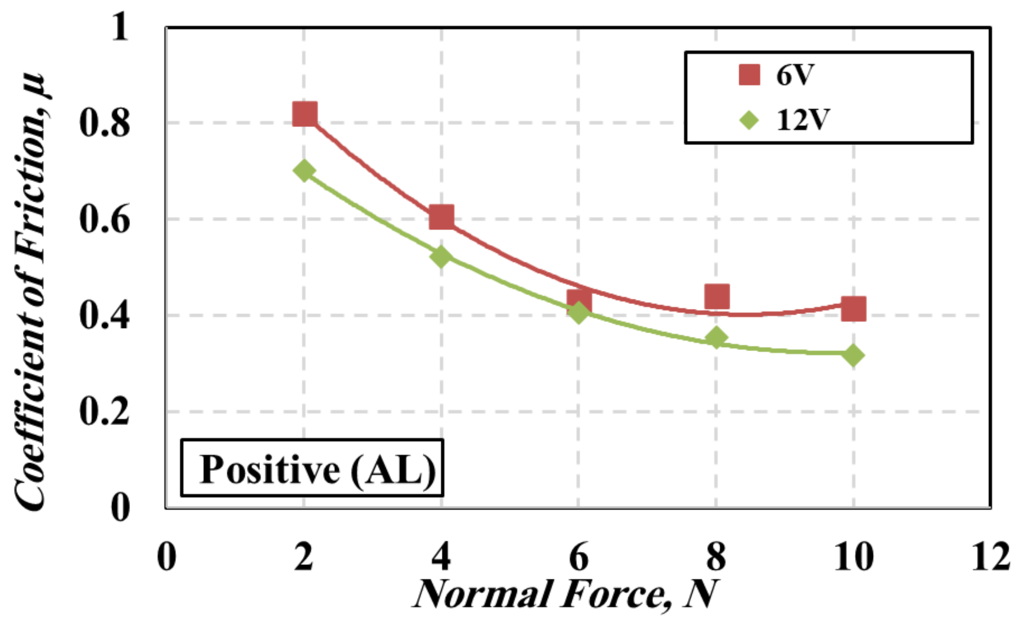




**Fig. 7 Friction coefficient for Lithium grease dispersed by silica Nanoparticles under 6 and 12V for different polarities.**

**Frictional behavior for lithium grease dispersed by $SiO_2$ Nanoparticles and CNT.**

**The friction coefficient values displayed by sliding of a steel ball on lithium grease dispersed by $SiO_2$ Nanoparticles and CNT illustrates in Fig.8. It is clearly visible that, the friction coefficient decreases with increasing normal load. It is clearly seen that the friction coefficient values for the negative Al sheet polarity was higher than positive polarity.**

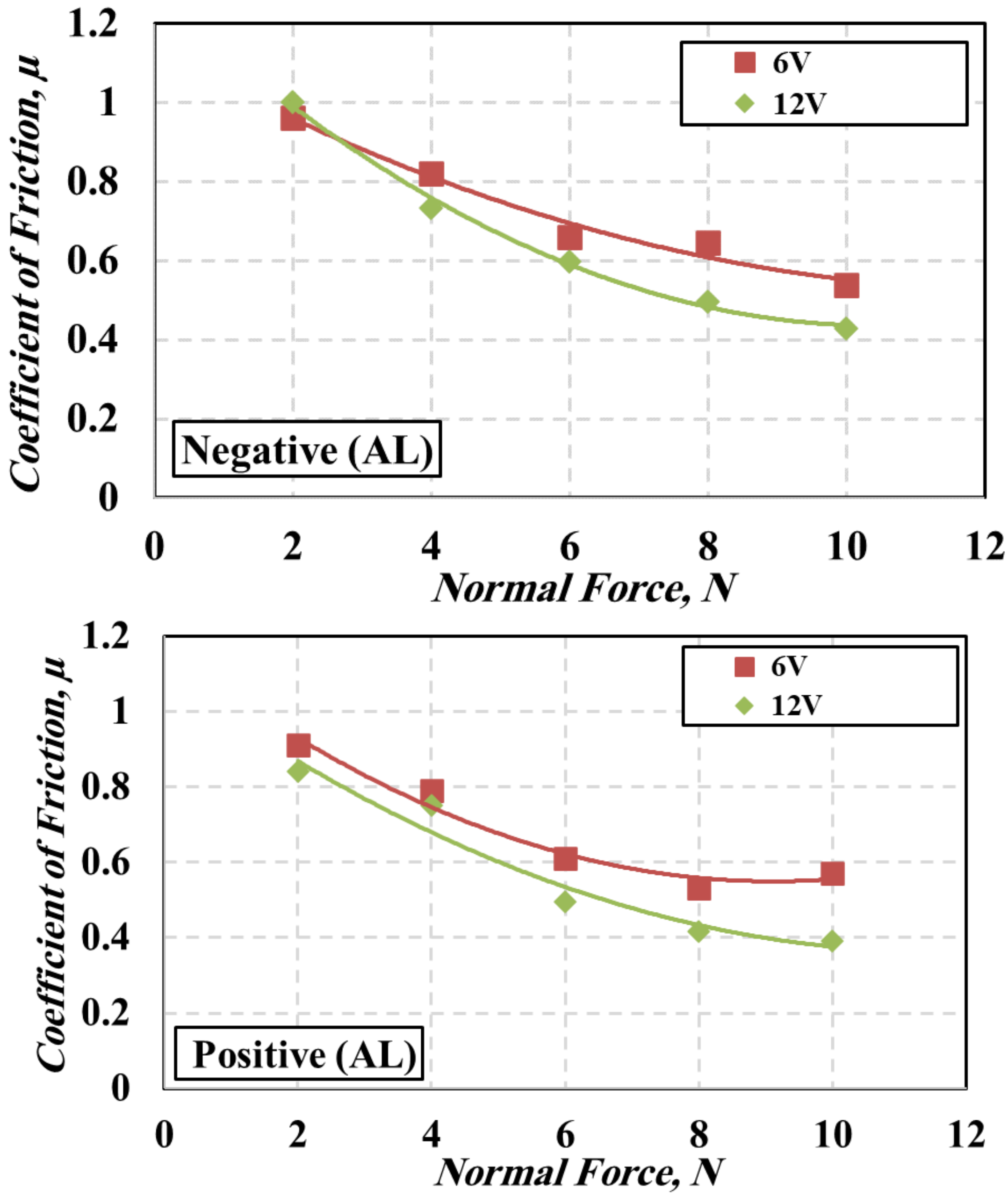



**Fig. 8 Friction coefficient for Lithium grease dispersed by silica Nanoparticles and CNT under 6 and 12V for different polarities.**

**It can be clearly observed that the friction coefficient values were higher than that observes for previous condition as shown in fig.9. This may be refer to electrostatic characteristics for CNT.**

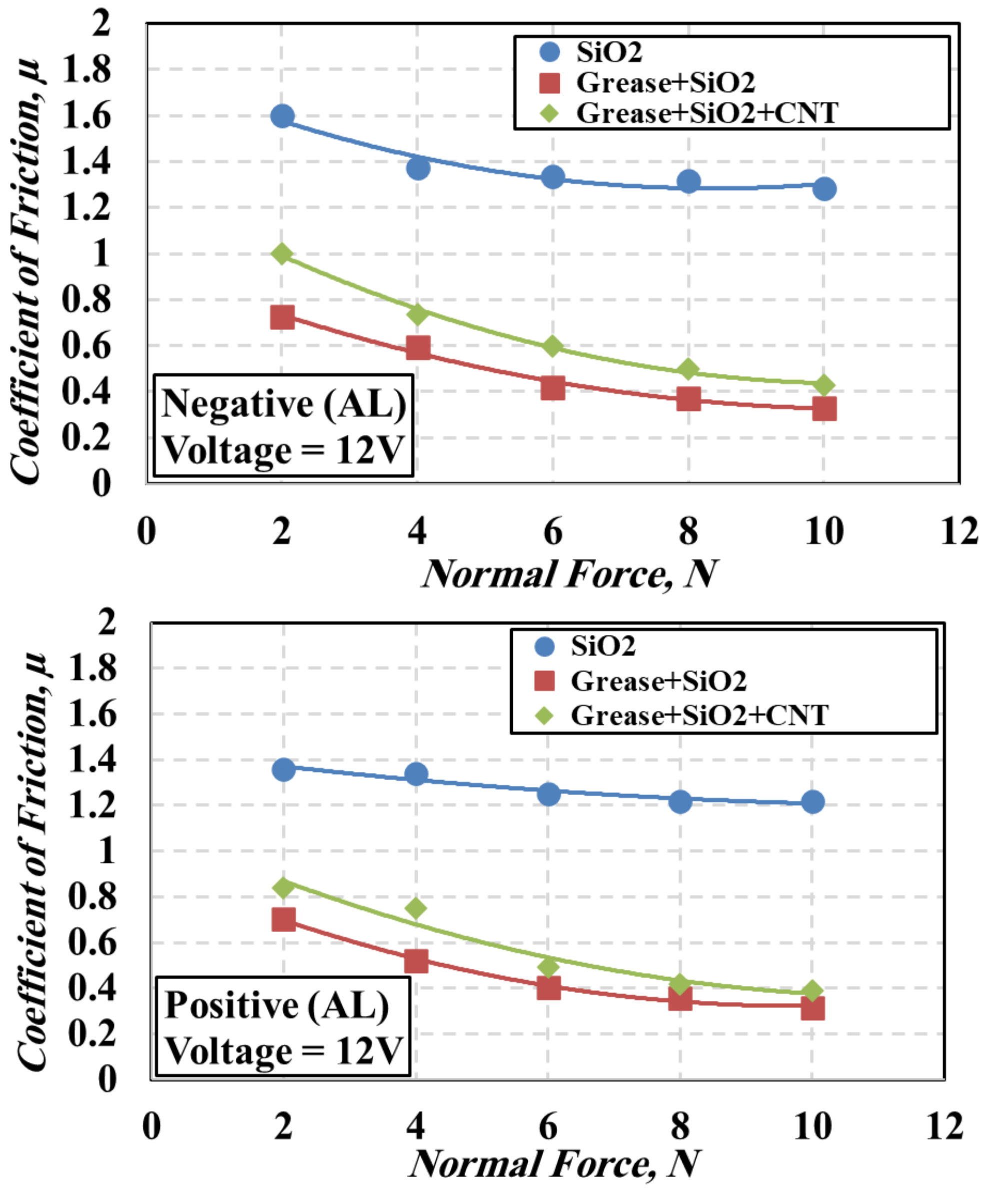



**Fig. 9 Friction coefficient for the three different conditions under 12V for different polarities.**

**In the case of adding CNT, the electrical charge of both the aluminum plate and the sand particles is weakened as shown in Fig. 10 and Fig. 11. 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.**

**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.**

**In addition, it can be noticed that there was slight enhancement in coefficient of fraction in a case of the aluminum sheet had a positive charge. This may be attributed**

**to, a repulsion occurred between the sand particles and the surface of the aluminum sheet. This led to decrease the density of the sand particles at the surface of the aluminum. This ultimately caused a reduction the coefficient of friction more than the second case when aluminum sheet had a negative charge.**

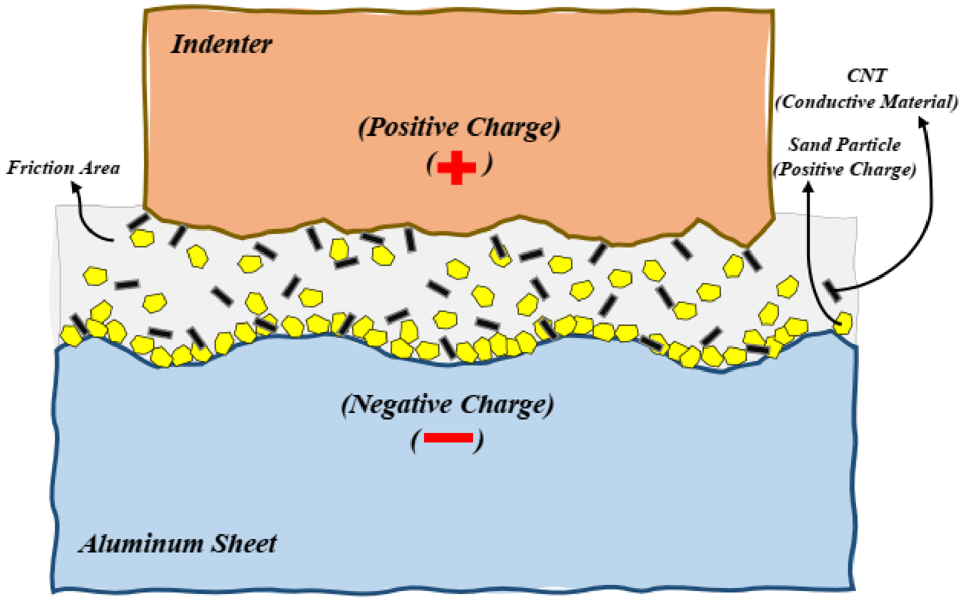



**Fig. 10 Distribution of Nano silica particles and CNTs on the Al sheet surface under the applied volt. (Al sheet has a negative charge).**

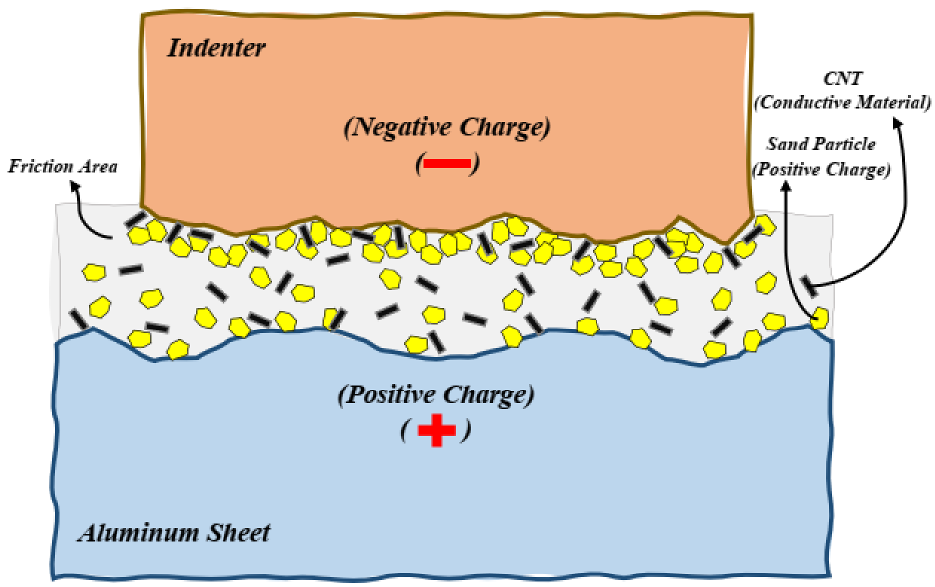



**Fig. 11 Distribution of Nano silica particles and CNTs on the Al sheet surface under the applied volt. (Al sheet has a positive charge).**

**Wear results for silica Nano particles under several DC volts**

**The relationship between wear scar width and normal load is shown in Fig. 12. It is noticed that, an increase in scar width was observed with increasing the normal load.**

On the other hand it can be seen that, wear value decreased with increasing the volt values.

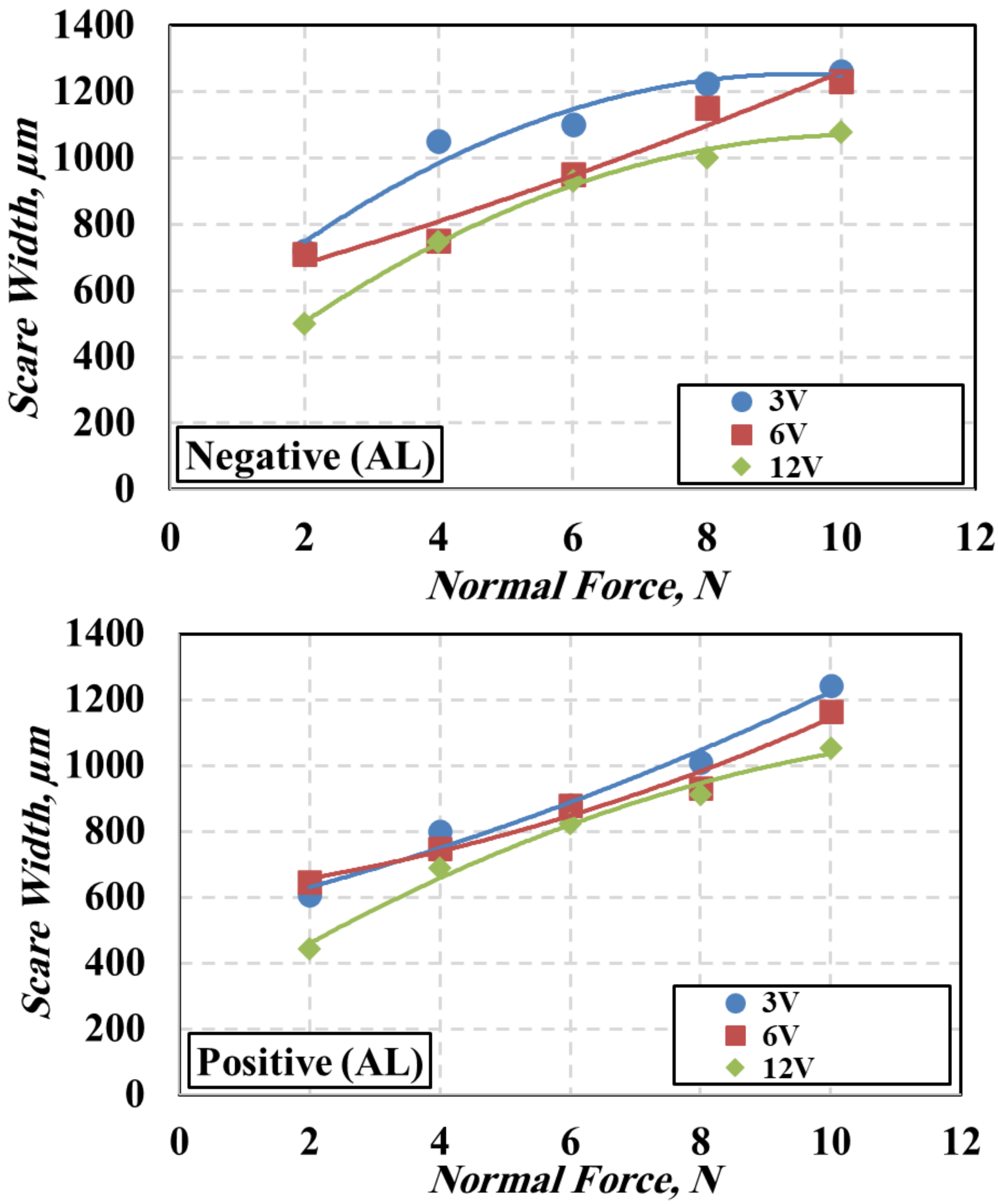



**Fig. 12 Wear results for silica Nano particles under several DC volts for both polarities.**

**Wear results for Lithium grease dispersed by $SiO_2$ Nanoparticles.**

**Figure 13 demonstrates the wear behavior for lithium grease dispersed by $SiO_2$ Nanoparticles. As shown abone, the grease plays a significant role in decreasing the scar width values. Also increasing the volt value leads to decreasing the wear value. It is noticed that, wear values increased with increasing applied normal load values.**

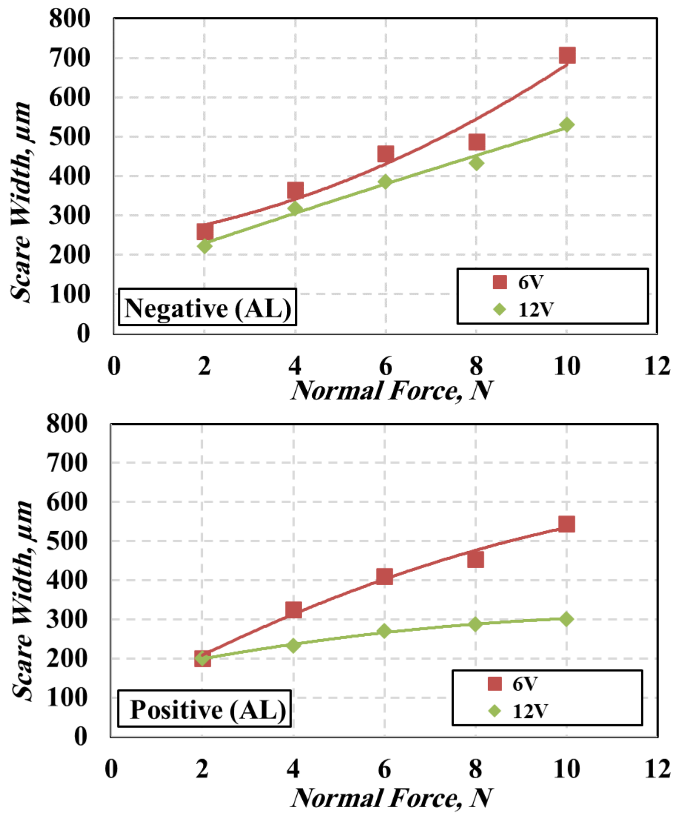



**Fig. 13 Wear results for Lithium dispersed by $SiO_2$ under 6 and 12V for different polarities.**

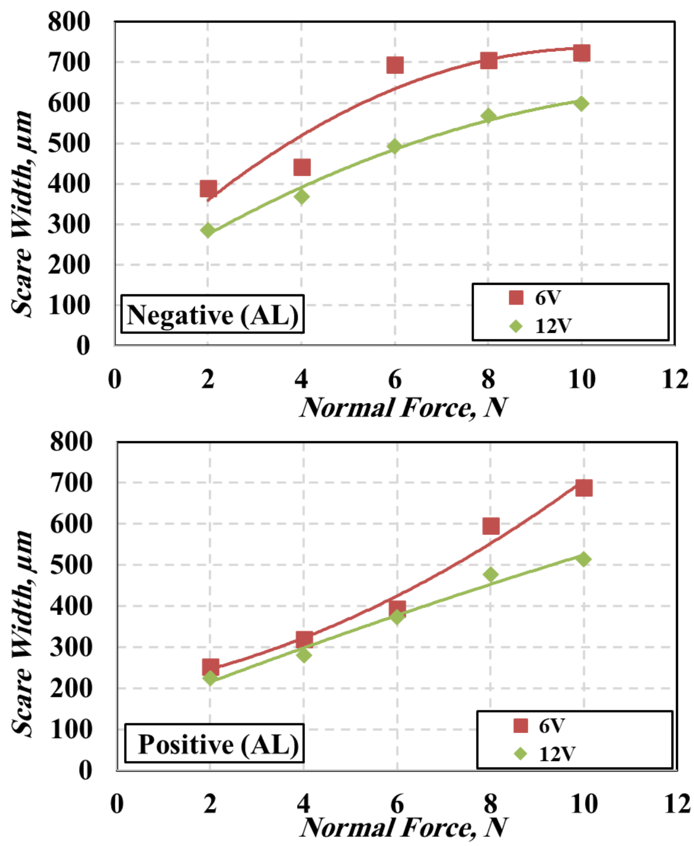



**Fig. 14 Wear results for Lithium grease dispersed by $SiO_2$ and CNT.**

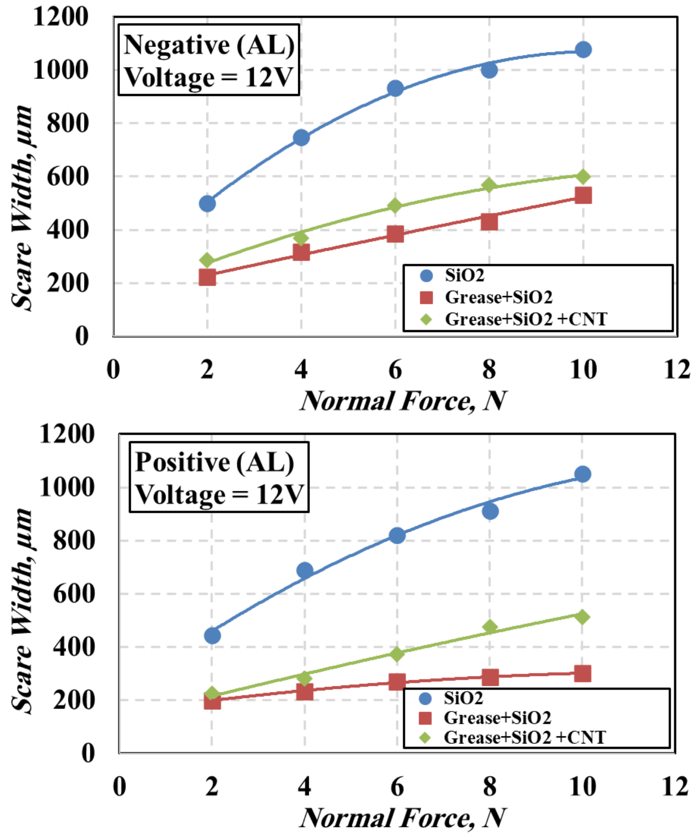



**Fig.15 Wear results for the three different conditions under 12V for different polarities**

**Wear results for Lithium grease dispersed by $SiO_2$ Nanoparticles and CNT.**

**Results of wear for lithium grease dispersed by $SiO_2$ Nanoparticles and CNT are presented in Fig. 14. It is clear that, the scar width increased with the increase of the applied normal load. Also, wear value decreased with increasing the volt value. It can be notice that the scar width values were higher than that observes for previous condition as shown in Fig. 15.**

## CONCLUSIONS

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

1. **The friction coefficient decreases with increasing DC volt value.**
2. **The friction coefficient values for the negative Al sheet polarity was higher than positive polarity.**
3. **It can also be clear that the wear values decreased with increasing volt values.**
4. **Minimum wear values were displayed by grease dispersed by $SiO_2$ Nano particles.**
5. **Combination of CNT/ $SiO_2$ slightly increase friction coefficient and wear.**

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