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TRIBOLOGICAL BEHAVIOUR OF STEEL LUBRICATED BY GREASE FILLED BY POLYMERIC ADDITIVES

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ABSTRACT:
In the present work, the effect of applying negative electric (DC) current on the friction and wear of carbon steel in presence of calcium-based grease dispersed by polymeric materials such as polyethylene (PE), polytetrafluoroethylene (PTFE) and polymethyl methacrylate (PMMA) is discussed. The experiments were carried out on cross pin wear tester under external negative DC electric current, -1.5, -3.0, -4.5 and -6.0 volts.

Based on the experimental results, it can be concluded that, the effect of polymeric particles dispersed in grease depends on the ability of polymeric particles to adhere into the contact surfaces. Friction coefficient with applied external negative current increase with increasing polymer content at the polymer have negative polarity. PMMA shows the significant effect on reduction friction coefficient and wear at negative current. It can be recommended that selection of polymeric materials based on the polarity and location in tribo-electric series, for dispersing greases.

KEYWORDS: Calcium Grease, PE, PTFE, PMMA.

INTRODUCTION
Presence of electric current and magnetic field around the tribocontact modified the mechanical properties of the surface and subsurface, [1]. The mean friction coefficient changed from 0.16 without electric current and magnetic field to 0.26 with them, and its variation reduces considerably. The worn surfaces were smoother with magnetic field application than that without it, and the modification of subsurface structure was observed. The magnetic field and the electric current modified the mechanical and chemical properties of this ferromagnetic material in the sliding contact by interaction with cyclic contact stresses and increasing the temperature on the contact surface. This interaction was characterized by an increase of the micro hardness, the activation of oxidation on the surfaces, the difference of contact noise level and the changes induced in subsurface structure.

The apparent friction coefficient was changed by reversing the polarity of the external electric field due to the change in real normal pressure. An extraordinary change in friction coefficient of graphite/graphite rubbing couples was discovered, [2], under a large DC current at a critical sliding speed, jumping from a high value (about 0.7) to a low value (about 0.07) as rubbing slows down or from the low value to the high value as rubbing speeds up. It was found that for intentionally insulated metallic contacts lubricated with liquid crystals the relative friction coefficient under boundary lubrication

conditions can be reduced by up to 35% by applying an external DC electric field, [3]. DC voltages were found to be able to promote the generation of chemisorbed and chemical reaction films of ZDTP additives in mineral lubricating oils on metal surfaces, leading to a reduction in friction, [4 - 6]. It was reported that an AC voltage has effects on lubricating ability of synovia constituents, [7- 8]. It was observed that for Al_2O_3/brass couple lubricated with emulsion of zinc stearate the change in friction coefficient due to an external DC voltage is not only remarkable, reaching 200 %, but also quick and reversible, [9]. Besides, friction coefficient of Al_2O_3/brass couple increased monotonously with increasing external electric field intensity in the range of 0 - 30 DCV, [10], and that the fastest increase of friction coefficient occurs within the range of 0 - 20 DCV.

The effect of an applied electric field on the running-in operation of a roller bearing was investigated, [11 - 13]. In the mixed lubrication regime, when the bearing was the anode, the friction coefficient increased and also the bearing temperature increased and showed signs of seizure. The bearing surface was oxidized as would be expected, because of an anodic reaction. However, when the bearing was cathode, the friction coefficient rapidly decreased and so did the bearing temperature. The effect of additives in highly refined paraffinic base stocks on wear under the influence of an electric current was also investigated, [14, 15]. The addition of sulfur compound decreased wear on the cathodic surface, while wear was increased on the anodic surface. It was found that an externally applied voltage may modify the wear behaviour of the lubricant and also, without friction, its decomposition and its reactivity on the surface, [16]. Because of triboelectrification, the charged surfaces can interact with each other due to the direct electrostatic forces, [17, 18]. Since these forces are strong and effective, they contribute a major part of the adhesion force.

Friction of polymers is accompanied by electrification. The basic mechanism of solid triboelectrification implies processes, which can be described in terms of surface conditions. During frictional interaction chemical and physichemical transformations in polymers promote increases in the surface and bulk states density, [19, 20]. Ionization and relaxation of those states lead to electric fields of the surface and bulk charges. Electrification in friction is a common feature, it can be observed with any mode of friction, and with any combination of contacting surfaces.

It was found that a correlation between friction coefficient and voltage generated was found for polymers sliding against polyethylene terephthalate and against steel in water and salt water lubricated conditions, [21]. Wear of the tested polymers decreased with increase of sand particle size down to minimum because of the sand embedment in the polymeric surface. It was found that, application of magnetic field decreased friction coefficient at dry sliding due to its influence to decrease the adherence of polyethylene worn particles into the steel counterface, [22]. Besides, the magnetic field favored the formation of oxide film on the contact surface, where it played a protective role in dry friction, modified the friction and changed wear from severe wear to mild.

In the present work, the effect of the negative electric current on the friction and wear of carbon steel in presence of calcium-based grease dispersing by polymeric materials such as polyethylene (PE), polytetraflouroethylene (PTFE) and polymethylmethacrylate (PMMA) is discussed.

EXPERIMENTAL WORK

Experiments were carried out using a cross pin wear tester, Fig. 1. It consists, mainly, of rotating and stationary pins of 15 mm diameter and 160 mm long. The rotating pin was attached to a chuck mounted on the main shaft of the test rig. The stationary pin was fixed

to the loading block where the load is applied. The main shaft of the test machine is driven by DC motor (300 watt, 250 volt) through reduction unit. Moreover, the motor speed is adjustable and can be controlled by varying the input voltage using an autotransformer. The test rig is fitted by a load cell to measure the frictional torque generated in the contact zone between the rotating and stationary pins. Normal load was applied by means of weights attached to a loading lever. A counter weight is used to balance the weights of the loading lever, the loading block and the stationary specimen. A digital screen was attached to the load cell to detect the friction forces. Friction coefficient is determined by the ratio between the friction force and the normal load and wear is determined by measuring the scar diameter on the optical microscope.

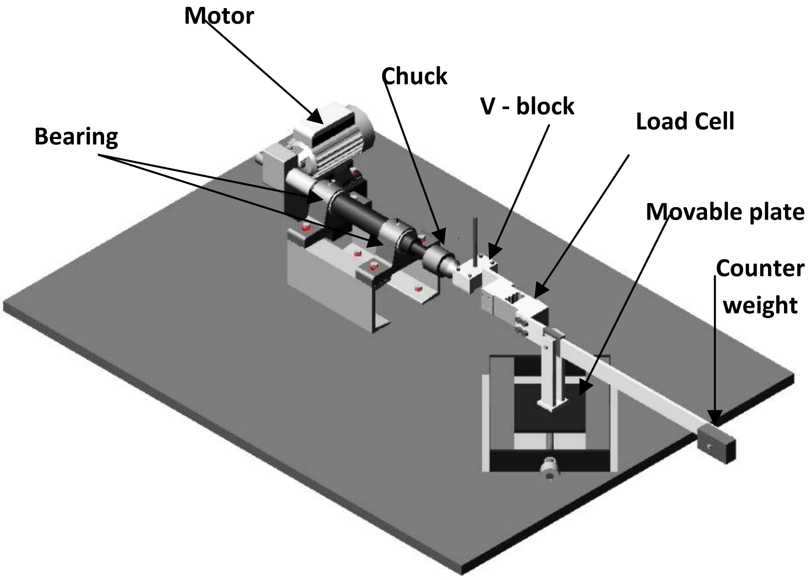

Fig. 1 Arrangement of the cross pin wear tester.

The Specimens were in the form of cylindrical with 15mm diameter and 160mm Length. The test specimens prepared from carbon steel with, Ultimate Stress, 746 MPa, yield stress, 547.1 MPa, modulus of elasticity, 9.5×10^3 MPa, surface roughness 0.8 µm. The tests were carried out at sliding velocity of 0.5 m/s and load of 10 N. The rotating specimens were greased before the test and further greasing was carried out every 30 second during the test. The test time was 5 minutes. The wear scar diameter was measured for the upper stationary pin using an optical microscope, Fig. 2, within an accuracy of ± 1 µm.

Fig. 2 Optical microscope.

Experiments were carried out at 25 °C using calcium based grease, the polymeric additives were polytetrafluoroethylene (PTFE), polymethyl methacrylate (PMMA) and polyethylene (PE). They were used as thickener for calcium-based grease at concentration of 5, 10 and 15 wt. %.

RESULTS AND DISCUSSION

Figure 3 show the relation between friction coefficient and percent of polymer content. It can be noticed that, the Friction coefficient decrease with increasing polymer content, For PMMA, friction coefficient show the lower values of friction coefficient because of PMMA particles is height strength then this particles rolling in the contact area. The PTFE, help for decreasing friction coefficient with increasing additive content. This behavior closed on the fact of lower friction value for PTFE particles. Add PE particles to calcium grease show significant reduction in friction coefficient.

Figure 4 shows the relation between friction coefficient and polymer content when negative electric current was applied. It can be noticed that, the friction coefficient increase with increasing PE and PTFE content. This behavior related to the polarity of PE and PTFE is negative and apply by external source of negative electric current shows significant increase of negative polarity, when sliding against positive steel surface the attractive action was show hence the friction coefficient increase. On other side the polarity of PMMA is positive, at sliding between steel surfaces the dissonance was come. The friction coefficient decrease with increasing polymer content up to 10% then increase at 15% polymer content.

Effect of negative electric current on friction coefficient for calcium based grease filled by polymeric particles, was shown in Fig. 5. It can be noticed that, the friction coefficient increase with increase additive content. Increasing electric current to -3.0 volt show more effect on increasing the negative polarity of polymeric compared to -1.5 volt. The polarity of polymers increased the adhesion force between steel surfaces. Then the friction coefficient increase.

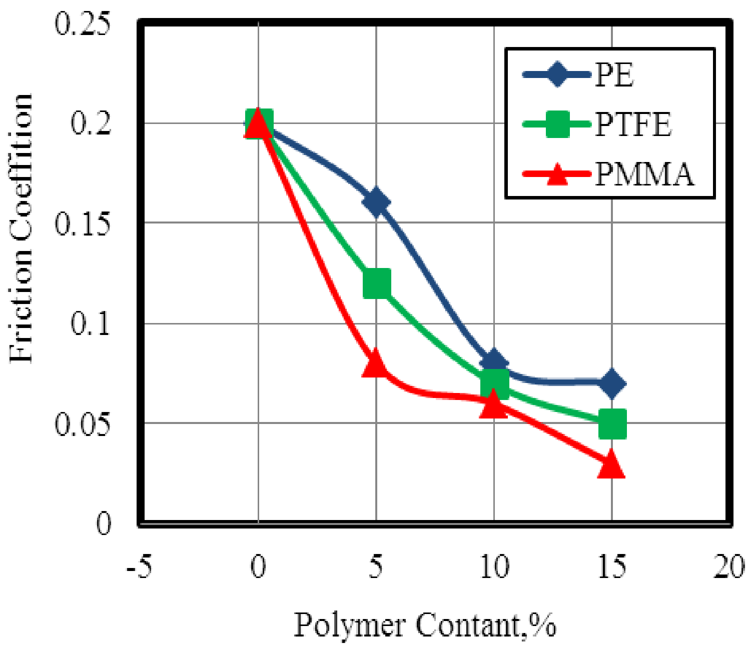

Fig. 3 Effect of polymers content filling calcium grease on friction coefficient.

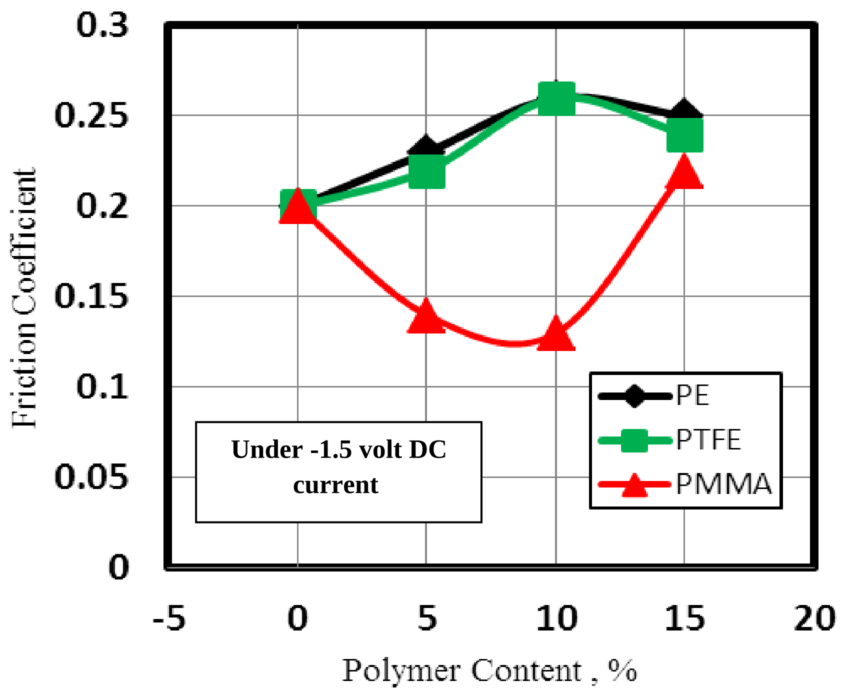

Fig. 4 Effect of polymers content filling calcium grease on friction coefficient under - 1.5 volts DC current.

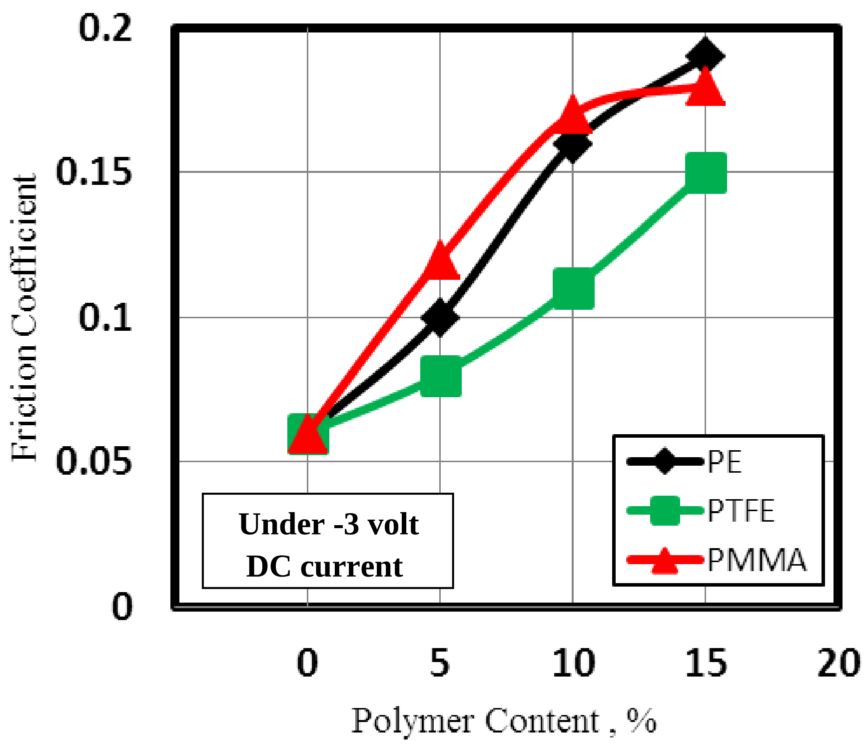

Fig. 5 Effect of polymers content filling calcium grease on friction coefficient under - 3 volts DC current.

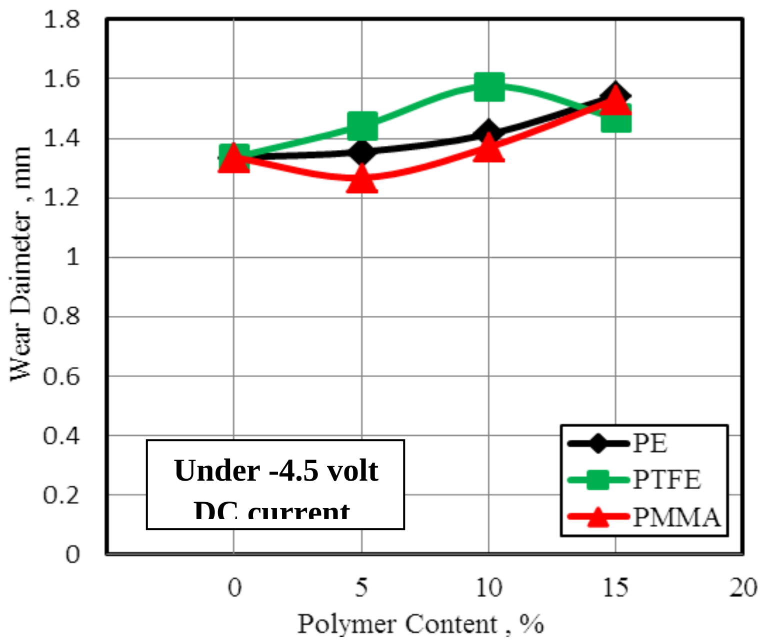

Fig. 6 Effect of polymers content filling calcium grease on friction coefficient under – 4.5 volts DC current.

Figure 6 shows the relation between friction coefficient and polymer content; under apply negative volt electric current was - 4.5 volt. It can be noticed that friction coefficient increase with increasing additive content up to 10% the decrease at 15 % polymer content. Increasing negative electric current to - 4.5 volt shows slightly increase in friction values compared to -3.0 volt. Friction coefficient increases to maximum values at 10 %, this behavior related to interaction between polymer particles and steel surface.

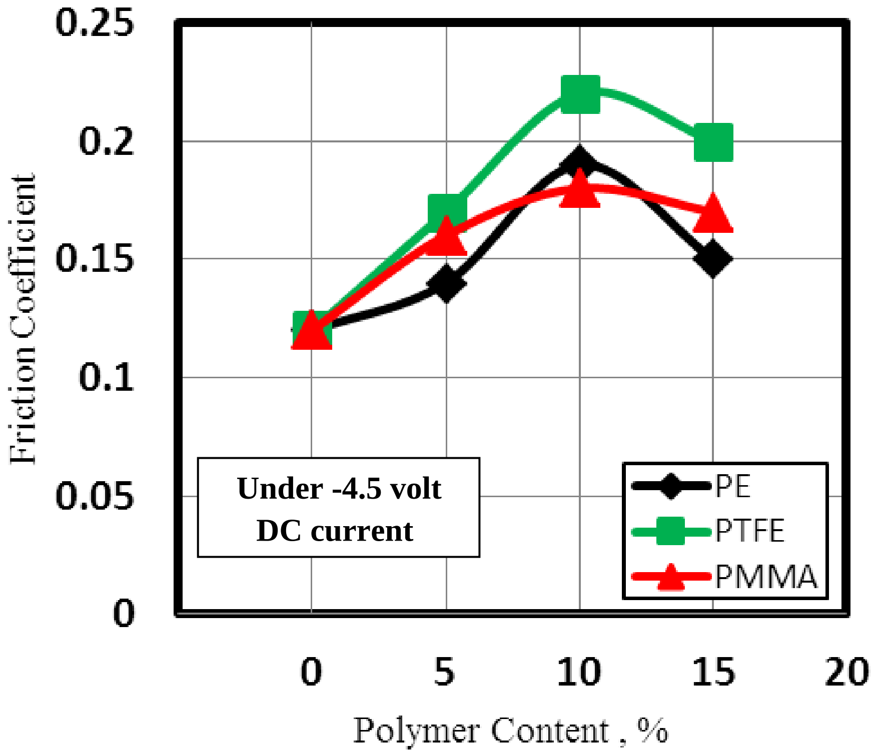

Fig. 7 Effect of polymers content filling calcium grease on friction coefficient under -4.5 volts DC current.

The relation between friction coefficient and polymer content under apply negative electric current -6 volt, shows in Fig. 8. It can be noticed that, friction coefficient increase with increase additive content. The maximum friction coefficient value observed at 15 % polymer content for PTFE and PMMA, while the values of friction coefficient decrease for PE. Increasing in friction coefficient values related to the location of each polymer in triboelectric series and the ability of each polymer to change the polarity.

Figure 9 shows the relation between wear diameter and polymer content. It can be noticed that, the wear diameter decreased with increasing additives content. Wear diameter show the lowest value for PMMA particles, this behavior related to the rolling action of PMMA particles, this action separated the contact surface and smooth contact between surfaces. The maximum wear diameter was 1.1 mm observed at pure condition, while the minimum value was 0.92 mm at 15 % PMMA.

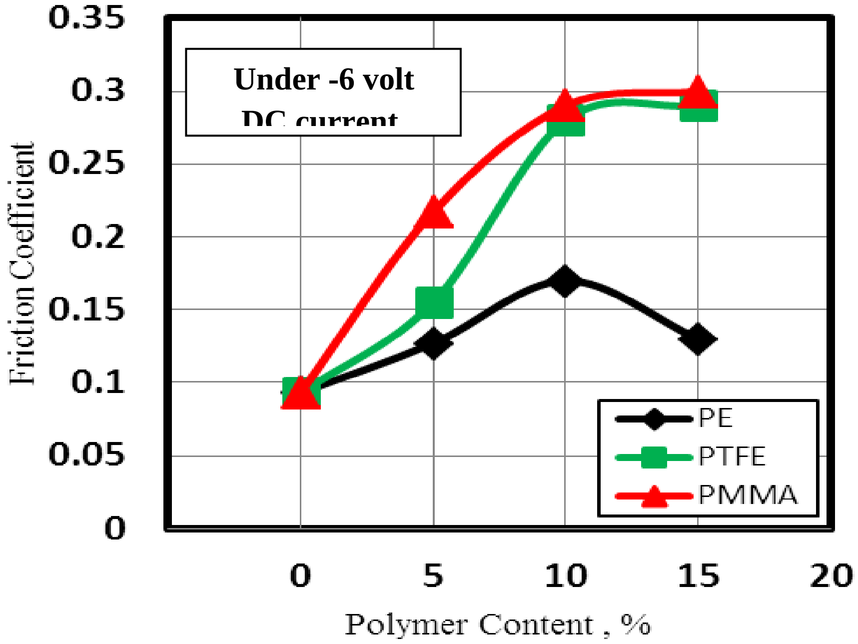

Fig. 8 Effect of polymers content filling calcium grease on friction coefficient under -6 volts DC current.

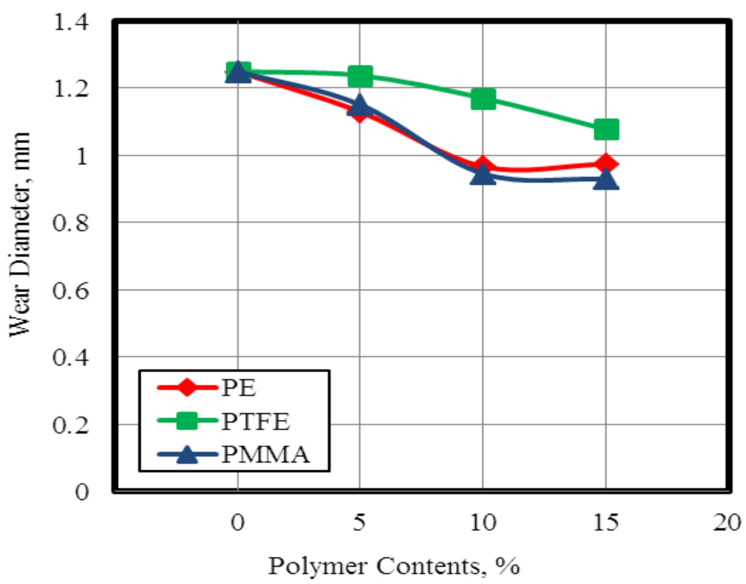

Fig. 9 Effect of polymers content filling calcium grease on wear diameter.

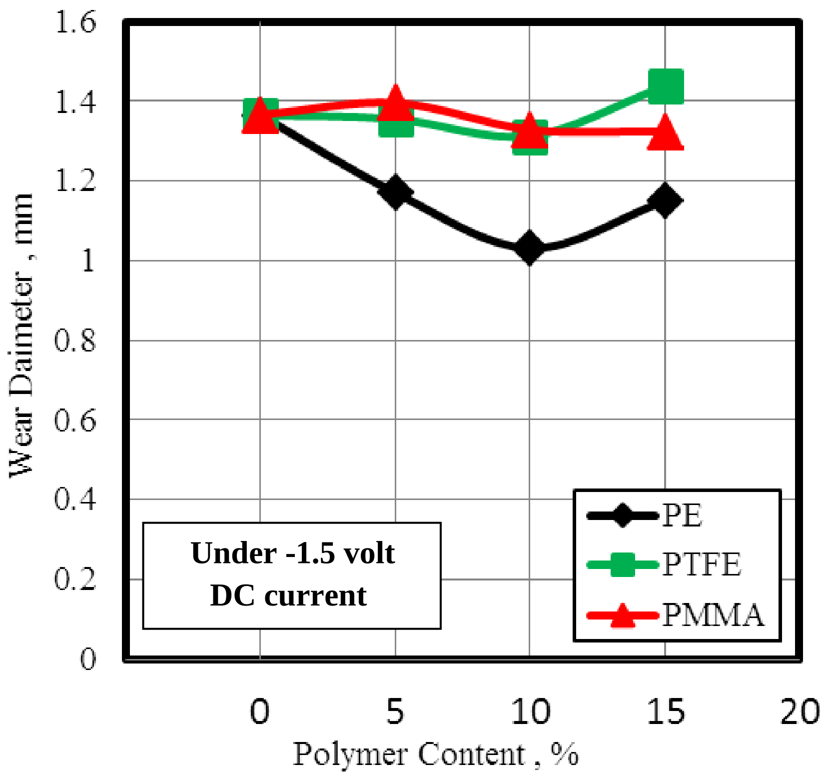

Fig. 10 Effect of polymers content filling calcium grease on Wear diameter under - 1.5 volts DC current.

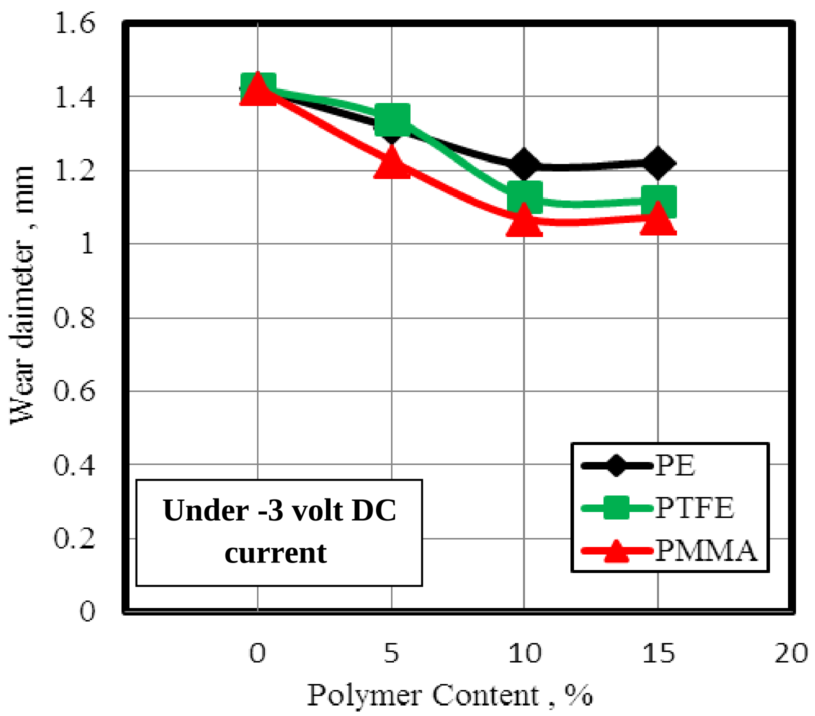

Fig. 11 Effect of polymers content filling calcium grease on Wear diameter under - 3 volts DC current.

Figure 10 shows the relation between wear diameter and polymer content, under negative volt DC current was - 1.5. It can be noticed that, the wear diameter slightly decreased with increasing additives content. The PE particles show the lowest wear value; it seems that to the adhesion force of PE into steel surfaces is high to stick on the steel surface so protect it from abrasion action. The minimum value of wear diameter was 1.0 mm noticed at 10 % PE.

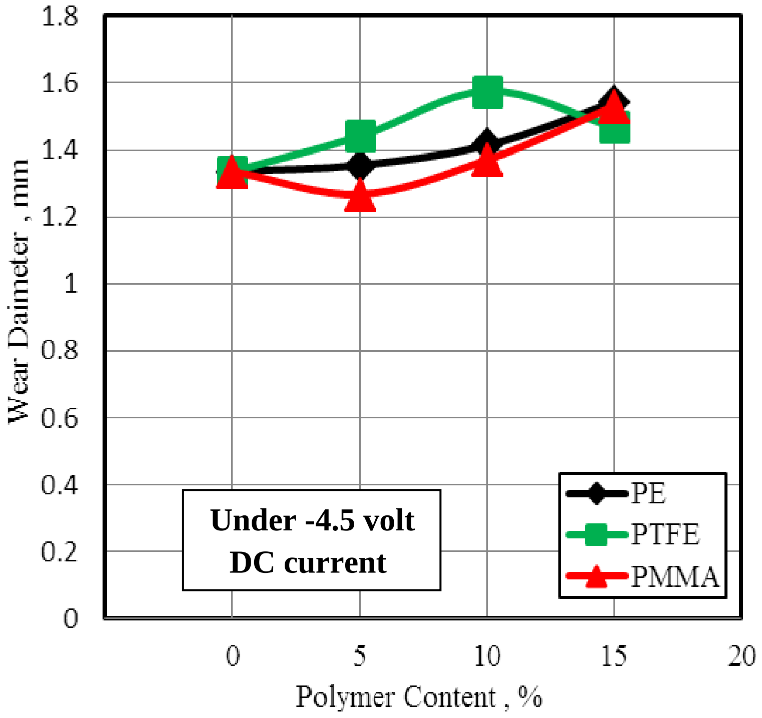

Fig. 12 Effect of polymers content filling calcium grease on Wear diameter under - 4.5 volt DC current.

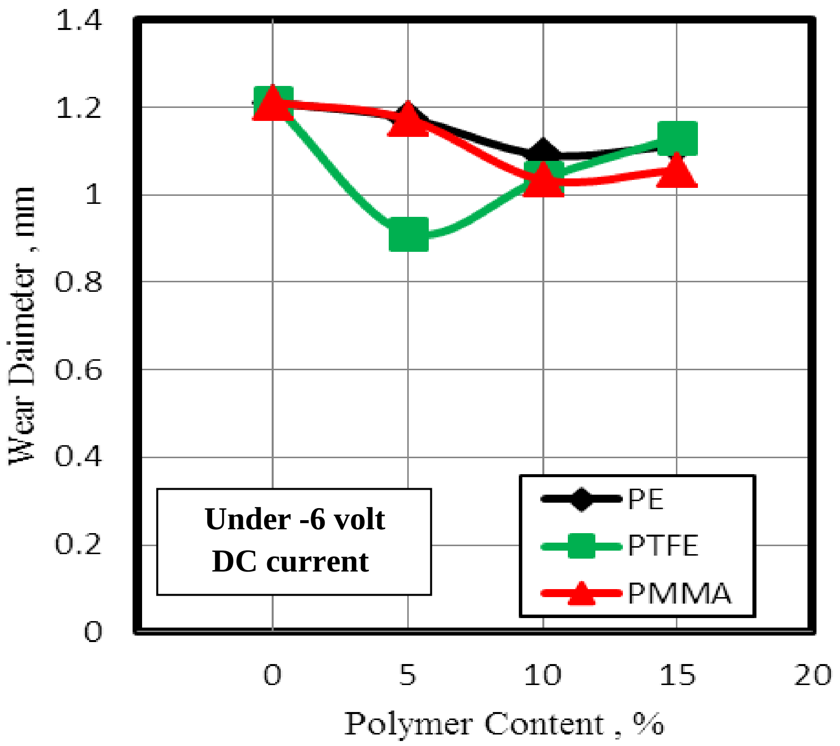

Fig. 13 Effect of polymers content filling calcium grease on Wear diameter under - 6 volt DC current.

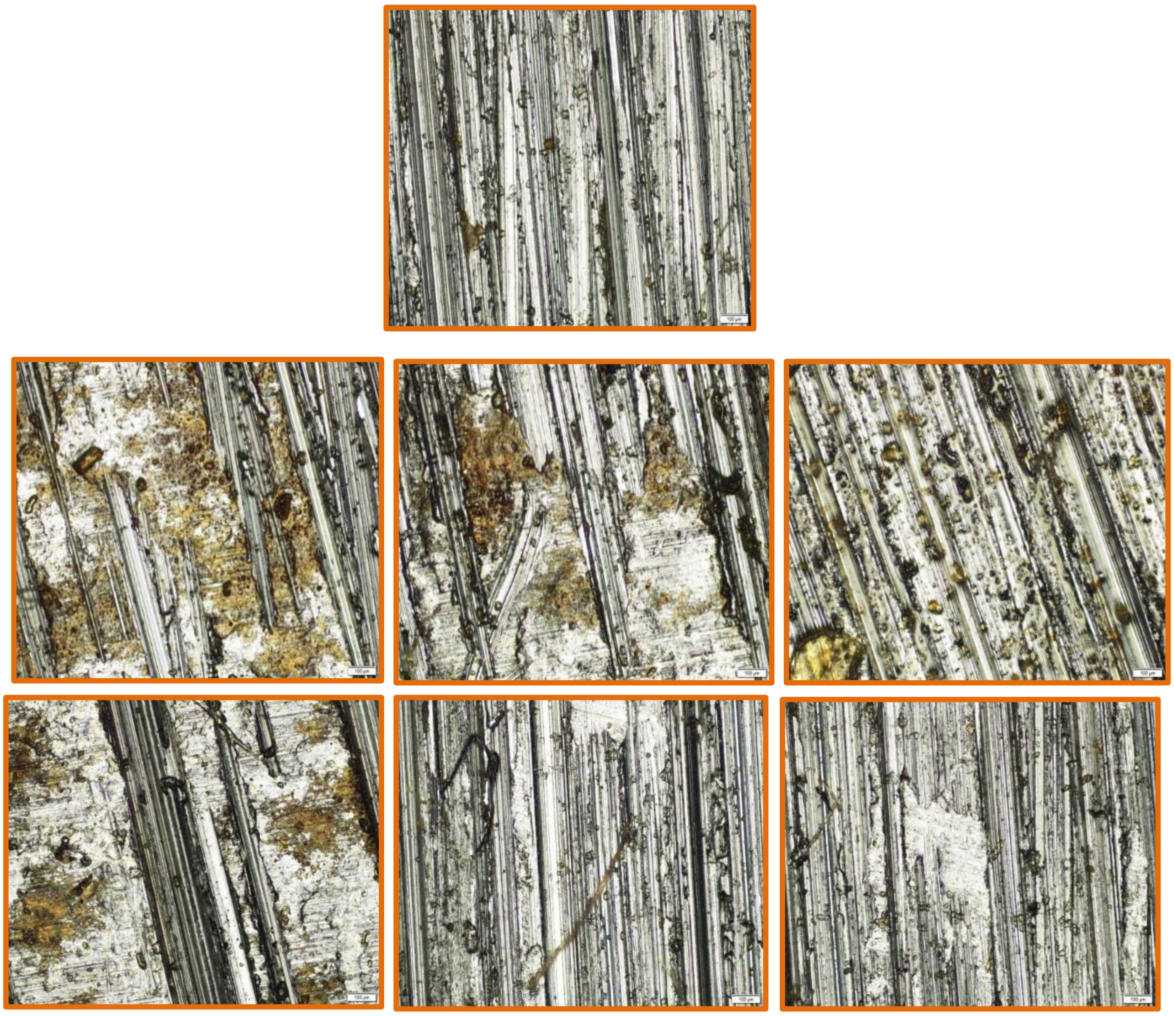

Figure 14. Microscopic images of the worn surfaces of steel surface lubricated by grease dispersing by polymeric additives PE, PTFE and PMMA. Under negative DC current.

The relation between wear diameter and polymer content with negative volt DC current - 3.0 was shown in Fig. 11. Generally, it can be noticed that, the wear diameter decreased with increasing additives content. PMMA show the lower wear diameter. It seems that the rolling action between PMMA and steel surface. Apply external current on steel surface increase the negative polarity of PTFE particles then the attractive force between particles and steel was increasing.

Increasing negative external current to - 4.5 volt DC current was shown in Fig. 12 show. It can be noticed that, the wear diameter increases with increasing polymer content. This behavior related to more attractive between two surfaces under the effect of polymer additives. The wear diameter decrease at grease filled by 5% PMMA, this behavior related to the rolling action between contact surfaces.

Figure 13 show the relation between wear diameter and polymer content. It can be noticed that, the wear diameter decreased with increasing additives content. The PTFE show the lowest values of wear diameter, this behavior related to stick particles on both surface and covered it between the contact surfaces. The contact between PTFE particles show relatively low shear strength and increase wear resistance. The negative electric current

show remarkable effect on reduction the wear diameter, the polarity of PTFE is negative with apply external negative current the adhesion between steel surface and PTFE particles was increase.

CONCLUSIONS

1. The effect of polymeric particles dispersed in grease depends on the ability of polymeric particles to adhere into the contact surfaces.
2. Friction coefficient with apply external negative current increase with increasing polymer content at the polymer have negative polarity.
3. PMMA shows the significant effect on reduction friction coefficient and wear at negative current.
4. It can be recommended that selection of polymeric materials based on the polarity and location in tribo-electric series, for dispersing greases.

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