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Oil Dispersed Polymers Characteristics under External Voltage, Tribological and Corrosion Variables

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Abstract

The present work illustrated the effect of three types of oil-dispersed polymers; low-density polyethylene (LDPE), high-density polyethylene (HDPE) and Polysulphide rubber (PSR) on the abrasive sliding wear of stainless steel. Both friction coefficient and wear scar diameter obtained at various applied external voltage, and polymers weight percentage at 0.5 m/s sliding velocity, 20°C and 5N applied load. The samples immersed in H_2SO_4 medium at test period ranges from 10 to 50 days. The effect of the corrosion medium carried out and investigated at various values of the external voltages. The wear resistance related to the total mass loss measured and the worn surfaces analyzed by optical microscope. The application of external voltage increases both friction coefficient and wear scar diameter. At various applied external voltage and polymer contents, the wear scar diameter and friction coefficient trends of PSR has a lower values followed by both LDPE and HDPE trends respectively. Negative applied voltage has lower scar diameter while positive voltages has lower friction coefficients except at -4 Volt.

Keywords: External voltage; Abrasive wear; Corrosion resistance; Polymers; Scar wear diameter; Friction coefficient and optical microscope

Introduction

Al-Ghamdi et al. [1] discussed the effect of sliding mode and medium on the electrostatic charge and corrosivity of epoxy/aluminium reinforced composites. Al-Gamdi et al. [2] discussed the effects of reinforcement/matrix interactions on the tribological and corrosive properties of aluminium/epoxy composites and the effect of abrasive wear variables and aluminium weight % on the epoxy/aluminium composite characteristics. Abdel-Jaber et al. [3] found that when electric voltage applied on the sliding steel surfaces, friction coefficient and wear decreased with voltage increasing. Addition of polymeric particles into oil caused significant friction increase in the presence of applied voltage, while wear significantly decreased. Hu et al. [4] measured electrostatic potential during friction between two kinds of stainless steels. Results showed a direct correlation between electrostatic potential and friction coefficient. Abdo et al. [5] examined the effect of applied load and relative velocity on the stick-slip amplitude under the effect of various excitation frequencies using pin-on-disc machine. Singh et al. [6] studied Electrostatic charging, discharging, and consequent surface modification induced by sliding dissimilar surfaces. Lin et al. [7] improved wear resistance because of the low ion energy and high ion-flux bombardment. Abdel-Jaber et al. [8] investigates the effect of magnetic field on the friction coefficient displayed by sliding surfaces lubricated by paraffin oil and dispersed by different lubricants additives. Friedrich et al. [9] Scratch tests carried out on various high performance polymers, including polybenzimidazole (PBI), polyparaphenylene (PPP), polyetheretherketone (PEEK), and polyimide (PI). In addition, the coefficient of friction considered as a possible measure to differentiate between the various materials tested. Abo-Dief et al. [10] developed polymer usage in the concrete composites for building and repairing concrete structures in KSA and Al-Ghamdi et al. [11] explored reinforced epoxy composites characteristics. Wasem et al. [12] found that contact electrification between metals and insulators lead to dramatic transient charge transfer phenomena during sliding contact. The high velocity events coincide with falling flateral forces and high current signals. Ahmed et al. [13] determined the electric static charge generated from sliding of rubber sole against epoxy floor reinforced by copper wires while Al-ghamdi et al. [14,15] discussed the effect of wool, acrylic and nylon textiles on the electrostatic charges and friction coefficient. The aim of the present work is to investigate the effect of the application of external voltage on both friction coefficient and scar wear diameter of polymer/SS. The corrosion test carried out at various sliding velocity, distance an immersion time.

Experimental Work

Test rig

Experiments carried out using cross pin wear tester shown in Figure 1. The device consists of rotating and stationary pin of 20 mm diameter and 160 mm long. The pin attached to a chuck that mounted on the main shaft that driven by DC motor (300W and 250V). Normal load applied by means of weight attached to a loading lever. A counter weight used to balance the weights of the loading lever, the loading block and the stationary specimen. A digital screen attached to the load cell to detect the friction forces. The friction coefficient determined by the ratio between the friction force and the normal load. The wear is determined by measuring the scar diameter on the optical microscope shown in Figure 2.

Transformer-coupled split-rail: Both positive and negative output voltages derived with a transformer-coupled split-rail design according to Nowakowski [16]. First, the negative output voltage implemented

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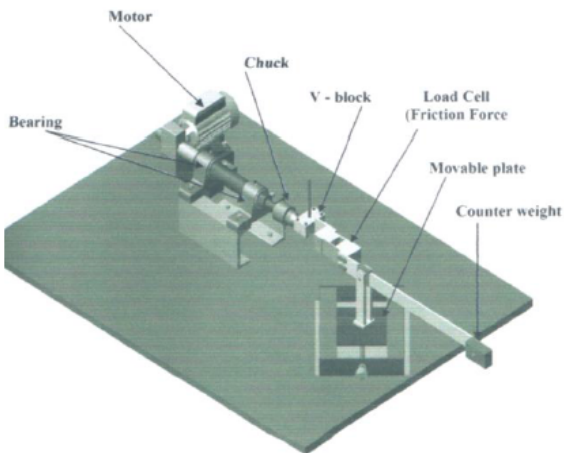

Figure 1: Wear test rig.

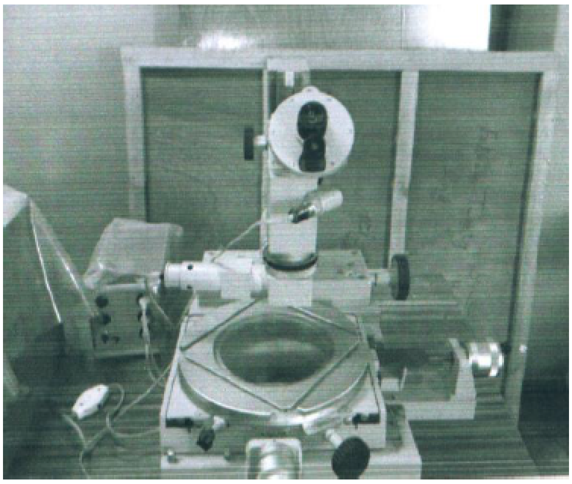

Figure 2: Optical microscope.

Figure 3: Sensitive electronic balance.

and the dc-dc converter configured to regulate the positive voltage and use the secondary winding to regulate the negative output. When a coupled transformer is used, the transformer's primary-side output voltage reflected to the secondary-side. The polarity of the primary and secondary windings is opposite to configure a positive secondary-side voltage from a negative primary-side voltage. The circuit demonstrates transformer coupled split-rail operation with dual outputs providing ± 18 V at up to 100 mA. The –18 V used as the ground reference for the converter in this application. Other output voltages are possible by changing the values of the converter's resistor divider.

Test specimens

Three cylindrical specimens of 20 mm diameter and 160 mm length used for each abrasive wear test condition and the mean result of them taken. Three types of polymers are used; low density polyethylene (LDPE), High-density polyethylene (HDPE) and Polysulphide Rubber (PSR).

Abrasive wear-test conditions

The wear test carried out at 0.5 m/s and 5 N load. The rotating specimens greased before the test and every 20 seconds during the test. The test time was 5 minutes. Experiments carried out at room temperature using lithium based grease with molybdenum disulphide (MoS2), graphite (C) and copper solid additives thickener for three polymer types that covers steel specimens with 5% to 25% wt.%. External voltage ranging from 0 to ±10.0 volt applied.

Corrosion test conditions

H_2SO_4 (0.2 N) solution was employed to find out its effect on the corrosion wear of the polymer/steel specimens, using sensitive ballistic electronic sensitive balance (Figure 3) to measure the weight of the specimens before and after immersion. The corrosion wear test carried out on test specimens at immersion time ranging from 10 to 50 days, sliding velocity ranging from 0.5 m/s to 8.0 m/s and sliding distance of 15 m, 20 m, 25 m and 30 m.

Results and Discussion

Effect of external voltage on friction coefficient

The effect of both polymers wt.% and external voltage on the friction coefficient is shown in Figure 4. At no voltage, it is clear that as the polymer content increases, the friction coefficient increases in all polymer types in agreement with Hongjun et al. [17]. They showed that the friction coefficient can be obviously affected by the presence of positive voltages (the voltages in which the lower specimen was used as cathode were called positive voltages or "+" voltages, while the voltages with a reverse polarity were called negative voltages or " - " voltages). A+ 20 D. C. V voltage can lead to a dramatic increase of friction coefficient by up to 200% [18,19]. Also, Abdel-Jaber et al. [3,20] showed that, for steel surfaces lubricated by oil, friction coefficient increased as the magnetic field increased due to the increase of the normal load caused by the magnetic force.

PSR has the lower friction coefficient followed by LDPE and HDPE respectively as shown in Figure 4a. Polyurethane rubber (PSR) has the lower friction coefficient due to its good wear resistance with moderate viscosity, high resistance to expansion and dissolving by organic solvents such as kerosene, gasoline, and lubrication oils.

When applying external voltage, the friction coefficient increases as shown in Figures 4b to 4f. It is clear that negative external voltage has higher effect on the friction coefficient on all voltage values except at -4 volt where the negative magnetic flux would increase the accumulation of the debris around contact asperities and cover steel surface that result in a lower wear and decreases friction coefficient.

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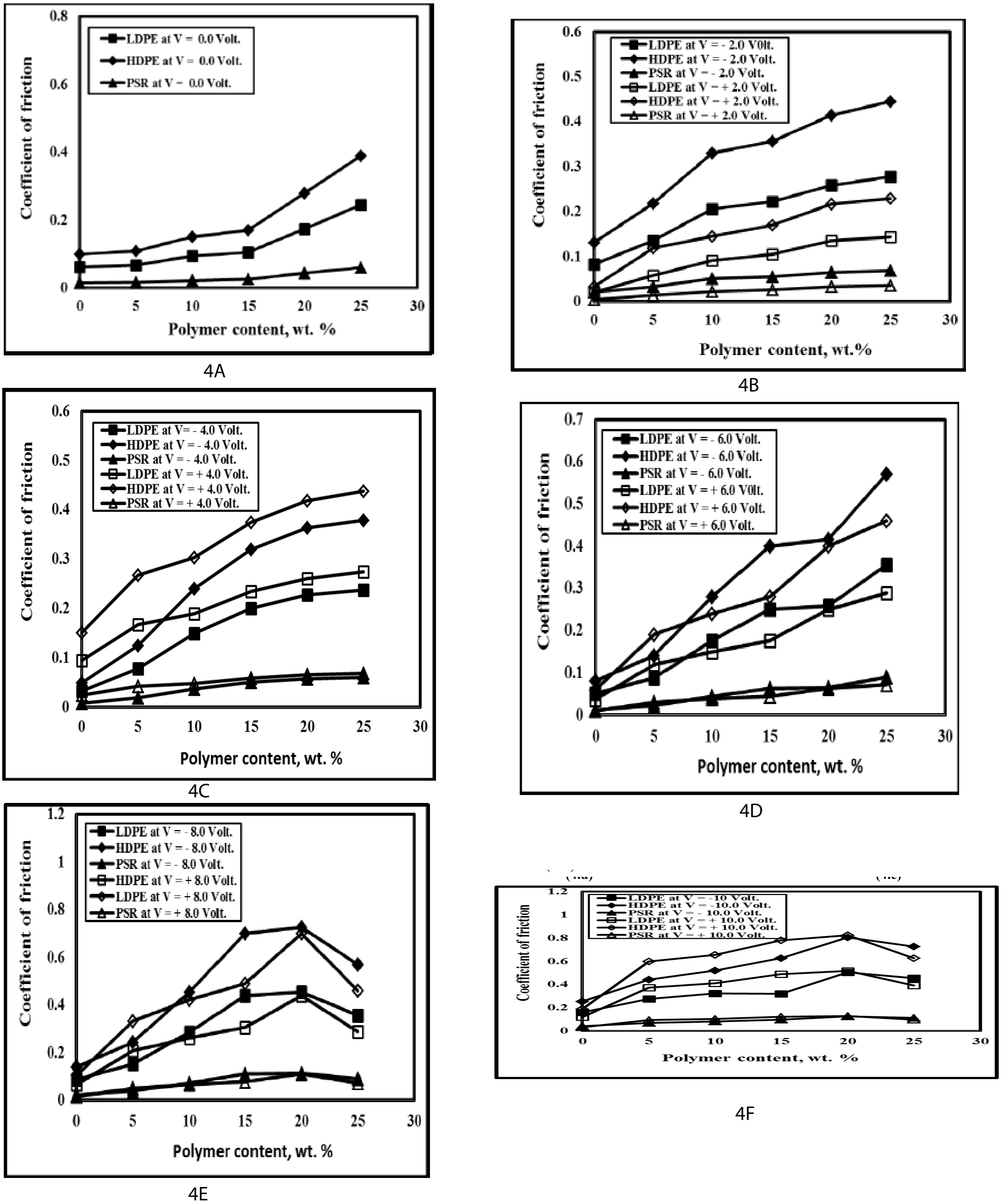


Figure 4: Variation of friction coefficient with polymer wt. % at 15.0 m sliding distance, 0.5 m/s sliding velocity and 5 N applied load.

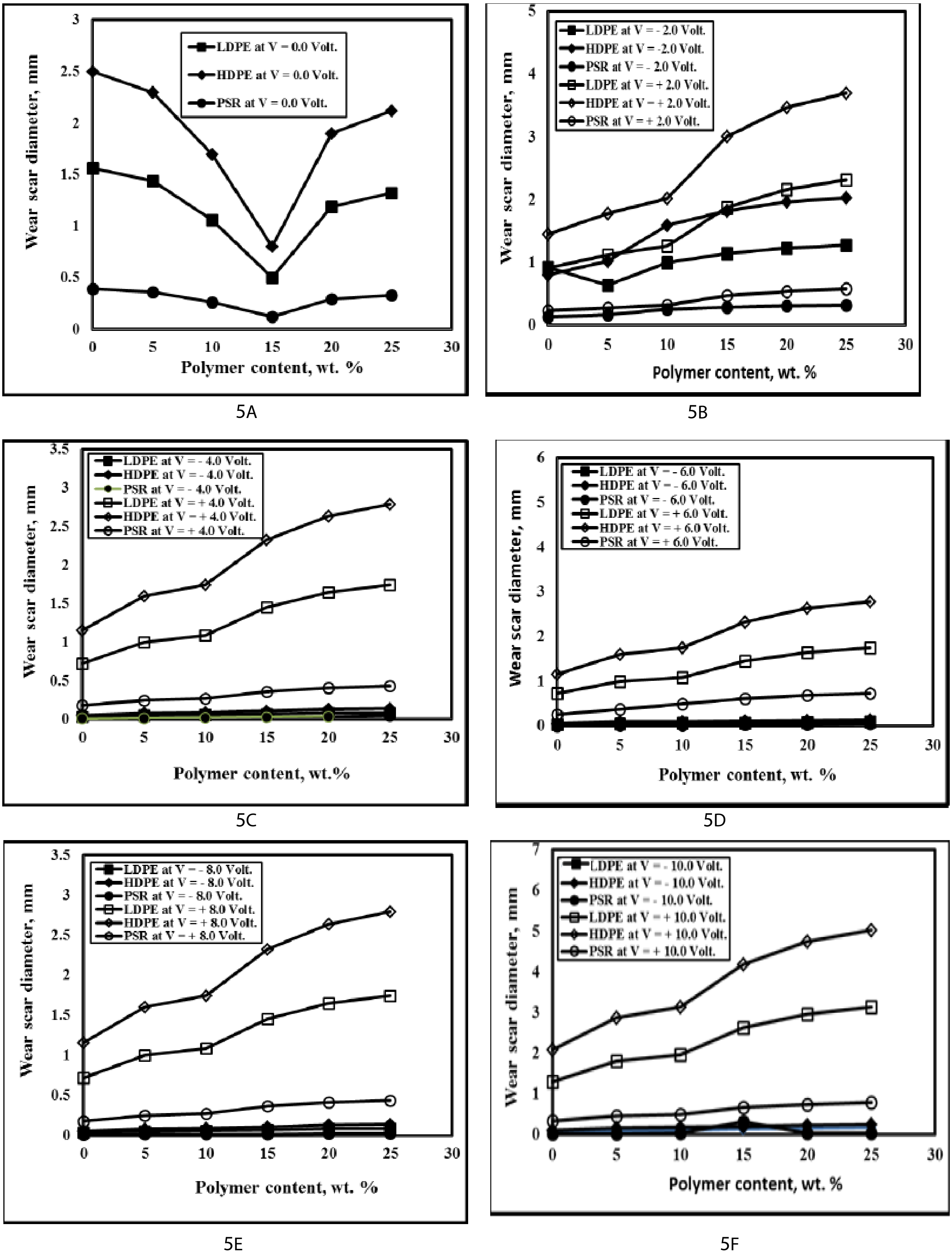


Figure 5: Variation of wear scar diameter with polymer wt. % at 15.0 m sliding distance, 0.5 m/s sliding velocity and 5 N applied load.

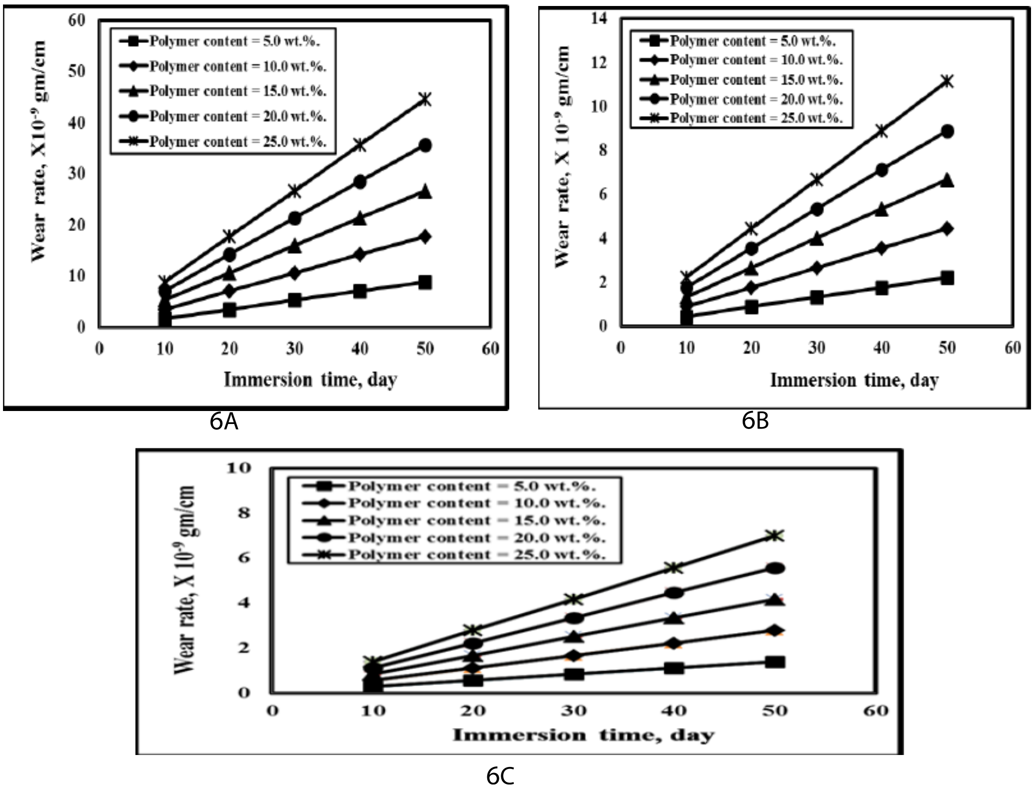


Figure 6: Variation of wear rate with immersion time at various polymer contents at 15.0 m sliding distance, 0.5 m/s sliding velocity and 5 N load.

At ±8.0 volt, 10.0 volt and 20% polymer wt. %, the magnetic field accelerated the reorientation of the oil molecules to be strongly adhered to the steel surfaces and the oil dispersed by polymer particles displayed the lowest values of friction coefficients in agreement with [4,17].

Effect of external voltage on wear scar diameter

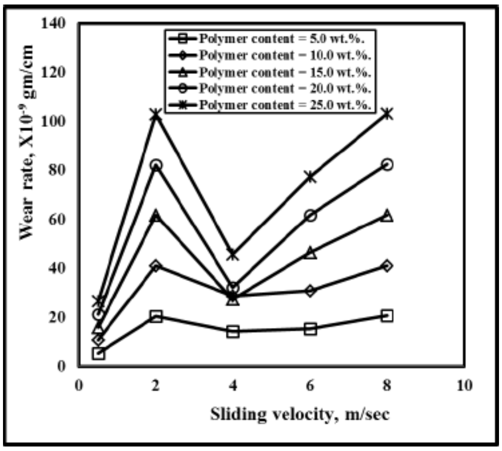
Figure 5 shows the relationship between polymer wt. % and wear scar diameter at external and no external voltages conditions. At no voltage, it is clear that as polymer content increases, the wear scar diameter decreases up to 15% polymer wt. % for all types of polymers. At polymer contents more than 15wt. %, an inflection occurs, and the wear scar diameter increases for all types of polymers as shown in Figure 5a. Also, it shown that HDPE has the higher scar diameter followed by LDPE and PSR respectively as represented before.

Figures 5b - 5f show that as the polymer wt. % increases, the wear scar diameter increases for all types of polymers, which means that both wear, and friction coefficient increases. While, Mohamed et al. [18] concluded that application of induction magnetic field decreased friction coefficient caused by the scratch of oil-lubricated steel. The decrease was significant for oil-lubricated steel. El-Zahraa et al. [19] concluded that under the effect of the magnetic field, friction coefficient showed significant increase. Magnetic field much affected the performance of oil dispersed by additives of electrical properties such as CMOC, DA and, C. PTFE particles dispersed in the oil much influenced by the magnetic field, where the lowest value displayed at the highest intensity. The same trend of friction decrease observed for PMMA particles dispersed in oil [20]. The positive external voltage effect higher compared to the negative external voltage effect. As the external voltage increases, the accumulation of polymers debris decreases due to its melting condition around contact asperities and clean the steel surface and the abrasion increases. This could increase the scar wear diameter. At + 8 and +10 volt, the particles fill the pits and valleys in the roughness of the sliding surface, thereby increasing the contact area and providing a reservoir of solid lubricant. This performance enhanced if the particles are strongly adhered to the contact area and the shear strength of the solid lubricant became less than the adhesion to the substrate. In addition, a film of solid lubricant built up of sufficient thickness to cover the contact area completely, and sliding takes place between two smooth oriented layers of lamellar solid lubricant that leads to lower wear and lower scar diameters as shown in Figures 5c to 5f.

Corrosion test

Hongjun et al. [21] concluded that the use of polymer micro/nanocomposites in electrical engineering is very promising and further research work be accomplished in order to diversify the polymer composites matrices and to improve their properties.

Figure 6 shows the relation between immersion time in 0.2 N H_2SO_4 and wear rate at various polymer contents. As the immersion time increases, the wear rate increases due to the aggressive effect of the acid. The wear rate trends of HDPE has higher wear rates followed by LDPE and PSR respectively due to that PSR contains polysulphide rubber which has good resistance for chemical solutions. After immersion, a chemical solution react with polymer, and the strength values decreases due to the defects that lead to an increase in the quantity of the absorbed solution, which leads to swelling and removal of the polymer layer that leads to higher wear rates. As the immersion time increases, the mechanical strength of polymers reduced by the plasticization of polymer surface because of the permeation of H_2SO_4 solution. Then the fracture toughness will decrease, and as the fracture toughness is proportional inversely with wear rate, then there is an increase in wear rates as noticed in Figure 6.



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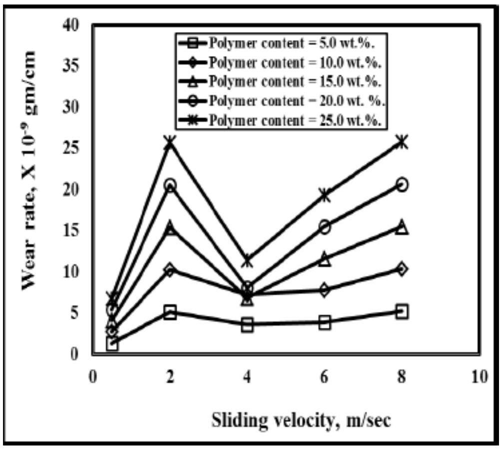

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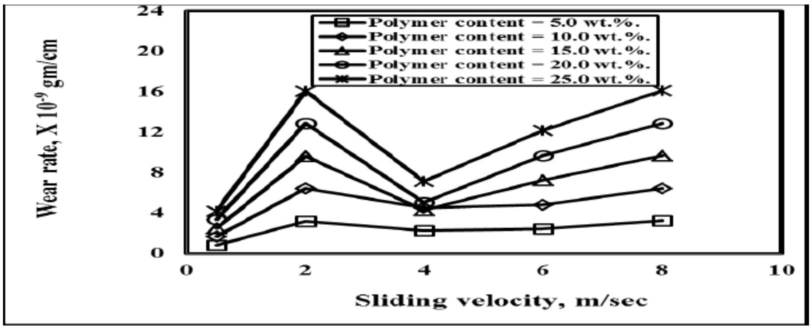

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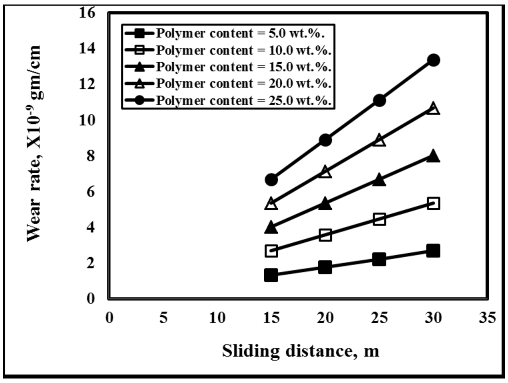
Figure 7: Variation of wear rate with sliding velocity at various polymer contents at 30 day sliding distance, 15 m sliding distance and 5 N.



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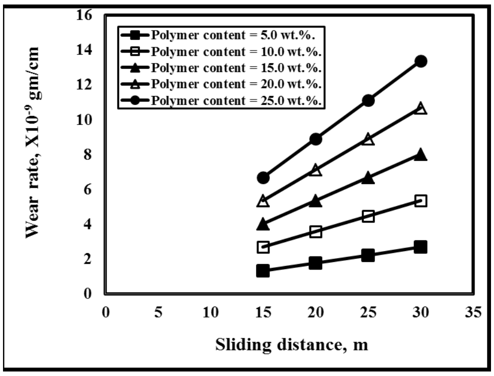

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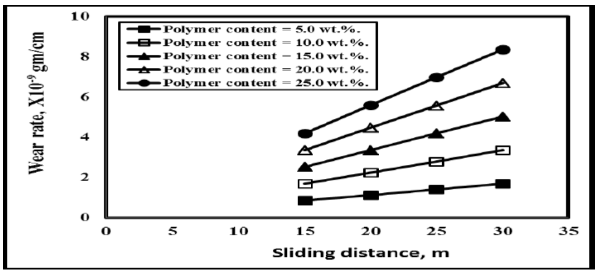

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Figure 8: Variation of wear rate with sliding distance at various polymer contents at 30 day sliding time, 0.5 m/s sliding velocity and 5 N applied load.

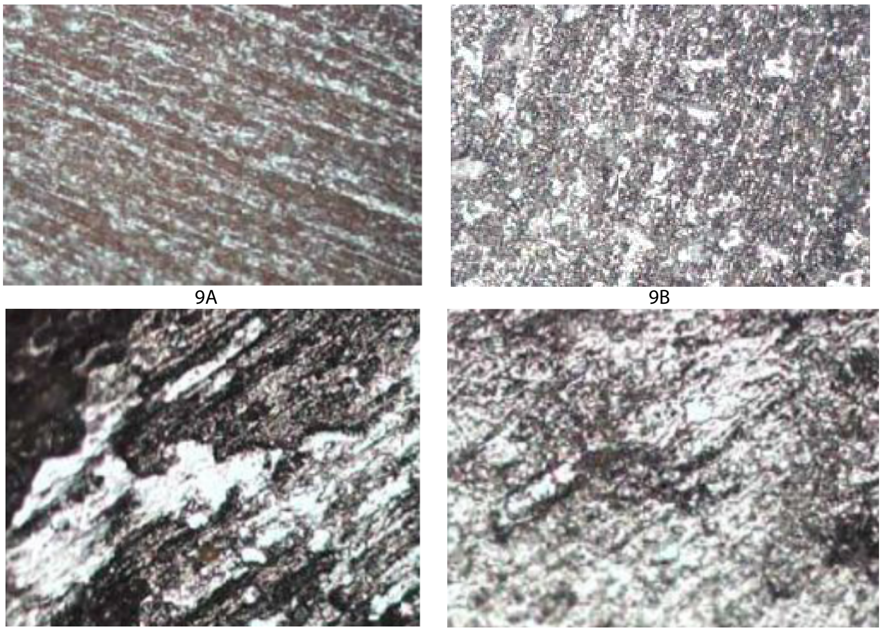

Figure 9: PSR/Steel specimens, 30 days, 0.5 m/s sliding distance and velocity and 5 N load, X300.

Effect of sliding velocity

The effect of sliding velocity on the wear rate at various polymer contents shown in Figure 7. The variation of sliding velocity is complex because the mechanism of wear include deformation and interfacial components, transfer also play an important role. For these reasons, no unique trend between wear rate and sliding velocity is to be expected and experiments show, that wear rate/sliding velocity relationships exhibiting maxima, minima or little variation can all be obtained, depending on the materials involved and the precise conditions of sliding imposed [22-30].

There are generally two regions, the low velocity region and the high velocity region. In the low velocity region (0.5–2.0 m/s) the wear rate tends to decrease, the temperature rise at the contact spot is not significantly high, the frictional stress is not thermally activated, and wear mechanism appear as initial quasi-abrasive wear. Therefore, prolific powdery worn debris easily observed that resist surface wear characteristics in agreement with Mohamed et al. [18].

In the high velocity region (4.0–8.0 m/s), the wear rate tends to increase with rising velocity since the temperature rise becomes significant, so that a deformation-frictional wear process can be thermally activated, and wear mechanism appears as adhesive wear. In addition, the PSR wear rate trends found lower followed by LDPE and HDPE trends respectively.

Effect of sliding distance

The effect of sliding distance on the wear rate at various polymer compositions shown in Figure 8. The results reveal that the wear rate increases with increasing sliding distance during the immersion in H_2SO_4. As the sliding distance during immersion increases, the surface-layer which affected by chemical solution will increase, and this means that much material will be lost as wear debris, and this leads to increase in wear rates. In addition, the wear rates values of PSR trends found lower followed by LDPE and HDPE respectively.

Metallographic examination

Figures 9a and 9b illustrate PSR test specimens before wear and Figures 9c and 9d after the wear test of 5 and 25 polymer wt. %. The appearance of grinding lines noticed.

Figure 10 shows the effect of corrosion test on PSR samples at both 5 wt.% (Figures 10a, 10b and 10c) and 25 wt.% (Figures 10d, 10e and 10f) at 10, 30 and 50 immersion time (days) respectively. It is clear that the H_2SO_4 solution interacts with the specimen's surface and makes it weak, damaged and changes their roughness with immersion time.

Conclusions

The following conclusions can be obtained from the above results:

1. The application of external voltage increases both friction coefficient and wear scar diameter in agreement with [28].
2. Friction coefficient of polymers/steel increased under a negative voltage, while the wear scar diameter increased under positive voltage.
3. As the polymer wt.% increases, both friction coefficient and wear scar diameter increases.
4. At various applied external voltage and polymer contents, the wear scar diameter trends of PSR has a lower scar diameter followed by both LDPE and HDPE trends respectively. Negative applied voltage has lower scar diameter compared to the positive applied voltage for all applied polymers.
5. At various applied external voltage and polymer contents, the friction coefficient trends of PSR has lower values followed by both LDPE and HDPE trends respectively. Positive applied voltage has lower friction coefficient compared to the negative applied voltage for all applied polymers except at V= -4 Volt.
6. At various polymer contents, the sliding velocity has the higher wear rate values followed by immersion time and sliding distance respectively.

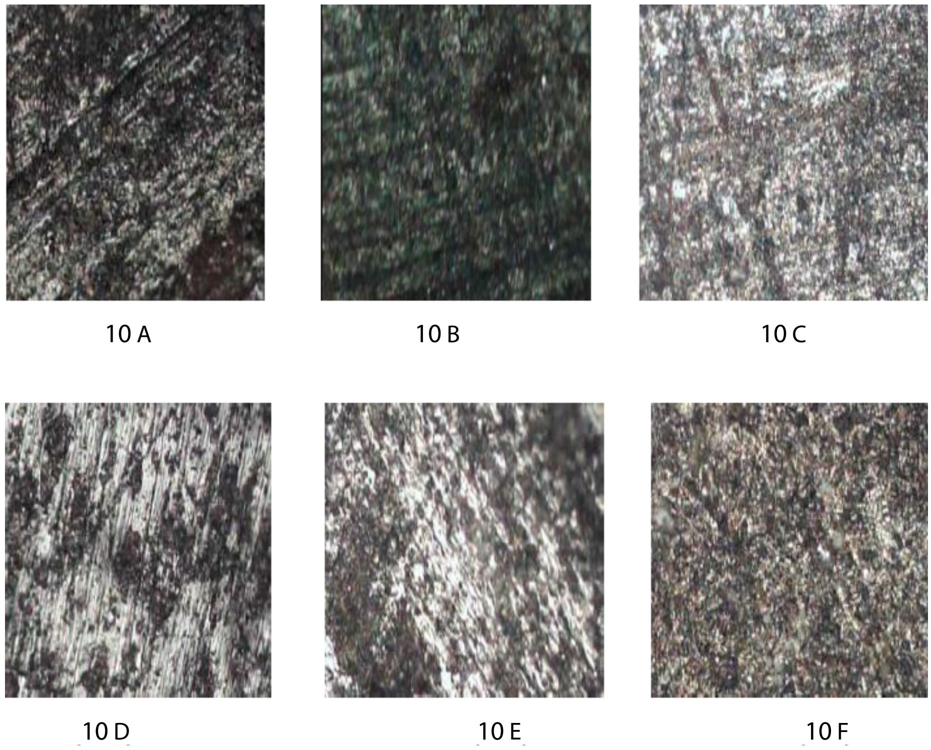

Figure 10: Wear specimens after corrosion, 0.5 m/s sliding velocity and 5 N load, X300.

References

1. Al-Ghamdi S, Al-Zahrani FA, Abo-Dief HM, Mohd AT (2013) Effect of sliding mode and medium on the electrostatic charge and corrosivity of epoxy/aluminium reinforced composites, The 13th AES-ATEMA Int. Conf., Montreal, Canada, p. 51-60.
2. Al-Gamdi SA, Al-Zahrain FA, Abo-Dief HM, Mohd AT (2013) Effects of reinforcement/matrix interactions on the tribological and corrosive properties of aluminium/epoxy composites, the 2013 (ICMAT-2013) Nanjing, China 1-10.
3. Abdel-Jaber GT, Mohamed MK, Ali WY (2014) Effect of magnetic field on the friction and wear of polyamide sliding against steel, Materials Sciences and Applications p: 46-53.
4. Hu S, Zhang Y, ShaoT (2014) Study of electrostatic potential induced by friction. Proceedings ESA Annual Meeting on Electrostatics: 1-11.
5. Abdo J, Tahat M, Abouelsoud AA (2009) The effect of excitation frequencies on stick-slip. 3rd Int Conf on integrity, reliability and failure, Porto/Portugal p. 1-8.
6. Singh SV, Kusano Y, Morgen PK, Michelsen PK (2012) Surface charging, discharging and chemical modification at a sliding contact. J of Applied Physics 111.
7. Lin J, Moore JJ, Sproul WD, Mishr B, Wu Z, et al. (2010) The structure and properties of chromium nitride coatings deposited using dc, pulsed dc and modulated pulse power magnetron sputtering, Surface & Coatings Technology 204: 2230-2239.
8. Abdel-Jaber GT, Mohamed MK, Al-Osaimy AS, Ali WY (2013) Effect of magnetic field on the performance of lubricant additives. J Applied and Industrial Sciences 1: 25-31.
9. Friedrich K, Sue HJ, Liu P, Almajid AA (2011) Scratch resistance of high performance polymers Tribology International 44: 1032-1046.
10. Abo-Dief HM, Ebrahim FFS, Altalhi AA, Mohamed AT (2015) Development of polymer usage in the concrete composites for building and repairing concrete structures in KSA. Int J Advanced Scientific and Technical Research (IJAST) 2: 43-52.
11. Al-Ghamdi SA, Al-Zahrani FA, Abo-Dief HM, Mohd AT (2013) Reinforced epoxy composites characteristics. J American Science 9: 297-303.
12. Wasem JV, Upadhyaya P, Langford SC, Dickinsona JT (2003) Transient current generation during wear of high-density polyethylene by a stainless steel stylus. J Applied Physics 93: 719-730.
13. Ahmed RA, Mustafa MM, Ali WY, Mohamed AT (2015) Electric static charge generated from sliding of rubber sole against epoxy floor reinforced by copper wires. J Electrostatics.
14. Al-Ghamdi SA, Abo-Dief HM, Mohamed AT (2014) Investigation of dielectric properties and frictional behavior of woven fabrics. The 17th International Conference on Advances and Trends in Eng Mats and their Applications, Montreal Canada p. 213-222.
15. Al-Ghamdi SA, Abo-Dief HM, Mohamed AT (2015) Effect of wool, acrylic and nylon textiles on the electrostatic charges and friction coefficients, 2015 AES-ATEMA International Conference, Toronto Canada: 87-98.
16. Nowakowski R (2012) Techniques for implementing a positive and negative output voltage for industrial and medical equipment. How 2 Power Dallas TX USA 1-6.
17. Hongjun J, Yonggang M, Shizhu M (1998) Effects of external DC electric fields on friction and wear behavior of alumina/brass sliding pairs. Science in China (Series E) 4: 617-625.
18. Mohamed MK, Alahmadi A, Ali WY, Abdel-Sattar S (2012) Effect of magnetic field on the friction and wear displayed by the scratch of oil lubricated steel. Int J of Eng & Technology 12: 137-143.
19. El-Zahraa FI, GT Abdel-Jaber, GT Khashaba MI, Ali WY (2015) Friction coefficient displayed by the scratch of epoxy composites filled by metallic particles under the influence of magnetic field, materials sciences and applications 6: 200-208.
20. Abdel-Jaber GT, Mohamed MK, Al-Osaimy AS, Ali WY (2013) Effect of magnetic field on the performance of lubricant additives. J applied and industrial Sciences 1: 25-31.
21. Hongjun J, Yonggang M, Shizhu W (1998) Effects of external DC electric fields on friction and wear behavior of alumina/brass sliding pairs. Science in China (Series E) 4: 617-625.
22. Alsema DH, Hulstc RV, Stachd EA, Duggere MT, De Hossonc JTM (2010) Wear mechanisms and friction parameters for sliding wear of micron-scale polysilicon sidewalls. Sensors and Actuators-A 163: 373-382.

23. Hongjun J, Yonggang M, Shizhu W, Hong J (1999) Effects of external electric fields on frictional behaviors of three kinds of ceramic / metal rubbing couples. Tribology Int 32: 161–166.

24. Vieira AC, Sequeira PD, Gomes JR, Rocha LA (2009) Dry sliding wear of Al alloy/SiCp functionally graded composites: Influence of processing conditions. Wear 267: 585–592.

25. Sudagar J, Venkateswarlu K, Jainshe L (2009) Dry sliding wear properties of a 7075-t6 aluminum alloy coated with nip in different pre-treatment conditions. J of Mats Eng and Performance: 1-9.

26. Dahm KL (2009) Fatigue-like failure of thermally oxidised titanium in reciprocating pin-on-plate wears tests. Wear 267: 409-416.

27. Babilius A (2005) Influence of temperature on tungsten carbide coating sprayed by different spray systems. Materials Science (Medžiagotyra) 11: 105-109.

28. Ebrahimzadeh I, Ashrafizadeh F (2014) High temperature wear and frictional properties of duplex-treated tool steel sliding against a two phase Brass. Ceramics International: 1-23.

29. Vieira AC, Sequeira PD, Gomes JR, Rocha LA (2009) Dry sliding wear of Al alloy/SiCp functionally graded composites: Influence of processing conditions. Wear 267: 585-592.

30. Bazaka K, Jacob MV (2011) Nano tribological and nanomechanical properties of plasma polymerized polyterpenol thin films. J of Material Research 26: 2952-2961.