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EFFECT OF SAND ON THE FRICTION COEFFICIENT DISPLAYED BY RUBBER SLIDING AGAINST EPOXY FLOORINGSFILLED BY IRONNANOPARTICLES

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ABSTRACT
The present work discusses the friction coefficient and electrostatic charge of epoxy composites filled by iron nanoparticles sliding against rubber to develop proper materials to beused as flooring materials ofhigh friction coefficient and low electrostatic charge.

It was found that presence of sand particles on the sliding surfaces strongly affected the friction coefficient. At sliding against dry sand contaminated rubber,friction coefficient slightly increased with increasing iron content. It decreased with load. Voltage increased with increasing iron content and the applied load. Presence of sand decreased the electric static charge. Rubber wetted by water and contaminated by sand showed that friction coefficient and voltage significantly increased with increasing iron content. The voltage values were much higher than that observed at dry sliding due to the ability of water to conduct the charge all over the sliding surfaces. Sand contaminating oil lubricated rubber,slightly increased friction coefficient with increasing iron content. The displayed friction values were relatively higher in spite of the presence of oil on the sliding surface. Voltage drastically decreased with increasing iron content. At sliding against sand contaminating water/oil emulsion lubricated rubber, friction coefficient significantly increased with increasing iron content. Epoxy free of iron displayed the lowest friction coefficient. Voltage significantly increased with increasing iron content. Rubber wetted by detergent and contaminated by sandshowed consistent trend of friction coefficient with increasing ironcontent. Voltage drastically decreased with increasing iron.

KEYWORDS
Friction,triboelectrification,electric static charge, epoxy, floorings,ironnanoparticles.

INTRODUCTION
Friction coefficient and electrostatic charge of epoxy composites filled by nanoparticles of aluminium (Al) sliding against rubber were investigated to develop proper materials to be used as flooring materials of high friction coefficient and low electrostatic charge, [1]. It was observed that at dry, water and detergent wetted surfaces, Al nanoparticles addition into epoxy matrix decreased friction coefficient with increasing Al content. At water contaminated by sand, detergent, oil, water/oil emulsion, oil contaminated by sand

and water/oil emulsion contaminated by sand wetted surfaces, friction coefficient increased with increasing Al. It was observed that at dry sliding, voltage decreased with increasing Al content. Voltage showed the maximum values for epoxy free of filling materials and decreased with decreasing load. Voltage showed drastic decrease with increasing Al contents. In the presence of sand particles, water contaminated by sand, detergent contaminated by sand and water/oil emulsion contaminated by sand on the sliding surfaces, voltage increased with increasing Al. For surfaces wetted by detergent contaminated by sand, oil and oil contaminated by sand, voltage drastically decreased with increasing Al.

Friction coefficient and electrostatic charge of epoxy composites filled by nanoparticles of aluminium oxide(Al_2O_3) sliding against rubber were investigated, [2]. It was observed thatat dry, water and detergentwetted surfaces, Al_2O_3 nanoparticles addition into epoxy matrixdecreased friction coefficient with increasing Al_2O_3 content. When sand particles were covering the sliding surfaces, no change was observed for friction coefficient with increasing Al_2O_3 content. Atwater contaminated by sand,detergent, oil, water/oil emulsion, oil contaminated by sand and water/oil emulsion contaminated by sand wetted surfaces, friction coefficient increased with increasing Al_2O_3. As for voltage as a measure of the electrostatic charge generated from friction, it was observed that at dry sliding, voltage decreased with increasing Al_2O_3content.

It was found that, at dry sliding, iron nanoparticles addition into epoxy matrix increased friction coefficient with increasing iron content, [3]. Voltage drastically decreased with increasing iron content. Voltage showed the maximum values for epoxy free of iron. Significant friction coefficient increase was observed at water wetted surfaces. Epoxy free of iron showed relatively lower voltage than that observed for dry sliding. As iron content increased voltage drastically decreased. Voltage drastically decreased with increasing iron. At oil/water emulsion, voltage and friction coefficient significantly increased with increasing iron.

Friction coefficient and wear of polyester composites reinforced by nanoparticles of Al, copper, iron and aluminium oxide, dry sliding against steel were investigated to develop new engineering materials with low friction coefficient and high wear resistance which can be used as bearing materials, [4,5]. Experiments were carried out at dry and oil lubricated surfaces. Pin on disc tribometerwas used to perform friction and wear experiments under the application of electric voltage.Experiments showed that, friction coefficient increased with increasing electric voltage for composites filled by Al, while at no voltage, friction coefficient decreased with increasing Al content. As the electric voltage increased wear decreased.

The field of nanotechnology is extending the applications of engineering and technology. The polymer based nanoparticles/nanocomposites are the fast growing field of research for developing the materials, [6]. There is an increasing demand to develop materials based on thermosetting polymers due to the relatively high thermal stability and environmental resistance as well as the good tribological performance. Thermosetting polymer composites are used as substrate, coating, and plastic bearings as well as in the automotive, railway and transport industries, [7]. The major drawback is their relatively poor wear resistance. While many thermoplastic materials show self lubricating behaviour, [8], while the lubricating properties of thermosetting polymers

need to be modified by solid lubricants or by the addition of nanoparticles of selected materials in particular ZnO nanoparticles.

Silica nanoparticle filled polypropylene (PP) and PP blends were studied. Mechanical property improvement was the major, [9 - 11]. It is well known that the intrinsic properties of semi-crystalline polymer material, including the mechanical properties, are determined by the microstructure of the final products, which is in turn dependent on the thermal or mechanical history that the material experiences during processing. There exists a great interest in the development of new polymer-clay nanocomposites in the expectation of improved physicochemical and mechanical properties with respect to the pure polymers and conventional composites, with the use of a relatively low filler proportion, [12 - 14]. Polycarbonate is an amorphous engineering thermoplastic which combines good thermal stability, transparency, impact resistance and the ability to be processed on conventional machinery. Thus, the surface properties are important for many applications such as medical, optics, automobile, etc., since problems related to scratching or wear on the surface are of interest in the case of this thermoplastic. New polycarbonate nanocompositesare being developed in order to improve the thermal, mechanical, electrical or optical properties of the base polymer.

The effect, of silane treatment of Fe_3O_4 on the magnetic and wear properties of Fe_3O_4/epoxy nanocomposites, was investigated, [15]. The results showed that the specific wear rate of surface-modified Fe_3O_4/epoxy nanocomposites was lower than that of unmodified Fe_3O_4/epoxy nanocomposites. The decrease in wear rate and the increase in magnetic properties of surface-modified Fe_3O_4/epoxy nanocomposites occurred due to the improved dispersion of Fe_3O_4 into the epoxy matrix.Many authors became interested in magnetic nanopowder reinforced polymer composites because magnetic nanoparticles have shown great potential for applications, including aircraft, spacecraft, magnetic hard disks, and the magnetic bars of credit card. These applications can take advantage of both the magnetic properties and wear properties of these compositions, [16]. Among the composites, one can produce magnetic nanopowder reinforced polymer nanocomposites that exhibit magnetic properties and wear properties superior to those of other composites. On the microscale of filling materials reinforcing polyester composites, several research works were carried out, [17]. Friction coefficients and wear rates of polyester composites reinforced by graphite fibres with different diameters and impregnated by vegetable oils (corn, olives, and sunflower oil) were measured to develop new engineering materials with low friction coefficients and high wear resistance which can be used in industrial applications as bearing materials. Corn and sunflower oil display good tribologicalbehavior of the polyester composites.

Several works were carried out to develop polyester composites to be used as self lubricated bearing material in different engineering applications. Polyethylene and glass fibres were used to reinforce polyester in order to increase wear resistance of the tested composites. Paraffin, glycerin, almond, olives, cress, sesame and baraka oils were added to polyester during molding to produce self lubricated composites, [18 - 20]. It was found that increasing oil content and polyethylene fibres decreased friction content. The highest friction and wear were displayed by composites free of oil. Composites containing olive oil displayed higher friction and lower wear than that containing almond oil. Impregnating polyester matrix by paraffin and glycerin oils caused significant reduction in friction coefficient and wear.

Friction of polymers is accompanied by electrification. During frictional interaction chemical and physichemical transformations in polymers promote increases in the surface and bulk states density. Electrification in friction is a common feature, it can be observed with any mode of friction, and with any combination of contacting surfaces, [21]. The potential difference generated by the friction of polymeric coatings against steel counterfacehas been measured. The effect of sliding velocity and load on the generation of electric charge on the friction surface has been investigated, [22]. The results indicated that, at dry sliding condition the potential generated from friction increases rapidly with increasing both of sliding velocity and load at certain values then decreases due to the rise of temperature which causes molecular motion and reorientation of the dipole groups in the friction direction and leads to the relaxation of space changes injected during friction.

The triboemission characteristics of both negatively and positively charged particles from various materials such as metals, ceramics and glass were studied, [23]. The results obtained during scratching the tested materials showed increasing emission intensity with increasing electrical resistance of the materials, [24]. Mechanisms of polarization and relaxation of dielectrics were used to provide explanation of the friction and wear behaviour of insulators.Unfilled and filled PA6 coatings by metal powders as well as high density PE, PA6, polypropylene coatings, reinforced by copper wire, were tested. Increasing the concentration of metal powder can reduce the effect of the applied voltage on friction and wear. Reinforcing PA6 and polypropylene coatings by copper wires increased the wear resistance and reduced the friction, [25]. The application of an electric field, however, is considered to promote the breakdown of EHL film formed, [26]. The influence of applying electric field on the tribological behaviour of steel in a vertical magnetic field produced by an AC or DC electric current was investigated. The effect of a magnetic field on both oxidation and concentrations of dislocations on the surface is presented, [27]. Experiments showed that a magnetic field applied through the sliding contact decreased wear rate.

Voltage generated as a result of the friction caused by the sliding of the tested polymers against each other as well as steel surface was measured, [28]. The test results showed that friction coefficient displayed by the sliding in salt water represented maximum values due to the relatively high value of voltage generated as a result of friction. Triboelectrification of metallic and polymeric surfaces was investigated at dry and lubricated sliding conditions. The effect of sodium chloride (NaCl), gasoline, diesel fuel, and hydrochloric acid (HCl) as contaminants in the lubricant on voltage and friction was discussed, [29]. The test results showed that relatively high voltage generated due to sliding of metallic surfaces against each other in salt water and oil dispersed by ethylene glycol while sliding of PA6 against steel surface produced the highest values of voltage at oil lubricated condition. In the presence of NaCl in water, relatively high value of voltage due to friction was observed accompanied by high value of friction coefficient. It was found that a correlation between friction coefficient and voltage generated was found for polymers sliding against themselves and against steel in water and salt water lubricated conditions, [30]. Wear of the tested polymers decreased with increase of sand particle size down to minimum because of the sand embedment in the polymeric surface. Further increase in sand particle size increased wear due to the removal of sand from the polymeric surface.

The aim of the present work is to investigate the influence of the addition of ironnanoparticles to epoxy composites on the friction coefficient and electric static charge generated from friction in the presence of sand particles. The proposed epoxy composites are aimed to be used as flooring materials.

EXPERIMENTAL

The test rig used in the present work, was designed and manufactured to measure the friction force displayed by the sliding of the tested epoxy composites filled by iron nanoparticles specimens against the rubber surface through measuring the friction force and applied normal force. The rubber surface in form of a sheet was placed in a base supported by two load cells to measure the horizontal force (friction force) and the vertical force (applied load). A digital screen was attached to the load cells to detect the friction and vertical forces. Friction coefficient was determined by the ratio between the friction force and the normal load. Voltage was measured after slidingof the tested composites against the rubber surface by the electrostatic field measuring device.

The test specimens were prepared from epoxy filled by iron nanoparticles. The specimens were poured in form of a cuboid of 50 × 50 mmand 6mm thickness adhered on a steel sheet fixed to wooden block. ironnanoparticles (100 nm) were added toepoxy composites in contents of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 wt. %.

Measurementsof friction coefficient as well as voltage generated from frictionwere carried out at different values of normal load. Test specimens were loaded against rubber counterface of 3 mm thickness which simulated the footwear surface. The load values were 20, 40, 60and 80 N. The sliding surfaces were lubricated by water, sand, water contaminated by sand, water + 2.0 vol. % detergent, water + 2.0 vol. % detergent contaminated by sand, oil, oil contaminated by sand, water + 2.0 vol. % oil and water + 2.0 vol. % oil contaminated by sand.Sand particlesof silicon oxide (SiO_2) up to 999 µm size were used, while paraffin oil was used.

Theelectrostatic fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens, Fig. 4. It measures down to 1/10 volt on a surface, and up to 20 000 volts (20 kV). Readings were measured by the sensor 25 mm apart from the surface being tested.

RESULTS AND DISCUSSION

Friction coefficient of epoxy composites sliding against dry sand contaminated rubber, Fig. 1, slightly increased with increasing iron content. It decreased with load. The presence of sand particles on the sliding surfaces strongly affected the friction coefficient. This behaviour can be explained on the basis that sand particlesroll along the surfaces about 90 % and slide only 10 %of the time. Only when the sand particle sticks toone surface and cut intothe other abrasion will occur.In the present work, one surface is rubber, while the other is epoxy filled by nanoparticles of iron. It is expected that sticking of sand will be in rubber and cutting will be in epoxy. Presence of iron would increase the resisting force during the microcutting process in the surface of the epoxy composites leading to a friction increase. During the cutting process caused by sand particles the displaced material from the sliding surface forms frontal and lateral ridgesin the front and each side of the wear track in theepoxysurface which increases the surface roughness and waviness, Figs. 2, 3.The volume ofmaterial displaced by the abrasive particle is distributedamong a frontal ridge, two lateral ridges and two chips. It

was pointed out that approximately 15% of the displacedmaterial is removed as a chip, and the rest forms ridgeson the metal surface. In some of the previous worksit was indicated that the frontal ridge is higher thanthe lateral ones.The formation of the frontal ridge accompanied with the sand particle microcutting in the slidingsurfaces may be responsible of the friction increase.The friction value fluctuates violentlyat the commencement of sand particle microcuttinguntil the frontal ridge formation stabilizes.

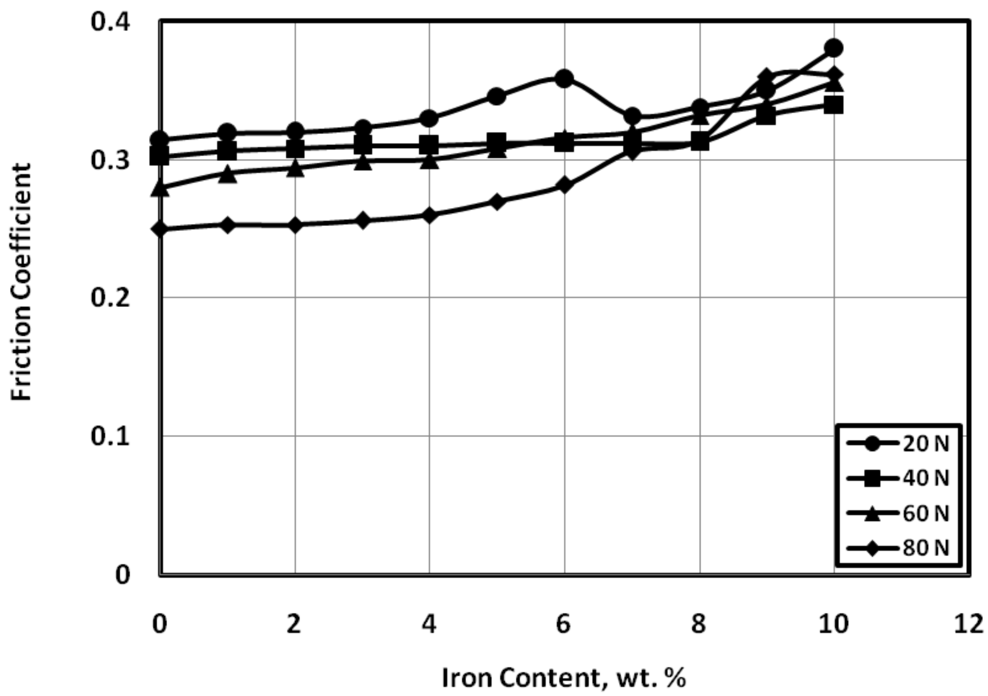

Fig. 1 Friction coefficient of epoxy composites sliding against sand contaminated rubber.

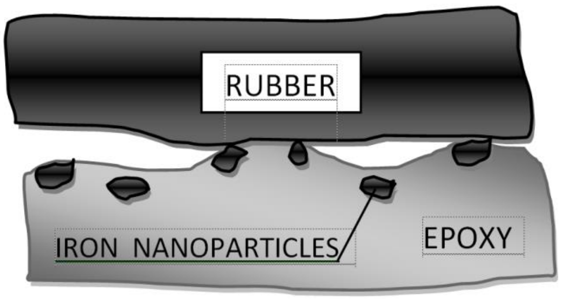

Fig. 2 Sliding surfaces without sand.

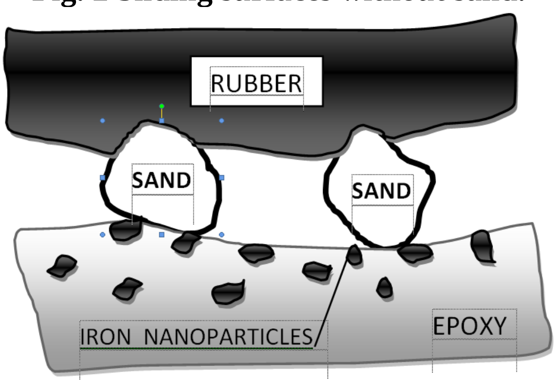

Fig. 3 Sliding surfaces contaminated by sand.

Friction of epoxy against rubber is accompanied by electrification. Based on that theory, one of the sliding surface gains positive electrostatic charge, while the other gains negative charge. As result of that, an electrostatic force is generated and this force influences the applied normal load. The magnitude of the electrostatic force is proportional to the electrostatic charge which depends on the rank of the rubbing surfaces in the triboelectric series. Voltage generated from epoxy composites sliding against sand contaminated rubber, Fig. 4, increased with increasing iron content and the applied load. Presence of sand decreased the electric static charge. It seems that sand isolated a fraction of the contact area so that the friction was mostly between sand particles and rubber from one side and epoxy composite from the other side.

The friction coefficient displayed by epoxy composites sliding against rubber wetted by water and contaminated by sand is shown in Fig. 5. Friction coefficient significantly increased with increasing iron content up to 10 wt. %, where the highest friction coefficient (0.49) was displayed at 20 N load. Water caused significant rise in friction compared to the dry sand contaminated sliding, Fig. 1, especially at the lowest load (20 N). It seems that water decreased sand particles sticking in the sliding surfaces.

The effect of iron on voltage is shown in Fig. 6. Voltage increased with increasing iron content.The voltage values are much higher than that observed at dry sliding due to the ability of water to conduct the charge all over the sliding surfaces. The highest load (80 N) showed the highest voltage.

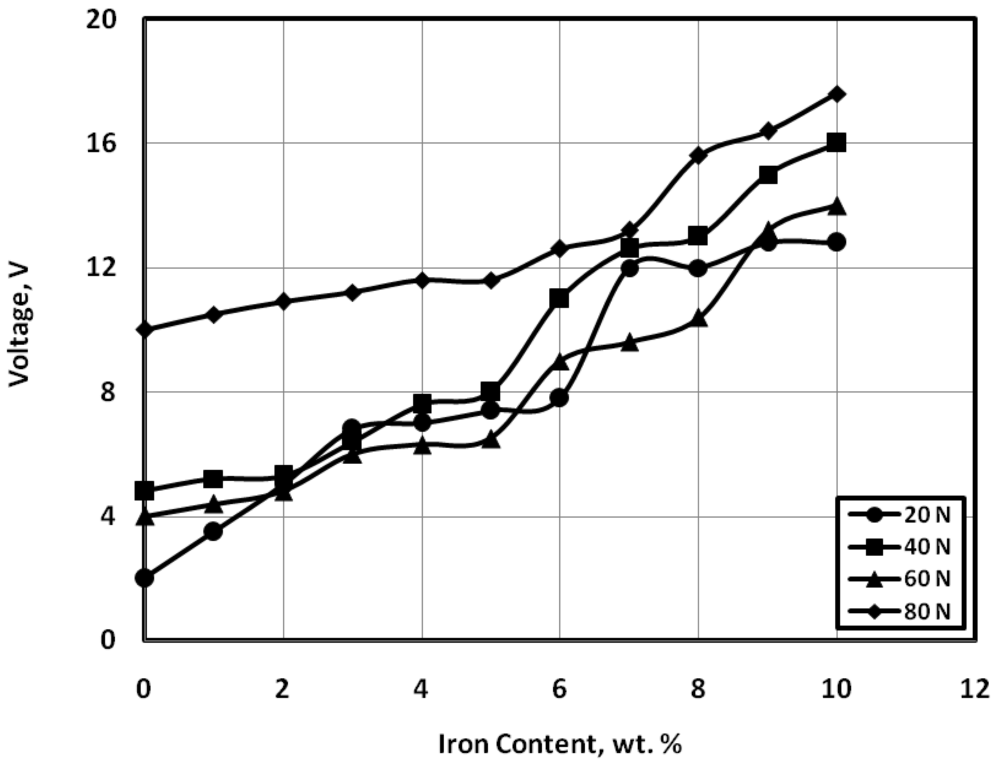

Fig. 4Voltage generated from epoxy composites sliding against sand contaminated rubber.

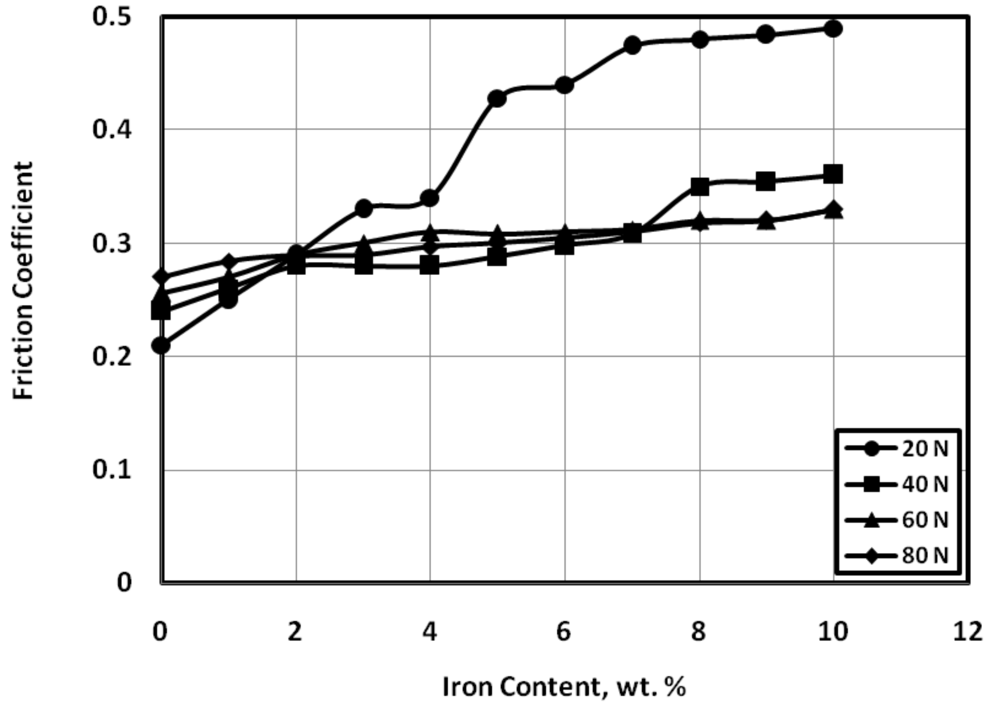

Fig. 5Friction coefficient of epoxy compositessliding against sand contaminating water wetted rubber.

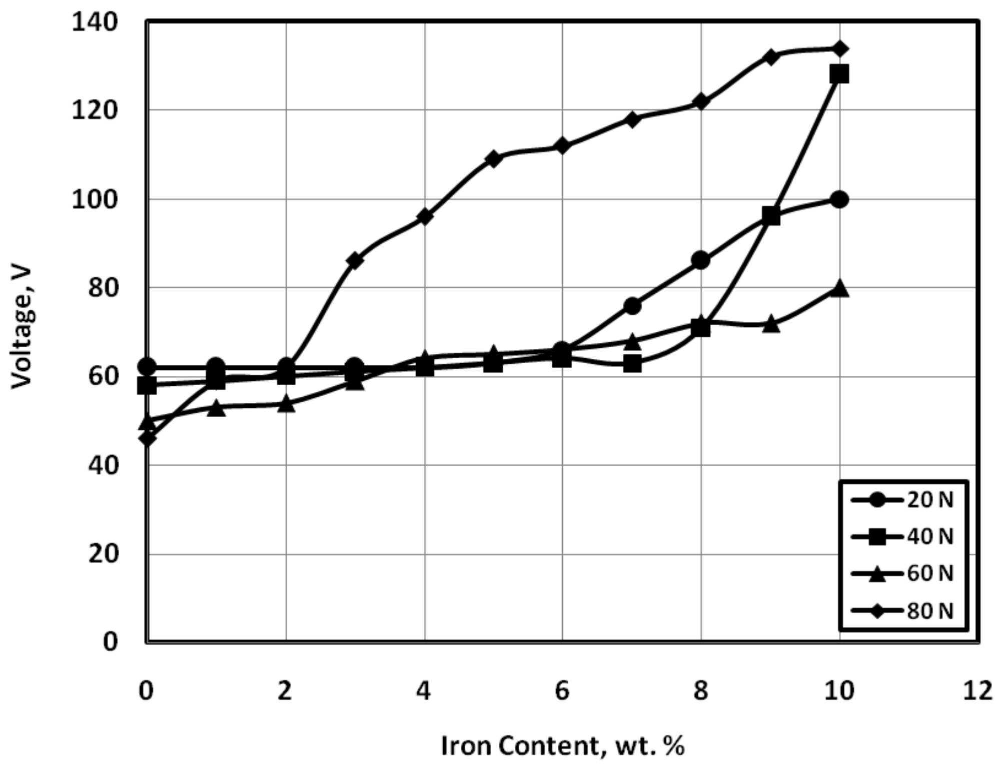

Fig. 6Voltage generated from epoxy compositessliding against sand contaminating water wetted rubber.

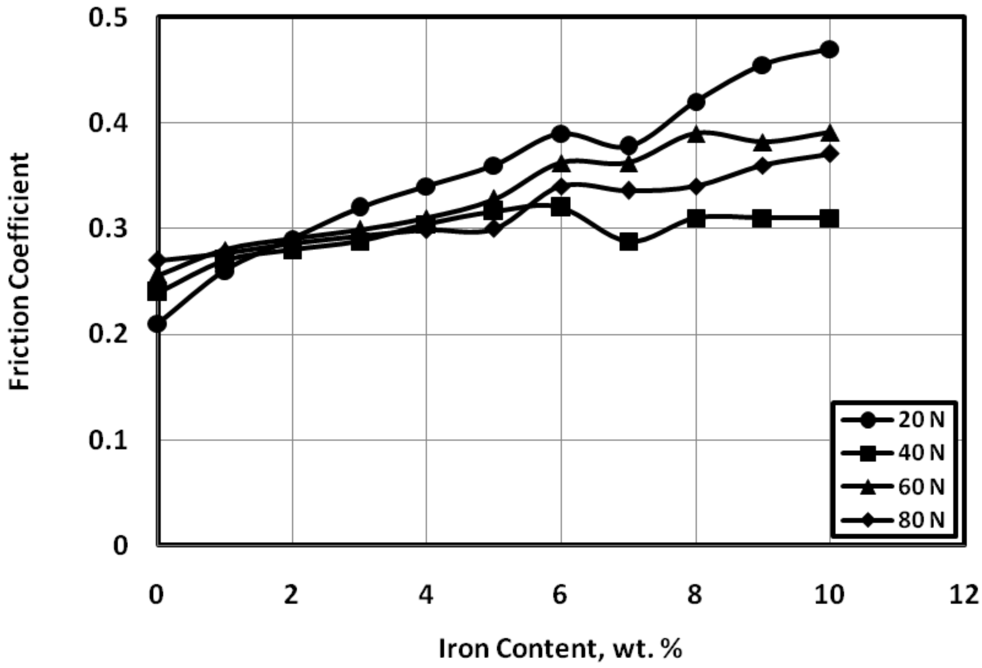

Fig. 7Friction coefficient of epoxy composites sliding against sand contaminating oil lubricated rubber.

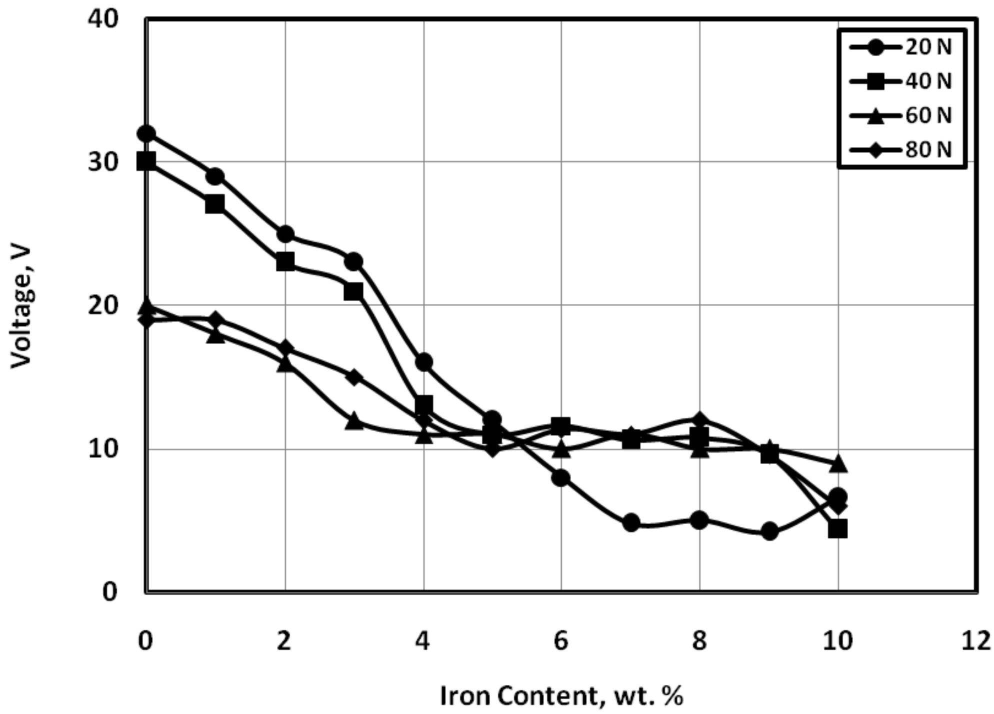

Fig. 8Voltage generated from epoxy compositessliding against sand contaminating oil lubricated rubber.

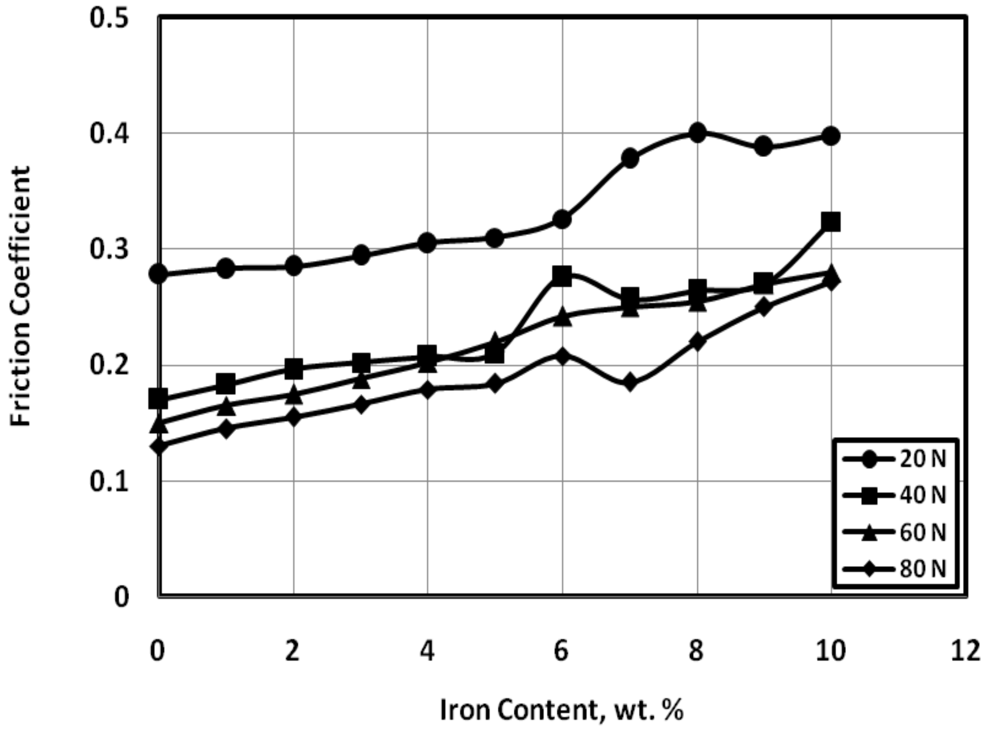

Fig. 9Friction coefficient of epoxy compositessliding against sand contaminating water/oil emulsion lubricated rubber.

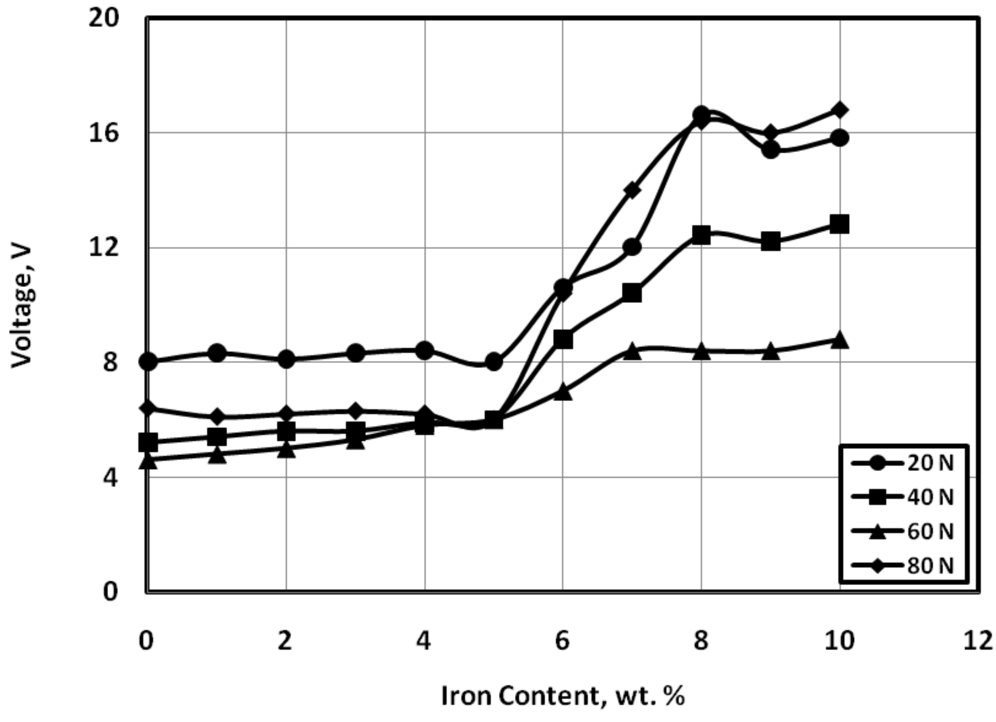

Fig. 10Voltage generated from epoxy composites sliding against sand contaminating water/oil emulsion lubricated rubber.

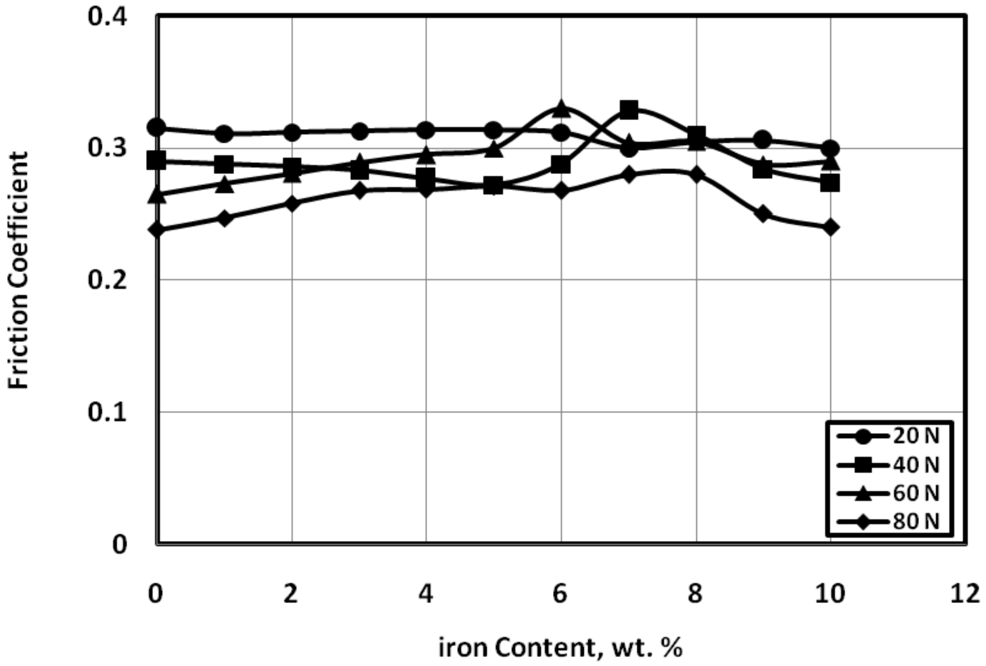

Fig. 11Friction coefficient of epoxy compositesslidingagainst sand contaminating detergent wetted rubber.

Friction coefficient displayed by composites filled by ironsliding against sand contaminating oil lubricated rubberis shown in Fig. 7. It was noticed that friction coefficient slightly increased with increasing iron content. At 10 wt. % iron content, the highest friction coefficient (0.47) was displayed by 20 N load. Epoxy free of iron displayed the lowest friction coefficient (0.21) at 20 N load. The displayed friction values are relatively higher in spite of the presence of oil on the sliding surface. Sand particles separated the rubber and epoxy so that the contact partially was sand/rubber and sand epoxy.

Voltage displayed by the sliding of epoxy specimens filled by ironis shown in Fig. 8, where itdrastically decreased with increasing iron content. The voltage reached the maximum (32 volts) at 0wt. % iron, while the lowest value (7 volts) was observed at 20 N load and 10 wt. % iron content. The friction decrease might be from the formation of the oil film on the sliding surfaces as well as the sand particles significantly decreased the rubber/epoxy contact and consequently decreased the triboelectrification of the sliding surfaces.

Friction coefficient of epoxy compositessliding against sand contaminating water/oil emulsion lubricated rubber, Fig. 9, significantly increased with increasing iron content. Epoxy free of iron displayed the lowest friction coefficient. The maximum value of friction coefficient (0.4) was observed at 20 N normal load and 8 wt. %iron content.

Voltage generated from epoxy composites sliding against sand contaminating water/oil emulsion lubricated rubberis shown in Fig. 10, where it significantly increased with increasing iron content. At 10 wt. % iron, the maximum value of voltage (17 volts) wasdisplayed by 80 N load. Epoxy free of iron displayed the lowest voltage (4.6 volts) at 60 N loads.

Friction coefficient showed consistent trend with increasing ironwhen sliding against rubber wetted by detergent and contaminated by sand, Fig. 11. The maximum value of friction coefficient (0.4) was observed at 20 N normal load and 10 wt. %iron.

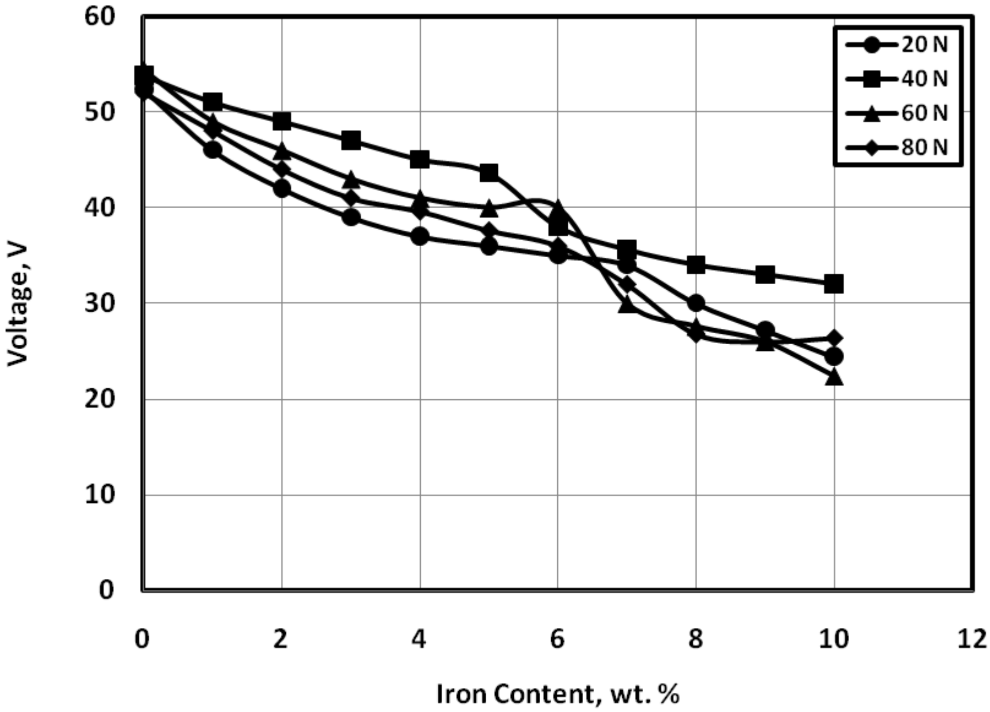

Fig. 12Voltage generated from epoxy compositesslidingagainst sand contaminating detergent wetted rubber.

Voltage generated from the sliding of epoxy specimens filled by ironis shown in Fig. 12. Voltage drastically decreased with increasing iron. The voltage approached maximum value (54 volts) for epoxy free of iron, while the lowest value (22 volts) was observed at 60 N load and 10 wt. %iron.

CONCLUSIONS

1. The presence of sand particles on the sliding surfaces strongly affected the friction coefficient. At sliding against dry sand contaminated rubber,friction coefficient slightly increased with increasing iron content. It decreased with load. Voltage increased with increasing iron content and the applied load. Presence of sand decreased the electric static charge.
2. At sliding against rubber wetted by water and contaminated by sand, friction coefficient significantly increased with increasing iron content. Voltage increased with increasing iron content.The voltage values are much higher than that observed at dry sliding due to the ability of water to conduct the charge all over the sliding surfaces.
3. At sliding against sand contaminating oil lubricated rubber,friction coefficient slightly increased with increasing iron content. The displayed friction values were relatively higher in spite of the presence of oil on the sliding surface. Voltage drastically decreased with increasing iron content.

4. At sliding against sand contaminating water/oil emulsion lubricated rubber, friction coefficient significantly increased with increasing iron content. Epoxy free of iron displayed the lowest friction coefficient. Voltage significantly increased with increasing iron content.
5. At sliding against rubber wetted by detergent and contaminated by sand,friction coefficient showed consistent trend with increasing ironcontent. Voltage drastically decreased with increasing iron.

REFERENCES

1. Mayada S. A., Khashaba M. I., Ali W. Y., "Friction and Triboelectrification of Epoxy Floorings Filled by Aluminium Nanoparticles", 10/2013, 67. Jahrgang, METALL, pp. 397 - 403, (2013).
2. Mayada S. A., Khashaba M. I., Ali W. Y., "Friction and Triboelectrification of Epoxy Floorings Filled by Aluminium Oxide Nanoparticles", Journal of the Egyptian Society of Tribology, Vol. 10, No. 4, October 2013, pp. 38 –56, (2013).
3. Shoush K. A., Elhabib O. A., Mohamed M. K., and Ali W. Y., "Triboelectrification of Epoxy Floorings", International Journal of Scientific & Engineering Research,Volume 5, Issue 6, June 2014, pp. 248 - 253, (2014).
4. Magda S., Khashaba M. I. and Ali W. Y., "Dry Sliding of Polyester Composites Filled by Nanoparticles Against Steel", Journal of the Egyptian Society of Tribology Vol. 9, No. 2, April 2012, pp. 43 – 59, (2012).
5. Magda S., Khashaba M. I. and Ali W. Y., "Oil Lubricated Sliding of Polyester Composites Filled by Nanoparticles Against Steel", Journal of the Egyptian Society of Tribology Vol. 9, No. 2, April 2012, pp. 60 – 75, (2012).
6. Sanes J., Carrion F.J., Bermudez M.D., " Effect of the Addition of Room Temperature Ionic Liquid and ZnONanoparticles on the Wear and Scratch Resistance of Epoxy Resin", Wear 268 1295–1302 (2010).
7. Kumar A. P., Depan D., Tomer N. S., Singh R. P., "NanoscaleParticles for Polymer Degradation and Stabilization—Trends and Future Perspectives", Progress in Polymer Science 34, pp. 479 – 515, (2009).
8. Brostow W., Chonkaew W., Menard K. P., Scharf T. W., "Modification of an Epoxy Resin with a FluoroepoxyOligomer for Improved Mechanical and TribologicalProperties", Mater. Sci Eng. A 507, pp. 241 – 251, (2009).
9. Hao W., Yang W., Cai H., Huang Y., "Non-Isothermal Crystallization Kinetics of Polypropylene/Silicon Nitride Nanocomposites", Polymer Testing 29, pp. 527 – 533, (2010).
10. Martin G., Barres C., Sonntag P., Garois N., Cassagnau P., "Co-continuous Morphology and Stress Relaxation Behaviour of Unfilled and Silica Filled PP/EPDM Blends", Mater. Chem. Phys. 113 (2e3), p. 889, (2009).
11. RuanW.H., MaiY.L., WangX.H., RongM.Z., ZhangM.Q., "Effects of Processing Conditions on Properties of Nano-SiO_2/Polypropylene Composites Fabricated by Pre-Drawing Technique", Compos. Sci. Technol. 67 (13), p. 2747, (2007).
12. Carrión F. J., Arribas A., Bermúdez M. D., "Physical and TribologicalProperties of a New Polycarbonate-OrganoclayNanocomposite", European Polymer Journal 44, pp. 968 - 977, (2008).
13. Liu A., Xie T., Yang G., "Comparison of Polyamide 6 NanocompositesBased on Pristine and Organic Montmorillonite obtained via Anionic Ring-opening Polymerization", MacromolChemPhys, 207, pp. 1174 – 81, (2006).

14. Yoo Y., Choi K. Y., Lee J. H., "Polycarbonate/MontmorilloniteNanocompositesPrepared by Microwaved Aided Solid State Polymerization", MacromolChemPhys, 205, pp. 1863 - 1868, (2004).
15. Park J. O., Rhee K. Y., Park S. J., " SilaneTreatment of Fe3O4 and its Effect on the Magnetic and Wear Properties of Fe_3O_4/Epoxy Nanocomposites", Applied Surface Science 256, pp. 6945 - 6950, (2010).
16. Birsan I. G., Circiumaru A., Bria V., Ungureanu V., "Tribological and Electrical Properties of Filled Epoxy Reinforced Composites", Tribol. Ind. 31, pp. 33 - 36, (2009).
17. Ibrahim R. A., Ali W. Y., "TribologicalPerformance of Polyester Composites Filled by Vegetable Oils", Mat.-wiss. u. Werkstofftech. 41, No. 5, pp. 1 – 6, (2010).
18. Abd El-Aal U. M., Hasouna A. T. and Ali W. Y., "Experimental Study of Abrasive Wear Resistant Polyester Composites", Journal of the Egyptian Society of Tribology, Vol. 7, No. 3, July, pp. 26 – 38, (2010).
19. Abdel-Jaber G. T., Mohamed M. K. and Ali W. Y., "Friction and Wear of Polyester Reinforced by Polyethylene Fibres and Filled by Vegetables Oils", 47. Tribologie - Fachtagung, Septembe, pp. 33/1 – 33/11, (2008).
20. Abdel-Jaber G. T., Mohamed M. K. and Ali W. Y., "Friction and Wear of Oil Impregnated Polyester–Glass Fibre Composites", 47. Tribologie - Fachtagung, 25 – 27 September, pp. 33/1 – 33/9, (2006).
21. Bely, V. A., Pinchuk, L. S., Klimovich, A. F. and Guzenkov, S. I., "Tribological Aspects of Electret State Generation in Polymers", Proceedings of The 5th Int. Congress on Tribology, EUROTRIB 89, Vol. 2, June 13 - 16, Espo, Finland, pp. 276 - 281, (1989).
22. Ali, W. Y., "Experimental Study of the Potential Generated by Friction of Polymeric Coatings", 4th Conference of the Egyptian Society of Tribology, EGTRIB'95, Jan. 4-5, Cairo, Egypt, (1995).
23. Nakayama, K. and Hashimoto, H., "Triboemission From Various Materials in Atmosphere", Wear, 147, pp. 335 - 343, (1991).
24. Fayeulle, S., Berroug, H., Hamzaoui, B. and Treheux, D., "Role of Dielectric Properties in the Tribological Behaviour of Insulators", Wear, 162 - 164, pp. 906 - 912, (1993).
25. Ali, W. Y., "Influence of Applied Voltage on Friction and wear of Polymeric Coatings Sliding Against Steel", Tribologie und Schmierungstechnik, 43. Jahrgang, March/April, pp. 83 - 87, (1996).
26. Yamamoto, Y., Ono, B. and Ura, A., "Effect of Applied Voltage on Friction and Wear Characteristics in Mixed lubrication", Proceedings of the VI Int. Congress on Tribology, Vol. 5 EUROTRIB'93, Budapest, Hungary, pp. 82 - 89, (1993).
27. Nery, H., Zaidi, H., Pan, L. and Paulmier, D., "Influence of Magnetic Field on Steel in Sliding Contact", Proceedings of the VI Int. Congress on Tribology, Vol. 5 EUROTRIB'93, Budapest, Hungary, pp. 70 - 75, (1993).
28. Youssef, M. M., Ezzat, F. M., and Ali, W. Y., "Triboelectrification of Polymeric Materials", PEDD 6, Proceedings of the 6th International Conference on Production Engineering and Design for Development, Cairo, Egypt, February 12 – 14, (2002).
29. Youssef, M. M., "Triboelectrification of Metallic and Polymeric Materials" Bulletin of the Faculty of Engineering, El-Minia University, Vol. 20, No. 1., July, pp. 31 – 41, (2001).
30. Youssef, M. M., Mahmoud, M. M. and Ali, W. Y., "Friction and Wear of Polymeric Materials Sliding Against Steel", Journal of the Egyptian Society of Tribology, Vol. 2, No. 1, April, pp. 18 – 31, 45. Tribologie-Fachtagung, 25^{th} – 27^{th}, September in Göttingen, pp. 9/1 – 9/14, (2004).