EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 16, No. 4, October 2019, pp. 25 - 35 ISSN 2090 - 5882
(Received July 12. 2019, Accepted in final form September 03. 2019) www.egtribjournal.com

TRIBOELECTRIFICATION OF EPOXY REINFORCED BY ALUMINIUM MESH

Ali A. S.[1] and Ibrahem R. A.[2]

[1]Mechanical Power Engineering Dept., Faculty of Engineering, Suez Canal University, EGYPT.
[2]Mechanical Engineering Dept., Faculty of Engineering, Beni-Suef University, Beni-Suef, EGYPT.

ABSTRACT
The aim of this study is to reduce electrostatic charge (ESC) generated from the walking of rubber shoes on epoxy floor. Aluminium (Al) mesh of different sizes has reinforced the epoxy, where the effect on the generation of the electrostatic charge (ESC) when slid against rubber is investigated. Tests have been carried out at dry, water and detergent wet sliding.

It was found that, as the mesh size of Al screen reinforcing epoxy increased, friction coefficient increased due the increase of adhesion between epoxy and rubber. This behavior can be explained on the basis of generation of double layer of ESC on the two sliding surfaces. Once charged, the two surfaces attract each other. The double layer of ESC generated on the sliding surfaces would increase the adhesion force acting between the two sliding surfaces and causing significant increase in friction coefficient. Presence of Al screen would equalize ESC generated on the surfaces and decrease the adhesion between the two sliding surfaces.

KEYWORDS
Triboelectrification, electrostatic charge, epoxy, aluminium mesh, rubber.

INTRODUCTION
Polymeric floor materials are extensively used to reduce slip accidents. When the materials of footwear/floor the risks associated with slipping and falling are related to the, contamination condition, and geometric design of the sole. Epoxy floors are applied due to their proper static and dynamic friction coefficient. One of the drawbacks of epoxy is the generation of ESC when rubber slides against it. ESC built up on shoes sole and epoxy during walking is transmitted to human body causing harmful and serious health problems.

Several attempts were carried out to investigate the effect of reinforcing epoxy by copper wires of different diameters on the generation of ESC and friction coefficient when rubber sole slides against epoxy floor, [1 - 4], where number of wires, location and

wires diameter reinforcing the matrix of the epoxy was studied. It was found that ESC measured in volts significantly increased with increasing the number of wires. Besides, ESC decreased with increasing the distance of wire from the sliding surface. When the wires were closer to the surface and the wire diameter increased, ESC increased. At water wetted sliding, ESC decreased due to the good water conductivity.

To ensure safe walking on the floor the values of static friction coefficient should be controlled. Using polymeric floors necessitates controlling ESC generated during walking. It is well known that walking and creeping on flooring generate electric static charge of intensity depends on the material of flooring. The materials of the floors as well as footwear can affect the generated charge. ESC and friction coefficient of bare foot and foot wearing socks sliding against different types of flooring materials were investigated under dry sliding condition, [5]. It was found that rubber floor showed the highest generated voltage among the tested floorings. The highest ESC values were displayed by polyester socks, while cotton socks showed the lowest ones. This observation can confirm the necessity of careful selection of the floor materials. ESC generated from walking of rubber shoes on the carpet was discussed, [6]. The humidity of contact surfaces has significant effect on the generation of ESC, [7 - 8], where the increased electrical conductivity of the sliding surfaces had influenced ESC.

Filling epoxy matrix by copper and brass particles displayed higher values of ESC than that observed for epoxy filled by iron particles, [10]. ESC was influenced by the load. ESC built up on human skin and or clothes in direct contact with human body are very harmful and can create serious health problems, [11]. At dry sliding, iron nanoparticles filling epoxy matrix increased friction coefficient. ESC drastically decreased with increasing iron content. ESC showed maximum values for unfilled epoxy.

ESC generated from the sliding of rubber footwear against PVC floor displayed lower values than that observed for epoxy floor, [12]. This observation confirms the suitability of PVC floor to be applied as indoor floor where bare foot walking is dominating.

The aim of the present study is to investigate the effect of reinforcing epoxy by aluminium (Al) mesh on the generation of the electrostatic charge (ESC) when slid against rubber. Tests have been carried out at dry, water and detergent wet sliding.

EXPERIMENTAL

The present work measureed ESC generated by the sliding of rubber epoxy reinforced Al screen of 0.5, 1.0, 2.0 and 4.0 mm mesh sizes, Figs. 1, 2. The electric static fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the ESC (electrostatic field) generated on the surface of the test specimens.

Tests were carried out at room temperature under varying normal loads. The test specimens were prepared from epoxy blocks of 50 × 50 mm^2 and 10 mm thickness adhered to wooden block of 50 mm height. The tested epoxy was pressed and slid against rubber of 60 Shore A hardness in form of sheets of 100 × 200 × 5 mm^3. The applied force was ranging from 10 to 200 N. After sliding, the ESC generated on the surface of the test

specimens was measured. The test rig used in the experiments to measure the friction force by the deflection of the load cell is shown in Fig. 3. The ratio of the friction force to the normal load was considered as friction coefficient. The load was applied manually. The test speed was nearly controlled to be 2 mm/s. All measurements were performed at 28 ± 2° C and 50 ± 10 % humidity. Test specimens were loaded against rubber counterface of 5.0 mm thickness which simulated the footwear surface. The sliding surfaces were dry, water wet and contaminated by sand particles of silicon oxide (SiO_2) up to 999 µm size. Cotton sock was used for tests carried out to investigate friction coefficient displayed by the sliding of foot wearing socks on the tested epoxy composites.

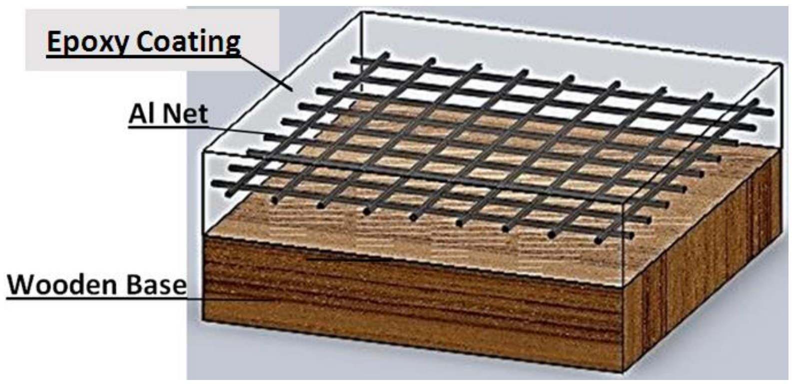

Fig. 1 Details of the test specimen.

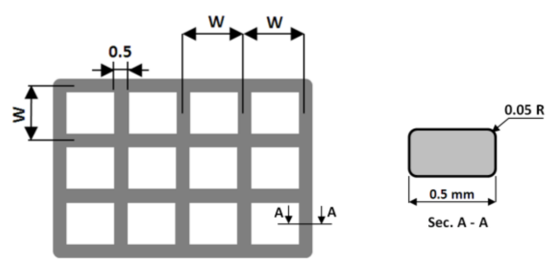

Fig. 2 Dimensions of the aluminium screen.

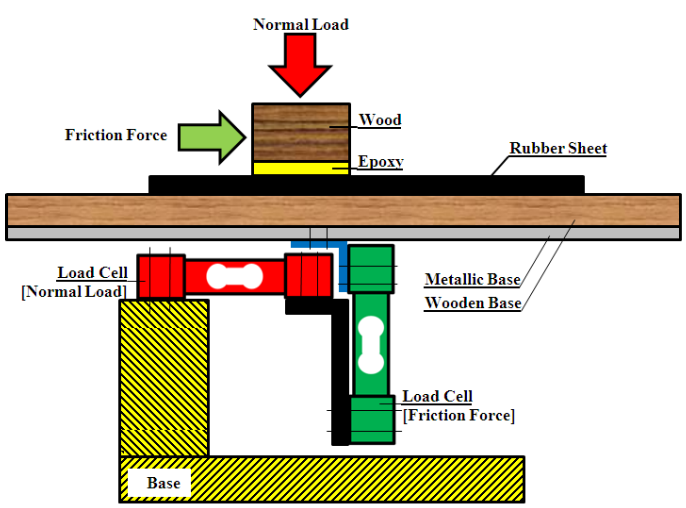

Fig. 3 Arrangement of the test rig.

RESULTS AND DISCUSSION

The relationship between friction coefficient and applied load is shown in Fig. 4 at dry sliding of the tested composites against rubber sheet. Friction coefficient decreased with increasing the normal load. Friction increase was related to the softening of epoxy caused by the heating during sliding. It is clearly seen that, as the mesh size of Al screen increased, friction coefficient increased. It seems that there was high adhesion between epoxy and rubber, which increased with increasing mesh size. Friction coefficient increased up to 0.97 for epoxy reinforced by Al screen of 4.0 mm mesh size at 20 N load. This behavior can be explained on the basis that triboelectrification is the generation of double layer of ESC on the two sliding surfaces. When two dissimilar materials are pressed or rubbed together, the surface of one usually becomes positively charged, while the other becomes negatively charged. The intensity of the generated charge depends on the pressure and velocity of rubbing. Once charged, the two surfaces attract each other. In the present work, epoxy reinforced by Al screen and sheet of rubber are sliding against each other. Epoxy as insulator contains a distribution of charges that are conserved. The double layer of ESC generated on the sliding surfaces would increase the adhesion force acting between the two sliding surfaces and causing significant increase in friction coefficient. Presence of Al screen would leak ESC generated on the surfaces. It is illustrated in Fig. 5 that Al screen decreased the intensity of ESC by attracting the negative and positive charges from the two contacting surfaces leading to the decrease of the values of ESC. In that condition, it is expected that the adhesion force between the two sliding surfaces decreases. It was observed that, Fig. 6. ESC significantly increased with increasing the normal load, where the intensity of ESC depends on the load. The figure shows that as the Al mesh size increased, ESC significantly increased. This behavior is attributed to the increased conductivity of epoxy composites that facilitates leaking the generated ESC out of the contact area. That result confirms the necessity of adding aluminium mesh, in the epoxy to reduce ESC.

At water wet sliding, the effect of Al mesh size on friction coefficient displayed by epoxy is shown in Fig. 7, where the highest value of friction coefficient was 0.73 at 20 N load for epoxy reinforced by 4.0 mm mesh size screen. Generally, the observed values were relatively lower than that observed for dry sliding. When the mesh size decreased to 0.5 mm, friction decreased down to 0.38 at the load. The friction values reflected that the effect of ESC was much higher than the effect of water film. Besides, friction coefficient was influenced by the load. Figure 8 shows that, water wet surface decreased ESC to 185, 158, 118 and 98 volts for epoxy composites reinforced by 4.0, 2.0, 1.0 and 0.5 mm respectively. Those values were lower than that generated in dry sliding. This behavior is attributed to the good conductivity of water that facilitates equalizing ESC generated on the two contact surfaces.

The effect of Al screen on friction coefficient is shown in Fig. 9. Friction coefficient slightly decreased with increasing the applied load. The values of friction coefficient represented lower values than that measured for dry and water wet sliding. It seems that sand particles partially disables the contact between epoxy and rubber surfaces, Fig. 10. In that sliding condition, the contact was partially sand/rubber, sand/epoxy and rubber/epoxy. Because sand is positively charged when rubs rubber and epoxy, the

intensity of ESC generated drastically decreased, Fig. 11. Consequently, the adhesion between the sliding surfaces decreased leading to the decrease of friction coefficient. This observation confirmed the influence of presence of sand particles on the both fricition coefficient and ESC.

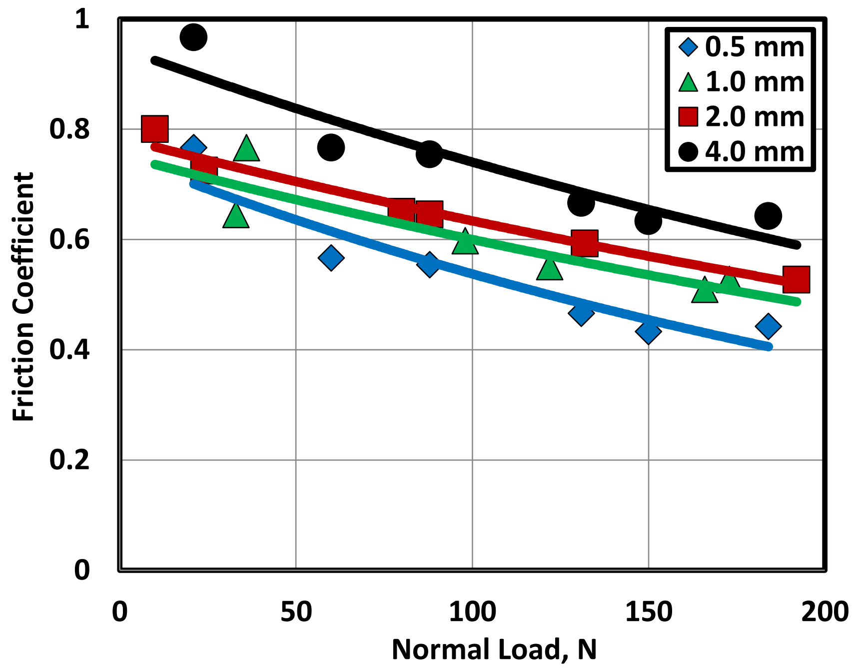

Fig. 4 Friction coefficient displayed by rubber sliding against dry epoxy.

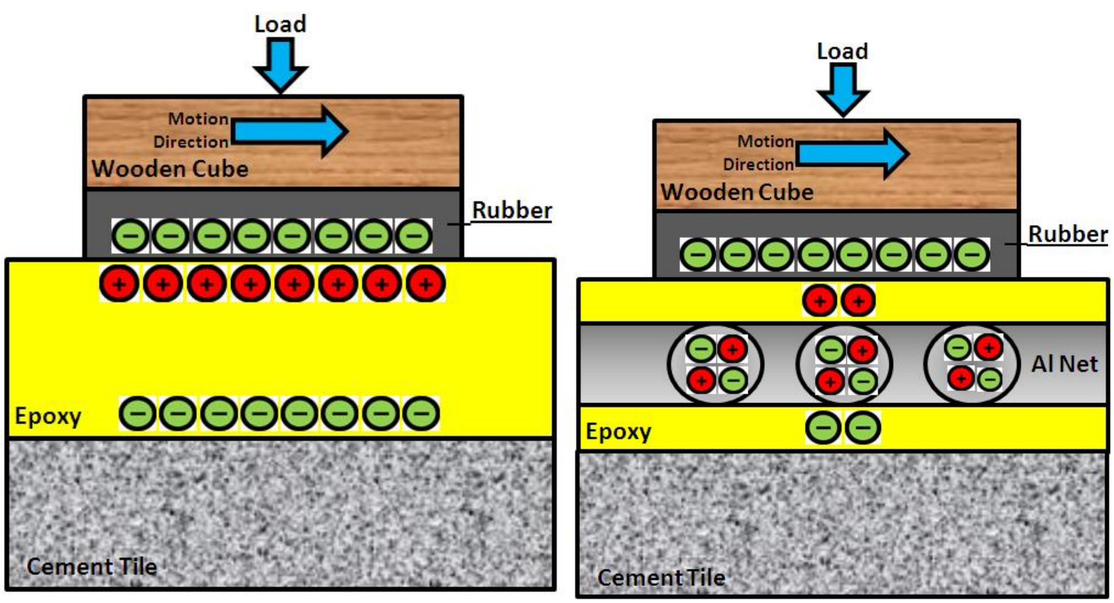

Fig. 5 Distribution of ESC on epoxy composite and rubber surfaces.

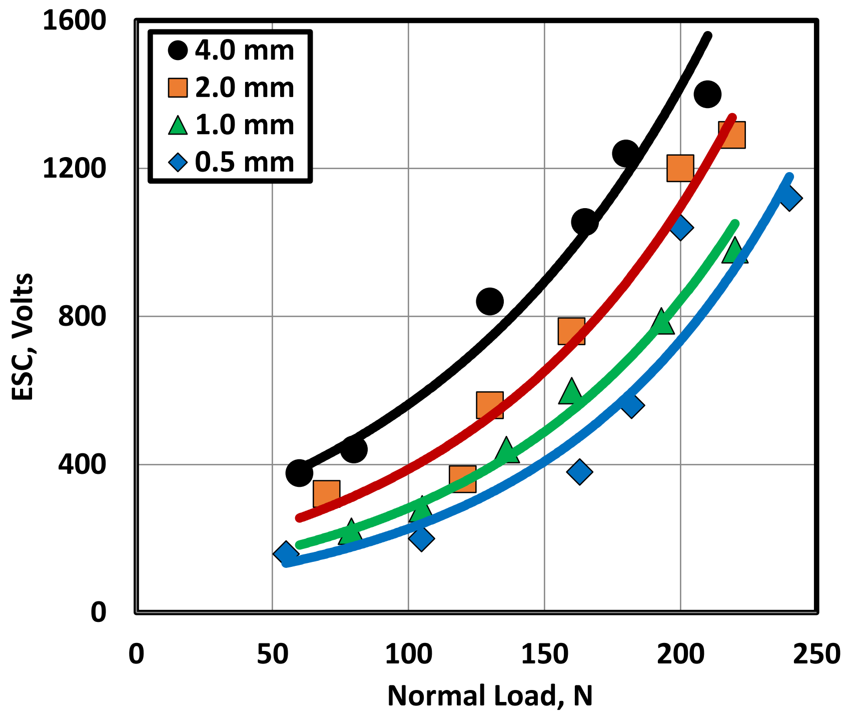

Fig. 6 ESC generated on dry epoxy when rubber slid on it.

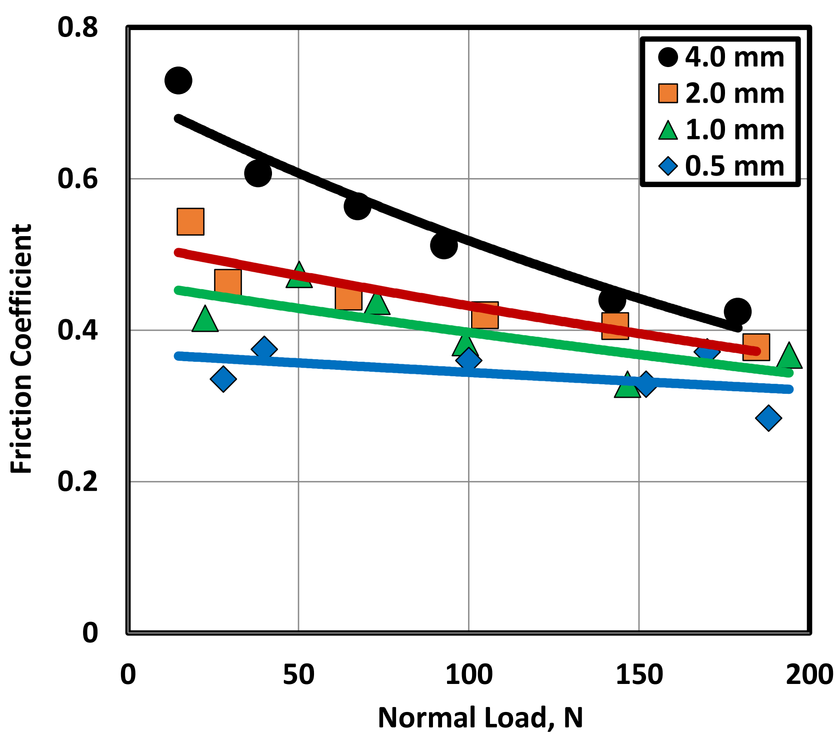

Fig. 7 Friction coefficient displayed by rubber sliding against water wet epoxy.

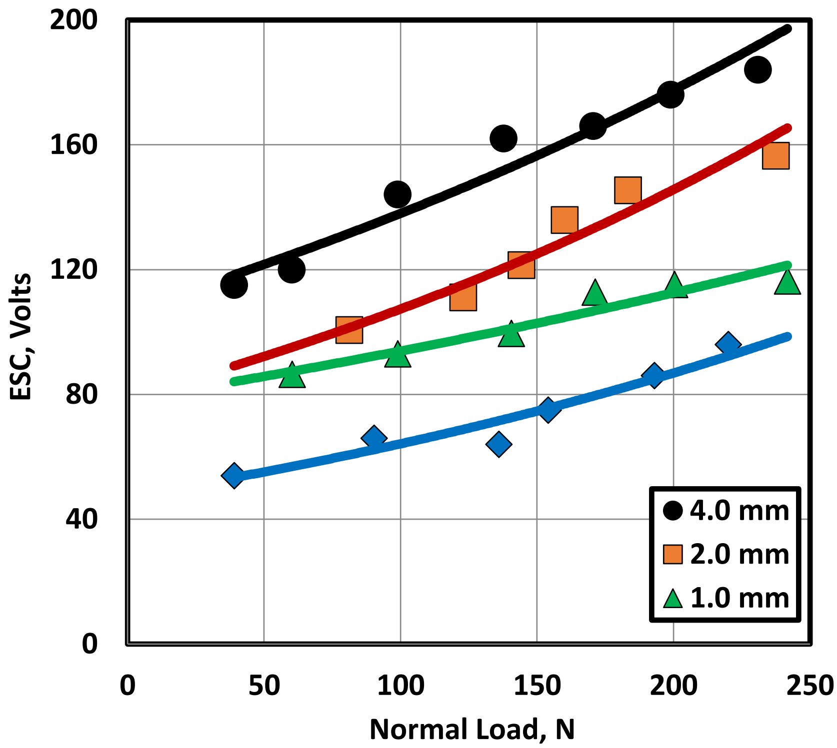

Fig. 8 ESC generated on water wet epoxy when rubber slid on it.

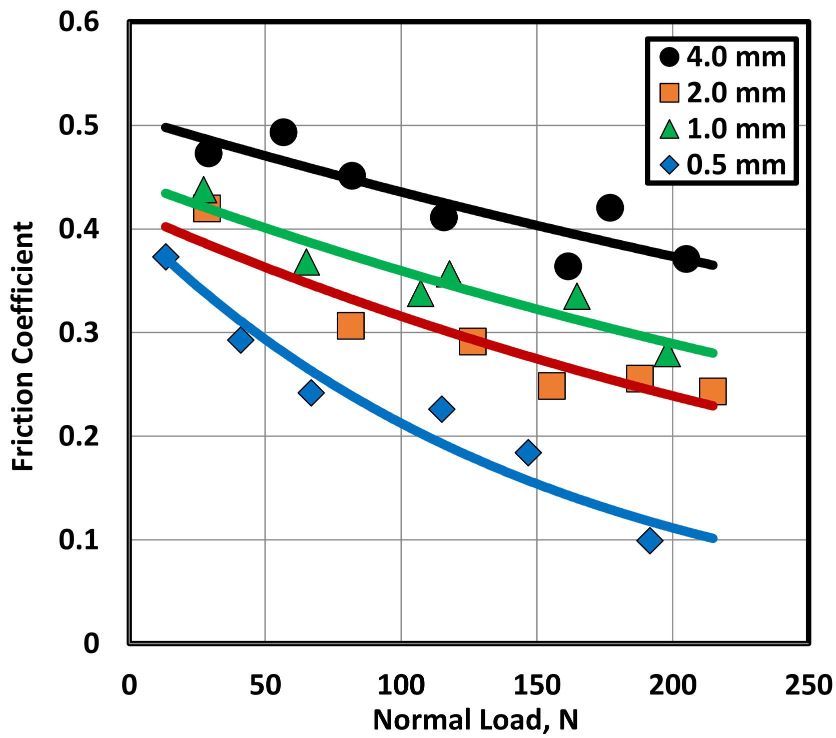

Fig. 9 Friction coefficient displayed by rubber sliding against epoxy covered by sand particles.

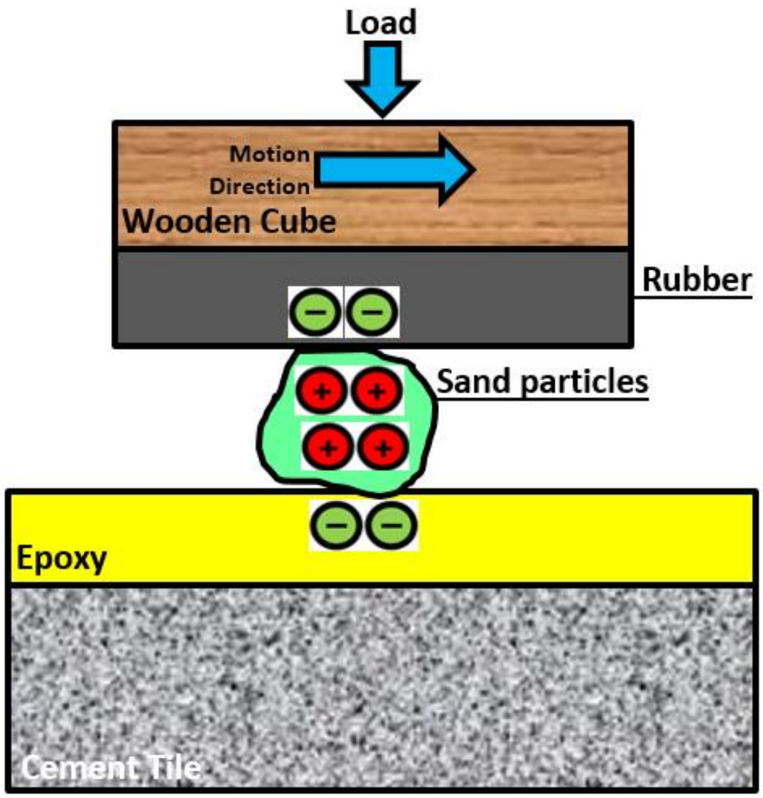

Fig. 10 Distribution of ESC on epoxy composite and rubber surfaces.

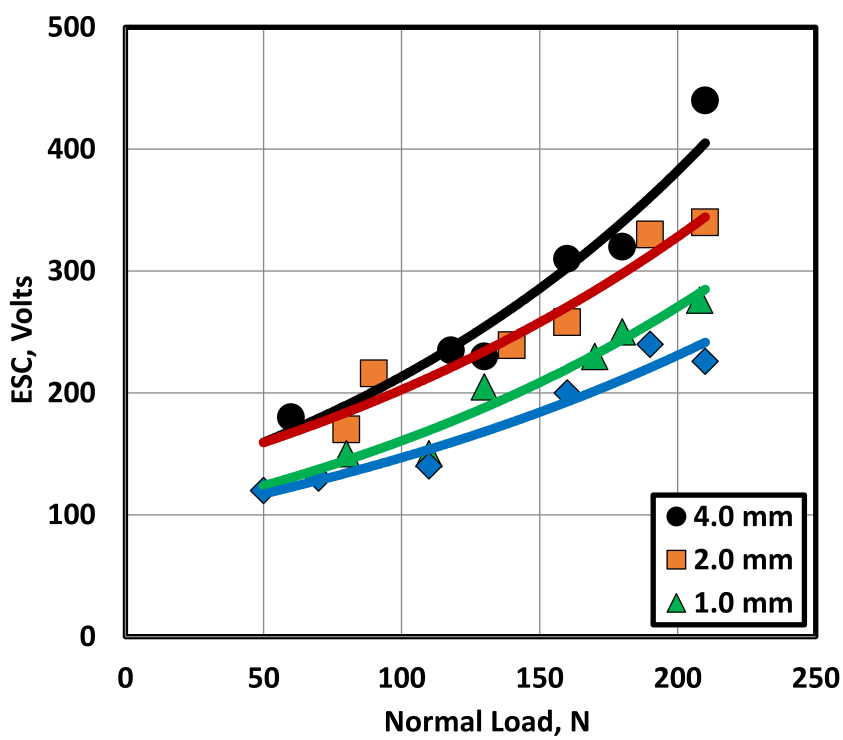

Fig. 11 ESC generated on epoxy covered by sand particles when rubber slid on it.

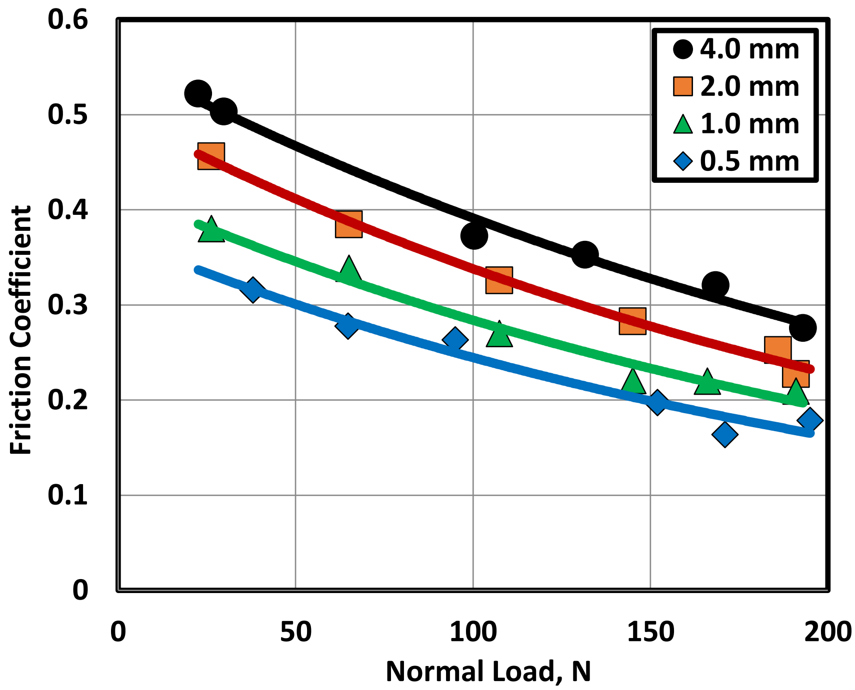

Fig. 12 Friction coefficient displayed by sock sliding against dry epoxy.

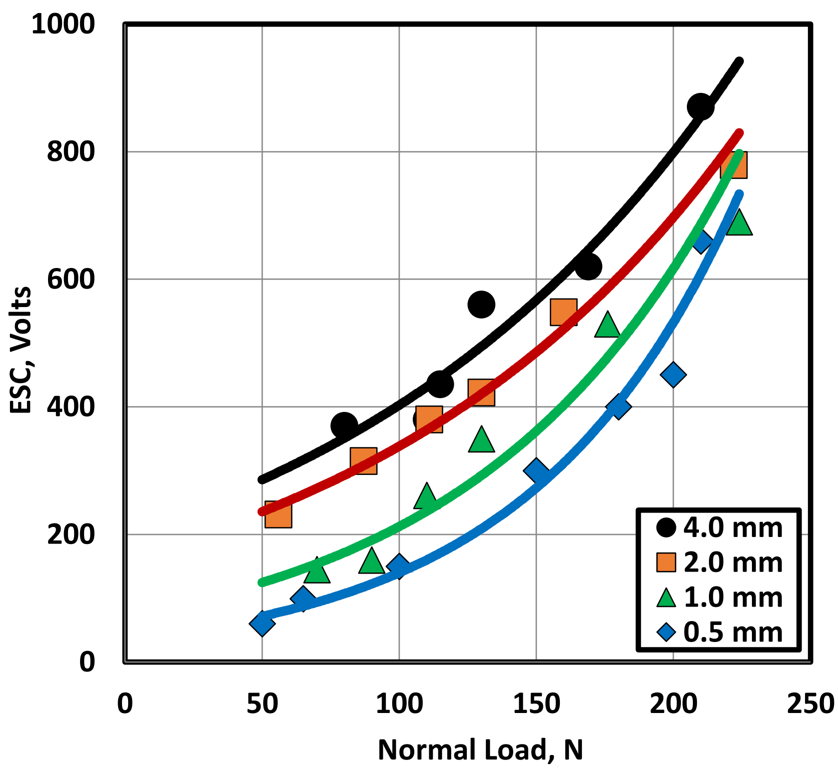

Fig. 13 ESC generated on dry epoxy when sock slid on it.

The same effect of Al screen is observed for socks sliding against epoxy composites, Fig. 12. Friction coefficient decreased with increasing applied load and decreasing the mesh size of Al screen. This observation confirmed the influence of ESC on friction coefficient, where the values of friction can be enhanced by controlling ESC generated on the sliding surfaces. ESC significantly increased up to 880, 750, 700 and 600 volts for epoxy reinforced by Al screen of 4.0, 2.0, 1.0 and 0.5 mm mesh size at 220 N load respectively. These values were higher than that noticed for sand contaminated sliding.

CONCLUSIONS

1. At dry sliding , friction coefficient decreased with increasing the normal load.

2. As the mesh size of Al screen reinforcing epoxy increased, ESC generated on the sliding surfaces and friction coefficient increased due the increase of adhesion between epoxy and rubber.

3. At water wet sliding, , the observed values of friction coefficient and ESC were relatively lower than observed for dry sliding. Friction values reflected that the effect of ESC was much higher than the effect of water film. This behavior is attributed to the good conductivity of water that facilitates equalizing ESC generated on the two contact surfaces.

4. Sand contaminated sliding displayed lower values of friction coefficient and ESC than that measured for dry and water wet sliding. That is because sand particles partially disables the contact between epoxy and rubber surfaces.

5. The same trend was observed for sliding of cotton sock on epoxy composites, while ESC recorded higher values than that noticed for sand contaminated sliding.

REFRENCES

1. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Electric Static Charge Generated from Sliding of Epoxy Composites Reinforced by Copper Wires against Rubber", EGTRIB Journal, Vol. 12, No. 3, July 2015, pp. 28 – 39, (2015).

2. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Increasing the Safety of Walking against Epoxy Floorings Reinforced by Metallic Wires", KGK, 05 2016, pp. 54 – 59, (2016).

3. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Effect of Electric Static Charge on Friction Coefficient Displayed by Sliding of Rubber Sole Against Epoxy Floor Reinforced by Copper Wires", EGTRIB Journal, Vol. 12, No. 4, October 2015, pp. 40 – 52, (2015).

4. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Frictional Behaviour of Epoxy Reinforced Copper Wires Composites", Advances in Materials Research, Vol. 4, No. 3, pp.165 -177, (2015).

5. El-Sherbiny Y. M., Samy A. M. and Ali W. Y., "Electric Static Charge Generated from Bare Foot and Footwear Sliding Against Flooring Materials", Journal of the Egyptian Society of Tribology, Vol. 11, No. 1, January 2014, pp. 1 – 11, (2014).

6. Greason W. D., "Investigation of a Test Methodology for Triboelectrification", Journal of Electrostatics, 49, pp. 245 - 56, (2000).

7. Diaz AF, Felix-Navarro RM., "A Semi-Quantitative triboelectric Series for Polymeric Materials", Journal of Electric statics, 62, pp. 277 - 290, (2004).

8. Al-Qaham Y., Mohamed M. K. and Ali W. Y., "Electric Static Charge Generated From the Friction of Textiles", Journal of the Egyptian Society of Tribology Vol. 10, No. 2, April 2013, pp. 45 – 56, (2013).
9. El-Sherbiny Y. M., Abdel-Jaber G. T. and Ali W. Y., "Friction Coefficient and Electric static Charge Generated From Rubber Footwear Sliding Against Flooring Materials", Journal of the Egyptian Society of Tribology, Vol. 11, No. 4, October 2014, pp. 13 - 24, (2014).
10. AlOtaiby A., Elhabib O. A. and Ali W. Y., "Reducing Electric Static Charge Generated From Epoxy Flooring Materials", Journal of the Egyptian Society of Tribology, Vol. 11, No. 4, October 2014, pp. 25 - 35, (2014).
11. 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. 1306 - 1312, (2014).
12. Elhabib O. A., Mohamed M. K., AlKattan A. A. and Ali W. Y., "Triboelectrification of Flooring Polymeric Materials", International Journal of Scientific & Engineering Research, Volume 5, Issue 6, June 2014 , pp. 248 - 253, (2014).