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REDUCING ELECTROSTATIC CHARGE GENERATED FROM SLIDING AGAINST POLYMERIC FLOOR IN HOSPITALS

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ABSTRACT
The present work proposes a method to reduce the electrostatic charge (ESC) generated on the the polymeric floor materials and polypropylene shoes used in hospitals. Copper strips are adhered to the back of the floor material and grounded to guarantee the leakage of the generated ESC when polypropylene shoes sliding against the floor.

Based on the experimental tests, it is observed that ESC has increased with increasing the number of strips, due to the generation of the double layer of ESC on the sliding surfaces. Thus, an electric field is generated leading to the generation of an extra ESC especially in the presence of copper strips. The increase of ESC consequently increases the adhesion force between the two surfaces, which lead to the increase friction coefficient. This observation can reduce the risk of slip accidents.

The presence of water/chlorine wet surface decreases the voltage lower than that generated at dry condition, where the water distributed the ESC. However, the friction coefficient slightly decreases (7 %), which confirms the safety of the floor material and prevents slip accidents during walking especially in the presence of water. The grounding system significantly decreases the voltage in floor material fitted by six strips by 79%.

KEYWORDS
Electrostatic charge (ESD), friction coefficient, floor material, copper strips, safety of walking.

INTRODUCTION
Polymeric materials aim to become more and more important in various industries as attractive substitutes to metals. Many studies have been conducted on the friction and wear of polymers, [1 – 3]. This phenomenon is called ‘triboelectric charging’ or ‘contact electrification’. The charged particles cause problems such as particle deposition and adhesion. ESD plays an important role in the friction coefficient of the rubbing insulators, [4]. Triboelectric charging of granular systems is widely observed in

industrial and natural systems, [5, 6]. The charging process is currently so poorly understood that it is not even clear whether it is the transfer of electrons or ions that causes charging, [7, 8]. The electrostatic charge effects (high voltage, surfaces sticking together, etc.) occur when an excess of either positive or negative charge becomes confined in small volume, isolated from charges of the opposite polarity.

In addition, if particles are excessively charged, an electrostatic discharge may occur, which can pose a risk of fire and explosion hazards; thus, to mitigate the adverse effects, it is important to elucidate the underlying triboelectric charging mechanisms. The electrostatic is, on the other hand, very useful in a number of applications that have been developed using the principles, [9]. Friction coefficient slightly increased with increasing metallic content. Based on the quantification of floor slip-resistance, the static friction coefficient of 0.5 was recommended as the slip resistant standard for normal walking conditions. For the test specimens friction coefficient exceeded 1.0 which confirmed that the floor made of the tested composites will be very safe for walking. At brass content where the generated voltage diminished, friction coefficient value approached 1.4. This observation recommends that composites to be used as floor tiles. Besides, addition of copper particles caused significant friction increase, [10]. The factors affecting friction coefficient measurement were the material and surface geometry of the footwear and floor, floor contamination conditions and even the slipmeter used, [11, 12]. Investigators have concentrated on the friction coefficient measurements on liquid contaminated floors because most slip/fall incidents occur on the surfaces of such floors, [13].

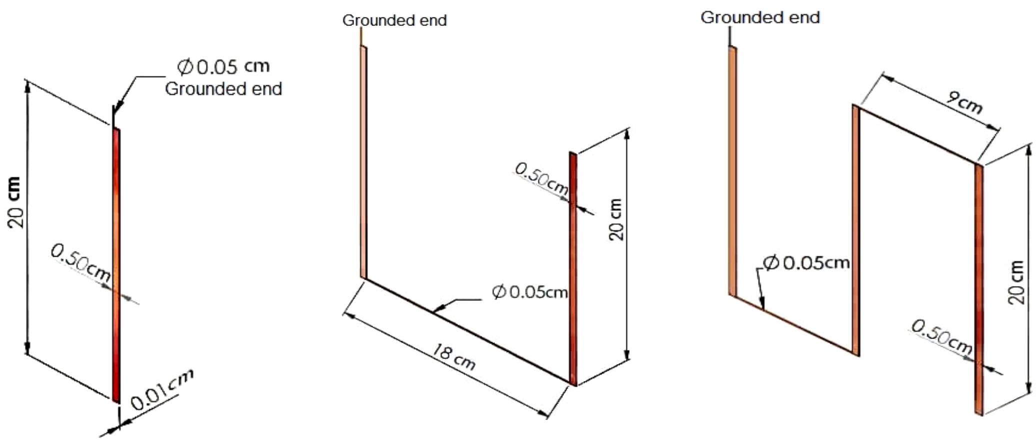
Safe walking on the floor was evaluated by the static friction coefficient. Few researches paid attention to the ESD generated during walking on the floor. It is well known that walking and creeping on floor can generate ESD of intensity depends on the material of floor. The effect of the static charge generation on the environment is influenced by electrical conductivity of the sliding surfaces. The effect of the type of floor materials on the generation of ESD and friction coefficient was discussed, [14].Relatively higher static and dynamic friction coefficient values may be required for safe walking when handling loads. There were two types of slips involved in pallet truck pulling. The slip distances of both of these slips interacted significantly with the weights of the load and the floor surface conditions, [15]. Voltage was influenced by the load, where it increased with load increasing. Based on the present observations, it can be concluded that as the electrical conductivity of the metallic particles increased the metallic particles content to obtain the zero voltage decreased. Voltage generated from the sliding of the tested composites against rubber was much higher than that observed at contact and separation, [16]. Based on the experimental observations, friction coefficient increased with increasing the diameter and the number of copper wires thus because, they were strongly influenced by the electric field and consequently the electric charge increased leading to an increase in friction coefficient, [17]. The double layer of the ESD generated on the sliding surfaces would generate an E-field inside the matrix of epoxy. Presence of copper wire inside epoxy matrix would generate extra ESD on the sliding surfaces leading to further increase in the adhesion force acting between the two sliding surfaces and causing significant increase in friction coefficient. Presence of water film facilitated the

distribution of ESD on the sliding surface. Detergent wetted sliding wetted sliding displayed values of friction much lower than that observed at water wetted sliding, [18].

In this study, ESD and friction coefficient have been measured during sliding against floor materials (A & B) under different loads ranging from 20 N to 200 N. The experimental tests have been carried at room temperature at dry and water/chlorine wet floor surface.

EXPERIMENTAL WORK

Figure 1 illustrates the copper strips adhered to the back of the sheet of floor material (A & B) by 300 × 400 mm² area and 5 mm thickness. The normal and friction forces are measured by using the friction test rig, where the base of the device is supported by two load cells: one measuring normal force and other cell measuring friction (horizontal force). Those load cells are attached by digital screens, as shown in Fig. 2. The friction coefficient was calculated by dividing friction force by the normal force and the sliding test was carried out at room temperature under different values of applied normal loads. The Arrangement of the experimental test is shown in Fig.4. After sliding 200 mm, against the floor material, the ESD generated on the polypropylene shoe is measured by using (Ultra Stable Surface Voltmeter) device. It measures from 0.1 to 20000 volts and readings are normally done with the sensor 25 mm from the tested surface.



One strip **Two strips** **Three strips**

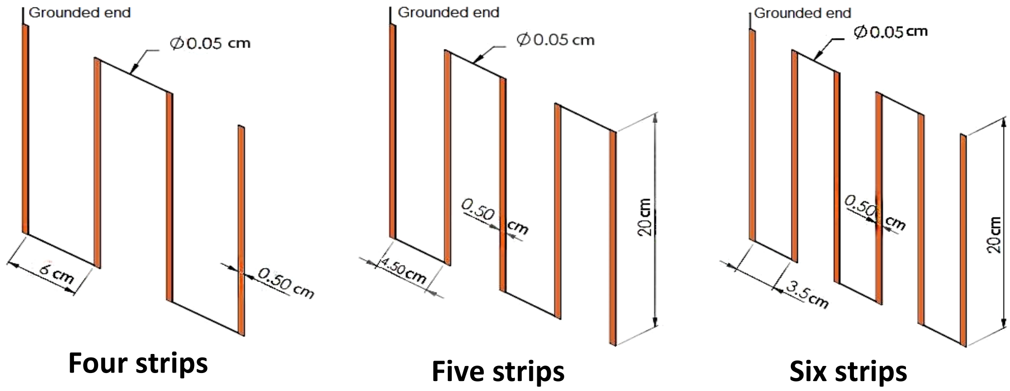


Fig.1 Distribution of the copper strips.

Table 1. The properties of floor materials A & B.

Material properties	***Material (A)***	***Material (B)***
Electrical resistance	**$5\times10^4 \leq$ R$\leq 10^6$ Ohms**	**R $\leq 10^8$ Ohms**
Static electrical charge	**< 2 KV**	**< 2 KV**
Total weight/m²	**3000 gram**	**3000 gram**
Slip resistance	**≥ 0.3 Low risk of slip**	**≥ 0.3 Low risk of slip**
Abrasion Thickness	**loss≤ 0.15mm Volume loss ≤ 4 mm³**	**Volume loss ≤ 4 mm³**
Bacteria and fungi resistance	**Does not favor growth**	**Does not favor growth**
Chemical resistance	**Good resistance**	**Good resistance**

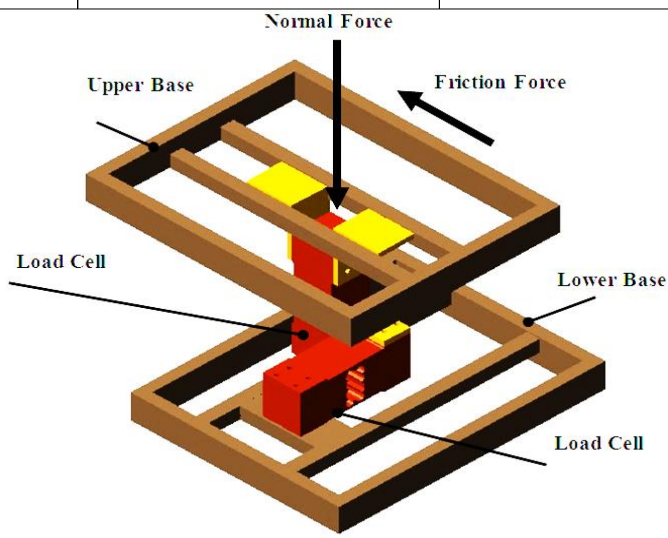


Fig. 2 Arrangement of the test rig.

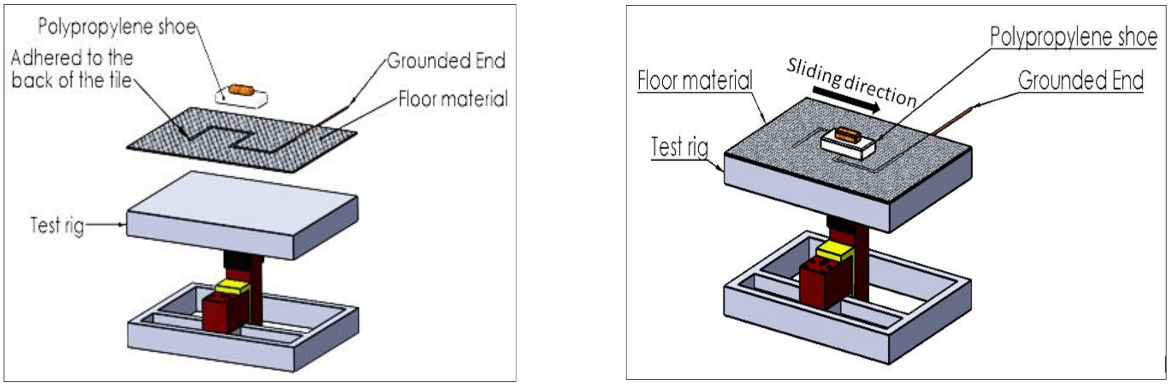


Fig. 3 Procedure of the test.

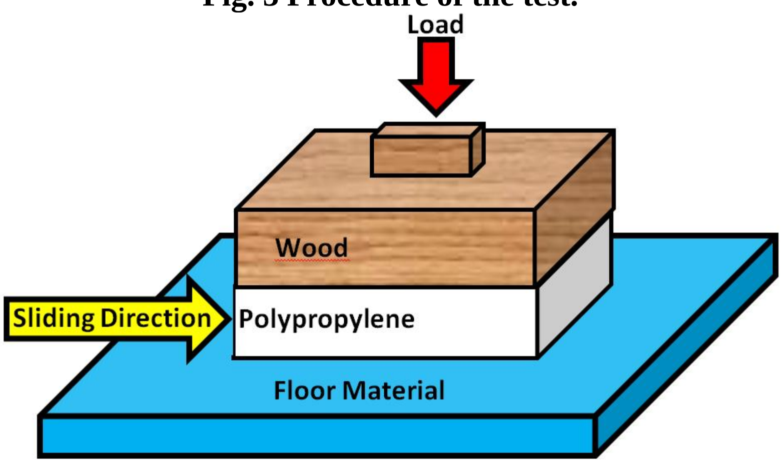


Fig. 4 Details of the sliding surfaces.

RESULTS AND DISCUSSION

After sliding against dry floor material (A), it has been noticed that the ESD generated on the floor material increased by increasing the number of strips, Fig. 5. The highest value of the generated voltage was 392 volts in specimen free of strips, while it was 979 volts in specimen fitted by six strips under the same applied load. This increase is attributed to the generation of the double layer of ESD and the presence of copper strips generated an extra of ESD. It was also noted that the voltage gradually increases with increasing applied normal load where the intensity of the generated charge depends on the pressure during sliding.

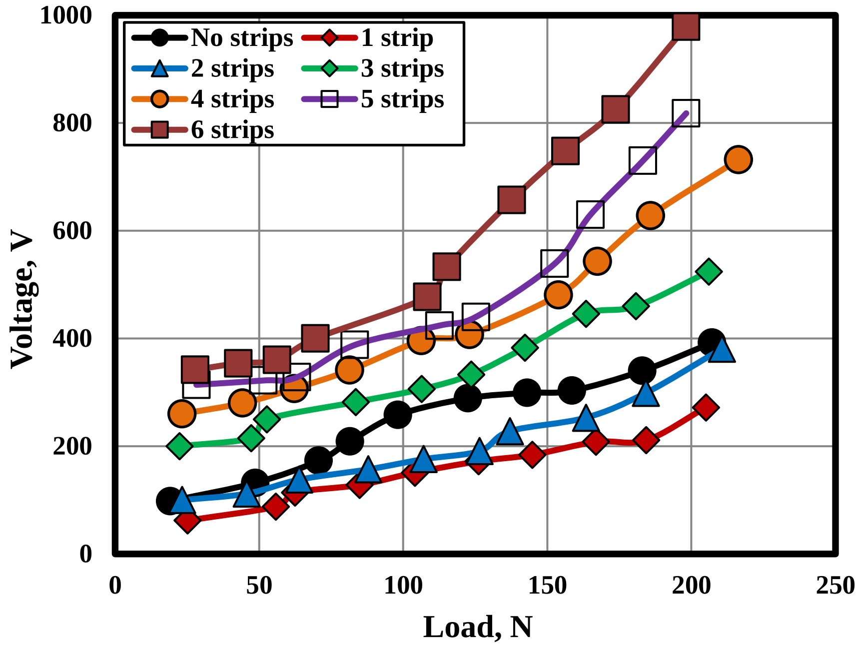


Fig. 5 Effect of number of strips on ESD on ungrounded material (A) at dry sliding.

The floor material as insulator contains a distribution of charges which are conserved, once the polypropylene shoe slides against the floor material, the double layer of ESC generates and consequently the generated electric field increases. Presence of copper strips adhered to the back of the floor material generates extra ESC on the sliding surface and increases the ESC. Based on that observation, it can be noticed that the ESC increases by increasing the number of strips, Fig.6.

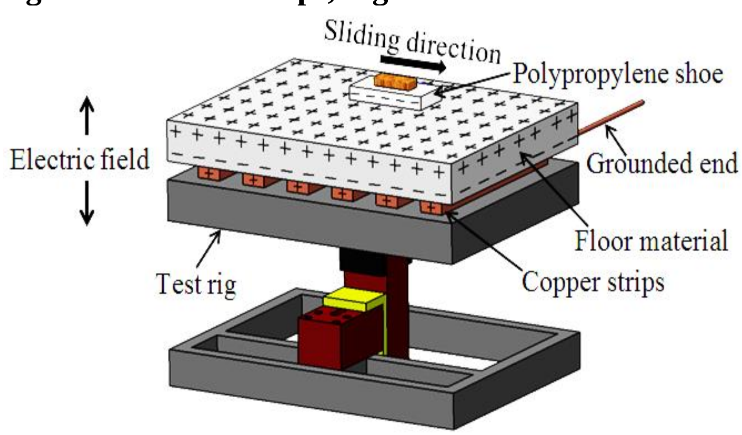


Fig. 6 Schematic illustration of ESC generated on ungrounded floor material and polypropylene.

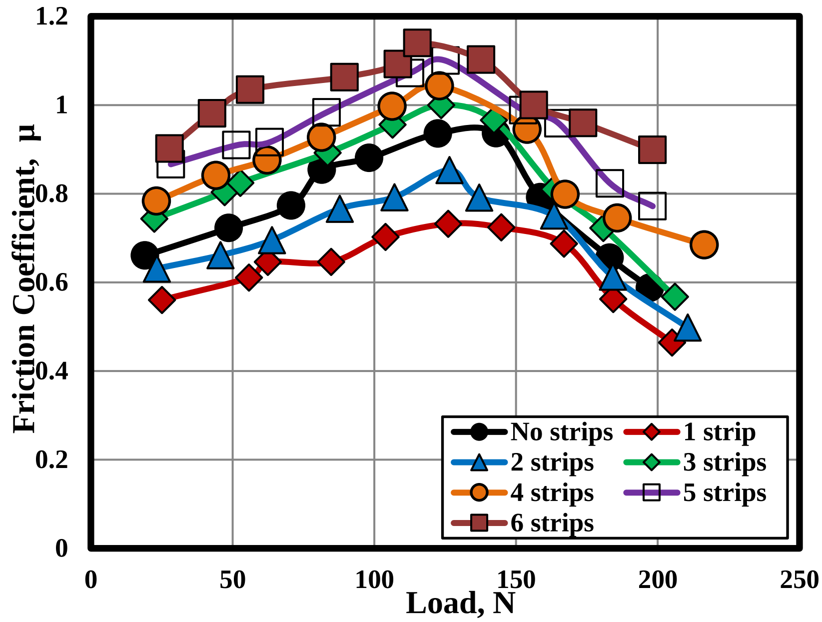


Fig. 7 Effect of number of strips on friction coefficient on ungrounded material (A) at dry sliding.

Figure 7 illustrates that the copper strips increase the friction coefficient from 0.94 in the specimen free of strips to 1.14 in the specimen fitted by six strips under the same applied load. It seems that increasing ESD, as illustrated in Fig. 5, increases the adhesion between contact surfaces and consequently the friction coefficient increases. This increase has a favorite effect which avoids slip accidents as a result of excessive movement during walking.

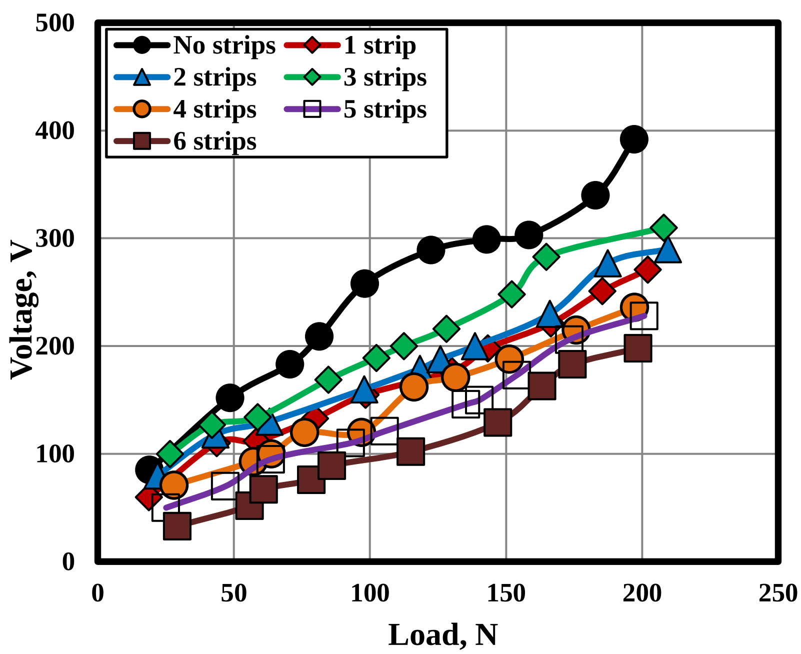


Fig. 8 Effect of number of strips generated on ESD on grounded material (A) at dry sliding.

Figure 8 shows that the voltage has decreased frequently with increasing the number of strips where, it was 198, 228 and 236 volts in the floor material fitted by six, five and four strips respectively at 200 N load. The grounded system has facilitated the leakage of the generated voltage from 979 in Fig. 5 to 198 volts in Fig. 8 in the specimen fitted by six strips.

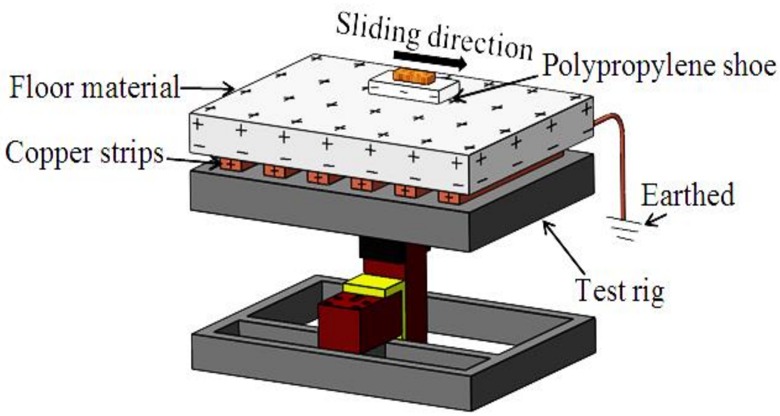


Fig. 9 Schematic illustration of ESD generation on the grounded floor material and polypropylene.

If the materials are then separated the charge will try to leak to earth. If there is no conducting path the charges remain on the sliding surface as static electricity. The grounding design test drastically decreased the ESD. Thus because, the grounding facilitated the leakage of an amount of voltage which is collected by adding the copper strips as discussed in Fig. 9. When the grounded end was connected to the earth, the charge escaped to the ground and reduced the gap between the positive and negative charges. This discussion confirms a decrease of voltage which observed in Fig. 8. The decrease of generated voltage because of the grounded system has a pronounced effect on adhesion force between contact surfaces where friction coefficient decreases. The friction coefficient decreases down to 0.74 in the floor material fitted by six strips as illustrates in Fig. 10 compared to what is observed (1.14) in Fig. 7.

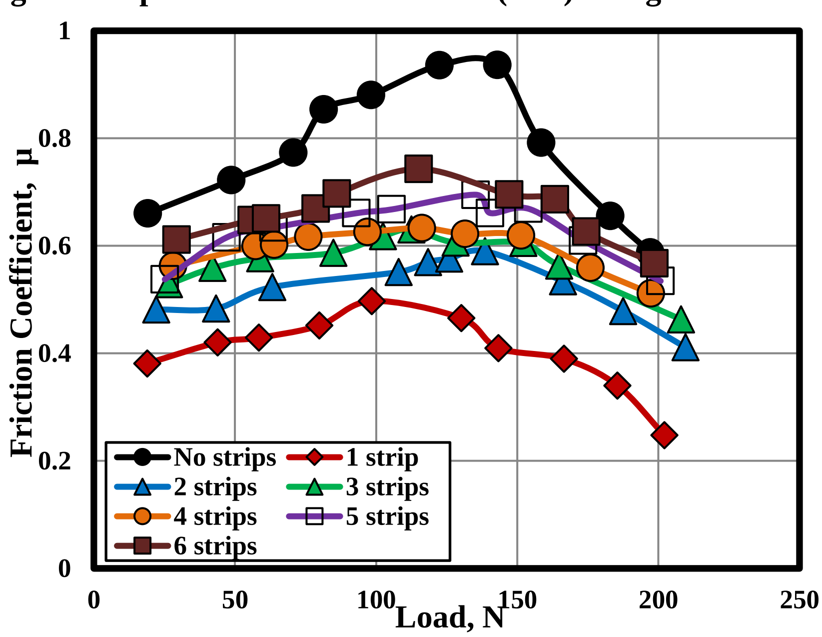


Fig. 10 Effect of number of strips on friction coefficient of grounded material (A) at dry sliding.

Dry sliding of polypropylene shoe against floor material B shows the same trend of results, where the voltage increases with increasing the number of strips and increasing the applied normal load, Fig.11. The electrical properties of the floor material have affected the voltage, where the ESC was 979 volts in Fig. 5 and decreased down to 817 volts in Fig.11 at the same sliding conditions. The electrical resistance of the floor material B is higher than that measured for material A, therefore ESC generated on material B decreases. Consequently, friction coefficient displayed by floor material B decreases. Figure 12 illustrates that the maximum value of friction coefficient on material B is 1.08 lower than that observed for floor material A fitted by six strips.

Grounding the copper strips decreased ESD from 817 volts in Fig. 11 to 174 volts in Fig. 13 for floor material B fitted by six strips. Friction coefficient decreases due to the decrease of voltage observed in Fig. 13. The increase of number of strips causes slight increase in friction coefficient up to 0.47, 0.56 and 0.64 for floor material B fitted by one, three and five strips respectively.

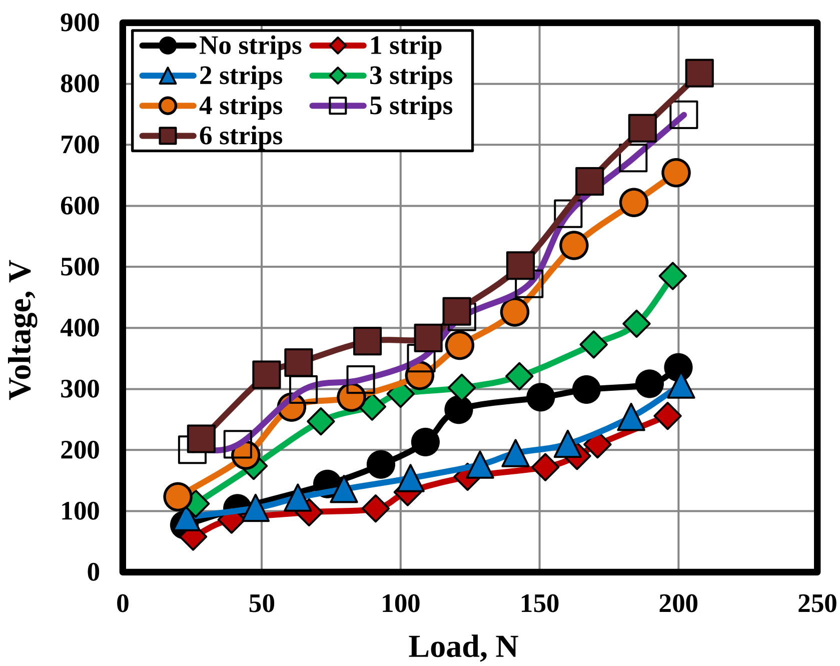


Fig. 11 Effect of number of strips on ESD on ungrounded material (B) at dry sliding.

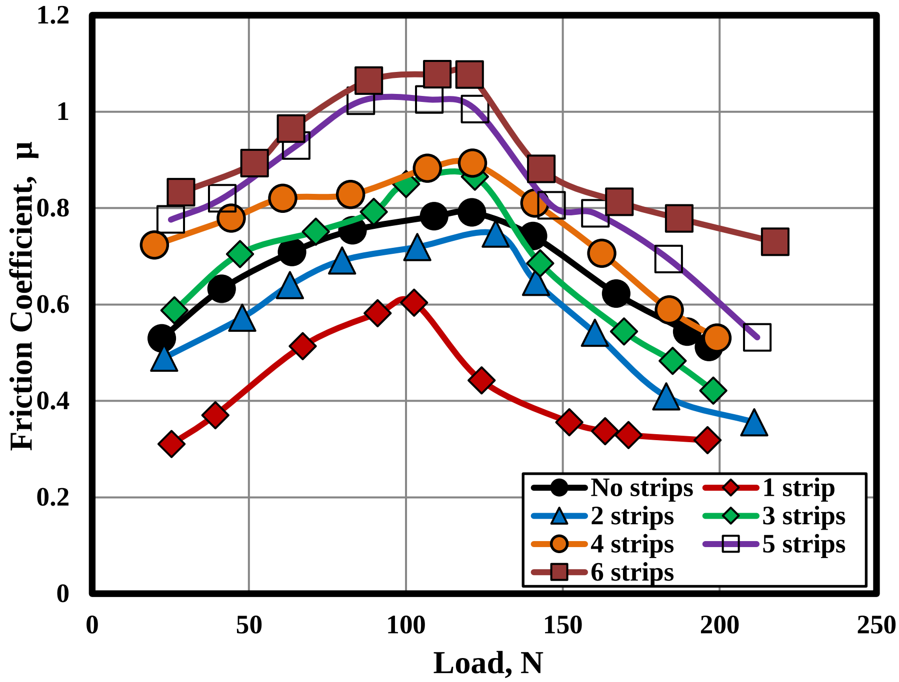


Fig. 12 Effect of number of strips on friction coefficient on ungrounded material (B) at dry sliding.

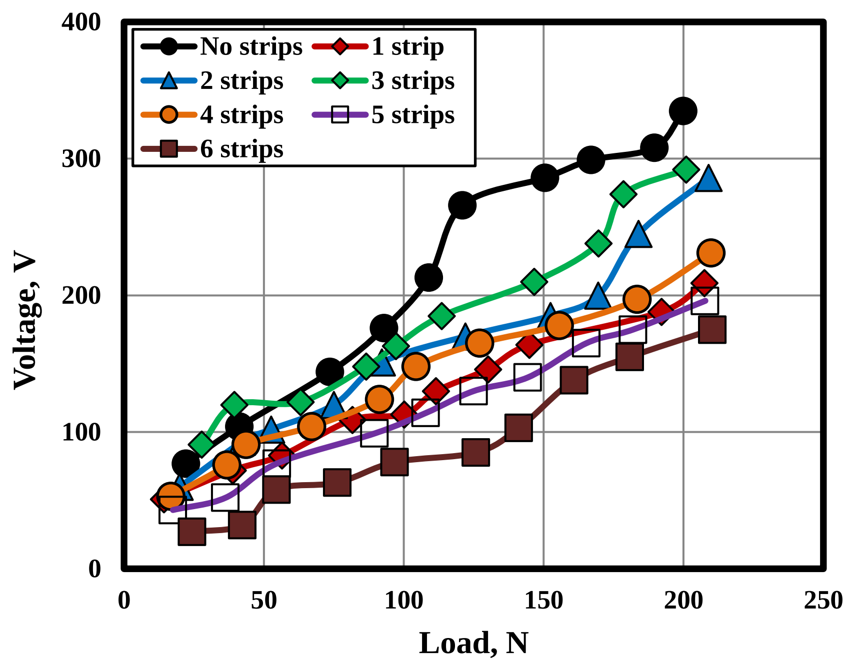


Fig. 13 Effect of number of strips on ESD on grounded material (B) at dry sliding.

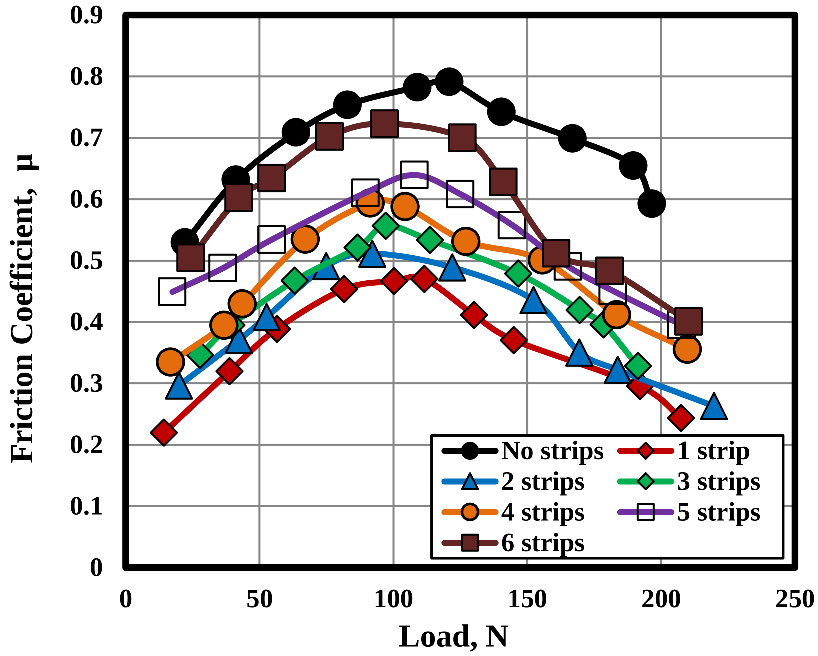


Fig. 14 Effect of number of strips on friction coefficient on grounded material (B) at dry sliding.

Figure 15 shows that ESC generated on polypropylene shoe during sliding against water/chlorine wet floor material A is lower than that observed at dry sliding in Fig. 5. Where the highest voltage is 137 volts compered to Fig. 5 where it is 979 volts for floor material fitted by six strips. Also, voltage decreases from 392 to 37 volts for specimen free of strips. This behavior is attributed to the good conductivity of water which facilitates leaking the generated charge out of the contact area.

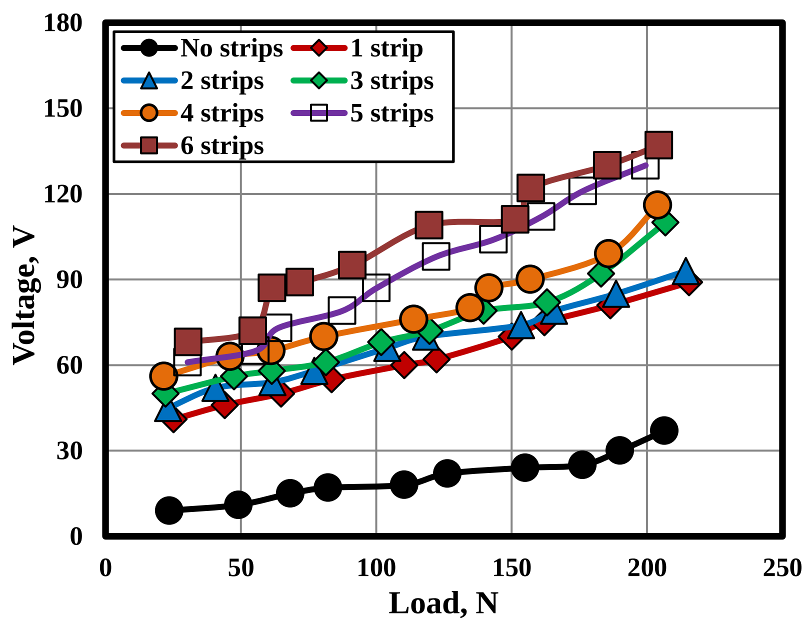


Fig. 15 Effect of number of strips on ESD on ungrounded material (A) at wet chlorine sliding.

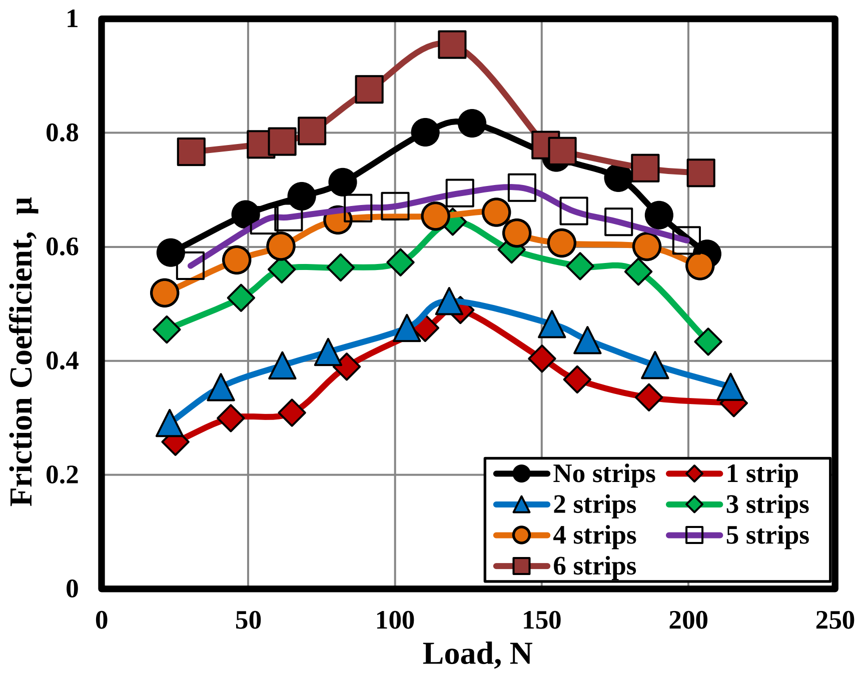


Fig. 16 Effect of number of strips on friction coefficient on ungrounded material (A) at chlorine wet sliding.

Presence of water/chlorine dilution wet surface facilitated decreasing voltage and friction coefficient. The friction coefficient decreases from 1.14 for dry sliding to 0.95 for wet sliding in the specimen fitted by six strips. But the friction coefficient decreases slightly (16 %). That behavior confirms that the floor material can be used safely during walking against water/chlorine wet floor. Grounded copper strips decreases ESC in the presence of water film more than dry sliding. ESC decreases from 198 volts in Fig. 8 to 23 volts in the specimen fitted by six strips. This result confirms that, grounding copper strips is the best way to leak ESC especially in the specimen fitted by six copper strips.

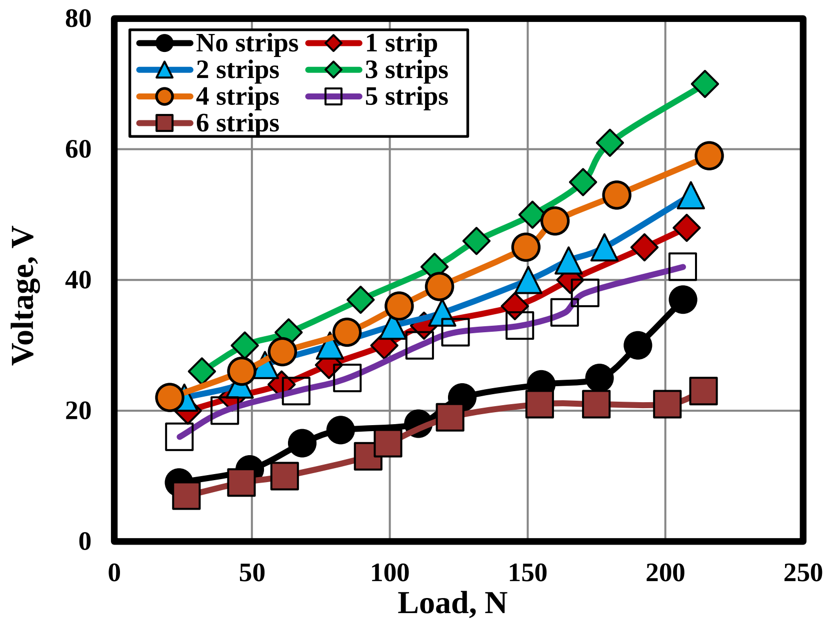


Fig. 17 Effect of number of strips on ESD on grounded material (A) at chlorine wet sliding.

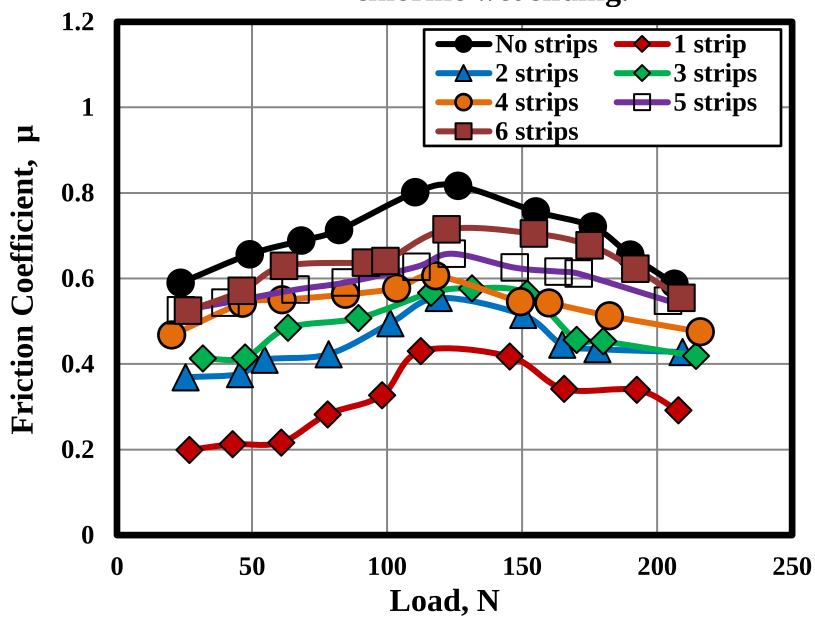


Fig. 18 Effect of number of strips on friction coefficient on grounded material (A) at chlorine wet sliding.

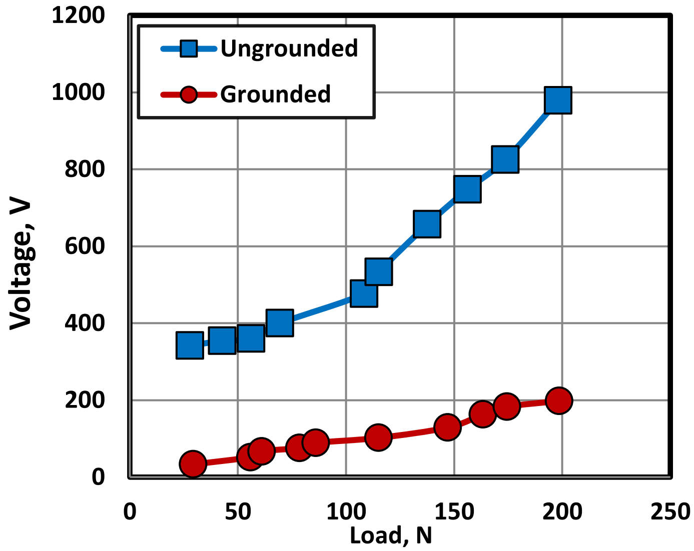


Fig. 19 Effect of type of grounding of the six copper strips on ESC generated on floor material (A) at dry condition.

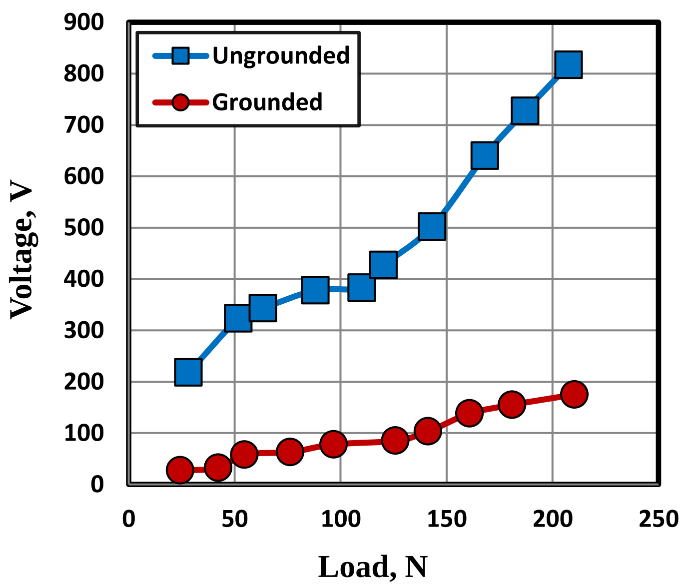


Fig. 20 Effect of type of grounding of the six copper strips on ESC generated on floor material (B) at dry condition.

The presence of chlorine in water on the floor material causes a high reduction in the generated voltage as shown in Fig. 17. Friction coefficient slightly decreases from 0.74 in Fig. 10 to 0.71 in Fig. 18. This performance confirms that the presence of copper strips causes drastic decrease in ESC and on the other hand enhances the friction coefficient to avoid slip accidents during walking. It is shown in Fig. 19 that, grounding copper strips drastically decreases ESC due to its leakage. When the grounded end was connected to the earth, ESD leaked to the ground by approximately 79%.

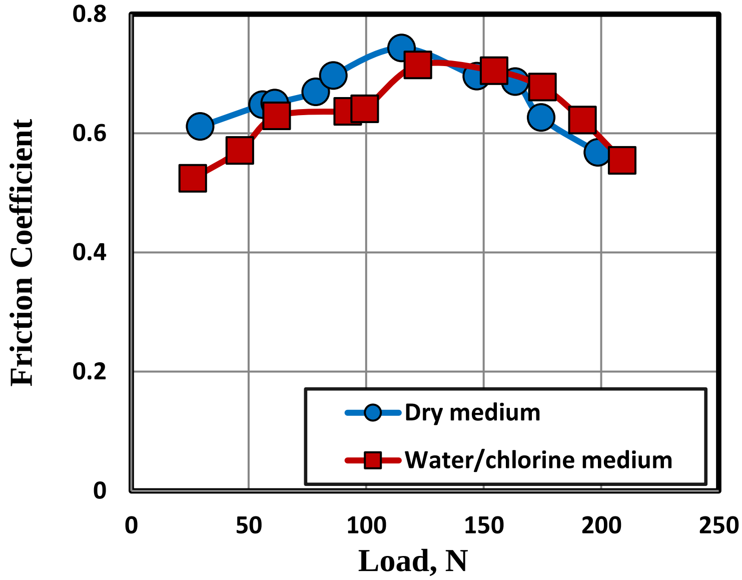


Fig. 21 Effect of type of medium on friction coefficient on grounded floor material (A).

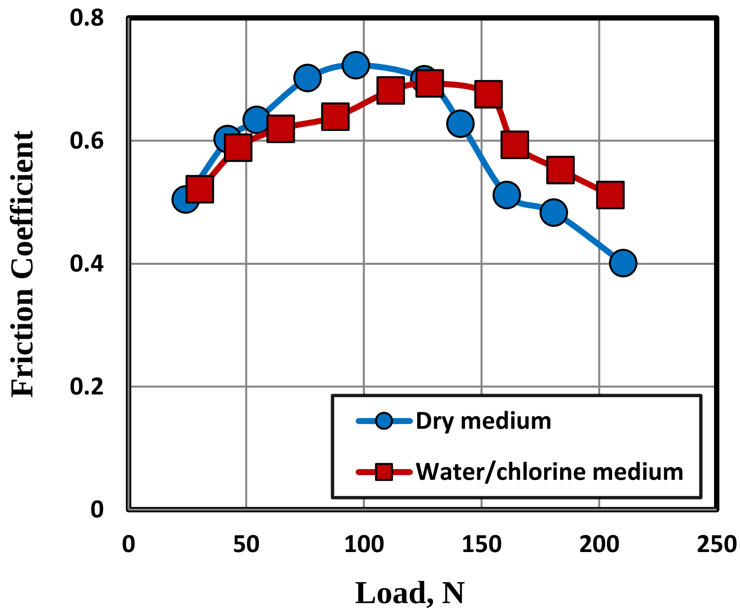


Fig. 22 Effect of type of medium on friction coefficient on grounded floor material (B).

Figure 20 illustrates the same trend of results in Fig.19 but, the floor material B causes lower decrease in ESC due to its higher electrical resistance. The use of six copper strips improves the friction coefficient where it slightly decreases (7 %) in the presence of water/chlorine dilution as shown in Fig. 21. The use of floor material B fitted by grounded six copper strips, Fig. 22, can be recommended to enhance the friction coefficient and decrease the ESD.

CONCLUSIONS

1. The ESD increases by increasing the number of copper strips, because the double layer of the ESD generated on the sliding surfaces causes an E-field which generates an extra ESD.

2. The increase of the ESD has a pronounced effect on adhesion force between the contact surfaces leading to an increase in the friction coefficient.

3. The grounding facilitates the leakage of 78 % of the generated ESD and consequently decreases the friction coefficient by 35 %.

4. At water/chlorine dilution wet sliding, the ESD is lower than that generated in dry sliding. This is due to the electrical conductivity of water, and on the other hand, the friction coefficient decreases only by 7 %, confirming the enhancement of the friction coefficient and avoiding slip accidents due to excessive movement, especially at wet sliding.

5. The floor material B generated ESD lower than that observed in floor material A. That may be attributed to the relatively higher electrical resistance of material B than A.

6. Finally, it can be recommended to use the floor material B fitted by grounded six copper strips.

REFERENCES

1. Myshkin N., Petrokovets M. and Kovalev A., "Tribology of polymers: friction, wear and mass transfer", Tribol. Int., Vol. 38, pp. 910 - 921, (2005).

2. Brostow W., Deborde J. L., Jaklewicz M. and Olszynski P., "Tribology with emphasis on polymers: friction, scratch resistance and wear", J. Mater. Ed., Vol. 25, pp. 119 - 132, (2003).

3. Brostow W., Kovacevic V., Vrsaljko D. and Whitworth J., "Tribology of polymers and polymer based composites", J. Mater. Ed., Vol. 32, pp. 273-290, (2010).

4. Ulrich P., "An overview of standards concerning unwanted electrostatic discharges", Journal of Electrostatics, Vol. 67, pp. 445 - 452, (2009).

5. Schien L.B., "Recent progress and continuing puzzles in electrostatics", Science 316, pp. 1572 – 1573, (2007).

6. McCarty L. S., Whitesides G.M., "Electrostatic charging due to separation of ions at interfaces: contact electrification of ionic electrets", Angew. Chem. Int. Ed. 47, pp. 2188 – 2207, (2008).

7. C. Liu, A.J. Bard, Electrostatic electrochemistry at insulators, Nat. Mater. 7 505–509, (2008).

8. AlOtaiby A., Elhabib O. A. and Ali W. Y., "Reducing Electrostatic charge Generated From Epoxy Floor Materials", Journal of the Egyptian Society of Tribology, vol. 11, No. 4, October 2014, pp. 25 – 35, (2014).

9. Chang W. R., "The effect of surface roughness on the measurements of slip resistance", International Journal of Industerial Ergonomics, Vol. 24 (3), pp. 299-313, (1999).

10. Chang W. R., "The effect of slip criteria and time on friction measurements", Safety Science, Vol. 40, pp. 593 - 611, (2002).

11. Chang W. R. and Mats S., "The slip resistance of common footwear materials measured with two slipmeters", Applied Ergonomics, Vol. 32, pp. 540-558, (2001).

12. Gronqvist R., "Mechanisms of friction and assessment of slip resistance of new and used footwear soles on contaminated floors", Ergonomics, Vol. 38 (2), pp. 224-241, (1995).
13. Manning D. P. and Jones C., "The effect of roughness, floor polish, water, oil and ice on underfoot friction: Current safety footwear solings are less slip resistant than microcellular polyurethane", Applied Erogonomics, Vol. 32, pp. 185-196, (2001).
14. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Electrostatic charge Generated From Sliding of Epoxy Composites Reinforced by Copper Wires Against Rubber", Journal of the Egyptian Society of Tribology, vol. 12, No. 3, pp. 28 – 39, (2015).
15. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Increasing The Safety of Walking Against Epoxy Floors Reinforced by Metallic Wires", Journal of the Egyptian Society of Tribology, Vol. 12, No. 3, pp. 40 - 54, (2015).
16. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Electrostatic Characteristics of Copper Wires Reinforced Epoxy Matrix Composites", Journal of the Egyptian Society of Tribology, Vol. 12, No. 2, pp. 55 - 68, (2015).
17. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Effect of Electrostatic charge on Friction Coefficient Displayed by Sliding of Rubber Sole Against Epoxy Floor Reinforced by Copper Wires", Journal of the Egyptian Society of Tribology, Vol. 12, No. 4, pp. 40 – 52, (2015).
18. Rehab I. A., Khashaba M. I. and Ali W. Y. "Electrostatic charge Generated On Floor Hospitals", Journal of Multidisciplinary Engineering Science and Technology (JMEST), Vol. 3 Issue 10, October – 2016, pp. 5729 – 5736, (2016).