EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 14, No. 1, January 2017, pp. 1 – 14 **ISSN 2090 - 5882**

ELECTROSTATIC CHARGE GENERATED ON FLOOR IN HOSPITALS

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ABSTRACT
The present work investigates two floor materials that are used in hospitals, operating rooms, intensive care units and factories. It is proposed to measure the electrostatic charge (ESC) generated on polypropylene shoes during walking against the tested floor materials.

The tested floor materials are provided by different numbers of copper strips adhered to their back, the strips are grounded to guarantee the leakage of the generated ESC. This test is carried under dry and water/chlorine dilution conditions. The experimental results showed that ESC increases by the increase of the normal load. Also, the measured voltage increases as the number of copper strips increases, where the strips work as conductor. In the case of water/chlorine wet contact surface, voltage displayed lower values than that generated at dry condition. It be concluded that the copper strips have increased the conductivity of floor material, where the grounding system significantly decreases the voltage by approximately 66% and 71% in the two tested floor materials.

KEYWORDS
Electrostatic charge, flooring material, copper strips, contact and separation test.

INTRODUCTION
Most matter is electrically neutral; the outer electron may be able to leave the atom it is orbiting under certain circumstances. When the rubber and nylon are connected the electron leaves the atom which became an excess positive charge and the electron's destination will have an excess negative charge. Generally, nylon likes to steal electrons will attract electrons from the surface but the other material likes to give away electrons. This is a famous "shoes on carpet" effect and the causes static charging, [1]. When the two dissimilar materials are connected together causing one to become + and the other - , the very little repulsion energy will be available on either object while they are close together. Only when they are separated will a significant of "spark" energy be stored on each object. In addition to sparking charged objects may be attracted to each other (or repelled), [2]. For users and manufacturers affected by unwanted electrostatic

discharge, the publication of standards concerning the control of such discharges is a great improvement and helps to prevent unwanted electrostatic discharge in potentially explosive atmospheres as well as around electrostatically sensitive device, [3]. The recycling of waste plastic in triboelectrostatic separation, depended on the triboelectric series and charging properties to predict material separation, [4].

Triboelectrification is the generation of double layer of ESC on the two sliding surfaces. The normal force, time of contact and velocity of rubbing are affecting the intensity of the generated charge. In the present work, epoxy reinforced by copper wires and sheet of rubber are sliding against each other. The distribution of charges on the sliding surfaces generates electric field. Epoxy as insulator contains a distribution of charges which are conserved. The double layer of the ESC 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 ESC on the sliding surfaces leading to further increase in the adhesion force acting on the two sliding surfaces leading to significant increase in friction coefficient, [5]. The properties of copper are very high electrical and thermal conductivities. Pure copper is used as a heat conductor, a building material, and a constituent of various metal alloys thus because it is soft and malleable, [6]. The copper is the second highest pure metal at room temperature in its high electrical (59.6×106 S/m) and also high thermal conductivity which partly explains low hardness, [7]. Safe walking on the floor was evaluated by the static friction coefficient. Few researches paid attention to the ESC generated during walking on the floor.

The floor materials and footwear are affected on the generated charge, [8]. The effects of copper wires when reinforcing epoxy specimen on the electric static charge generated from the contact of epoxy specimen with rubber sheet was discussed. Tests were carried at dry, water and detergent wetted mediums. The ESC affected by: the location of wires in the specimen(s), the wire diameter (Di) and the number of wires (nW). The ESC generated from contact and separation of, epoxy composites which were reinforced by copper wires, with rubber was studied. The experimental work explained that, the voltage increased by the increasing of (Di) and by increasing the (nW) and also it was dictated that, when the wire was closer to the surface that achieved maximum voltage, [9]. Slipping and falling are common phenomena in both workplaces and daily activities. The materials of floor or footwear, wetted condition and geometric design of the sole are related to the dangers of slipping and falling, [10 - 17]. Slip resistance of flooring materials is one of the major environmental factors affecting walking and materials handling behavior. Floor slipperiness is using the static and dynamic friction coefficient, [18, 19]. The electrical conductivity of the sliding surfaces is affected by the static charge generation on the environment. The effect of the type of flooring materials on the generation of ESC and friction coefficient was discussed, [20].

In the present work, electrostatic charge generated from contact and separation of the using floor materials reinforced by copper strips adhered to their back is investigated. An experimental testing program is designed to quantify ESC generated under different conditions of contact and different number of copper strips.

EXPERIMENTAL

Test specimens are prepared from sheets of (floor material A & B) of 300 × 400 mm² area and 5 mm thickness. Table 1 illustrates the physical and mechanical properties of floor material A & B. The copper strips (0, 1, 2, 3, 4, 5 and 6 strips) added under those sheets, Fig.1 illustrates the copper strips.

Table 1 The properties of floor material A & B.

Material properties	Material (A)	Material (B)
Electrical resistance	$5\times10^{4} \le R \le 10^{6}$ Ohms	$R \le 10^{8}$ 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

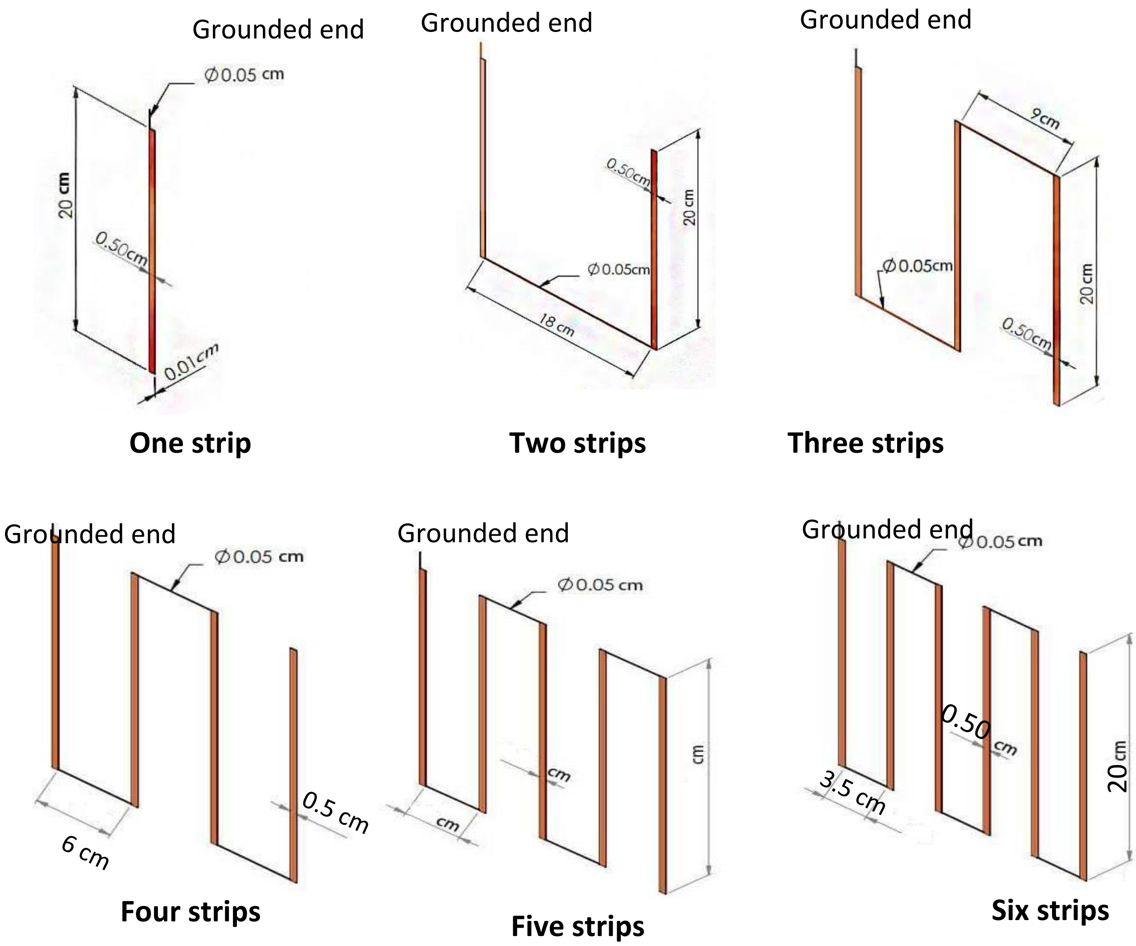

Fig. 1 Distribution of copper strips.

Contact and separation test has been carried out at room temperature under different values of applied normal loads ranging from 20 to 200 N measured by using the friction test rig illustrated in Fig. 2. Tests were carried out at dry medium and water + 1% chlorine dilution medium.

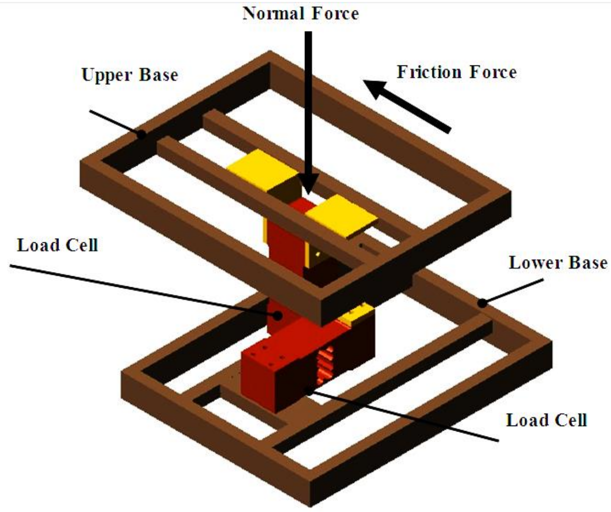

Fig. 2 Arrangement of the test rig.

Fig. 3 Electrostatic charge (voltage) measuring device.

Voltage has been measured by using (Ultra Stable Surface Voltmeter), after contacting the specimens with the polypropylene shoe for 10 second followed by separation, as shown in Fig. 4 to measure the generated ESC under the applied loads. The device shown in Fig. 3 illustrates that, a chopper-stabilized (rotating) sensor with a remote sensor head at the end of a 100 cm long flexible cable. This device can measure from 0.1 volt generated on a surface to 20 k volt and the sensor must be away from the surface by (25 mm). The contact and separation test has been carried at dry and chlorine wet floor materials.

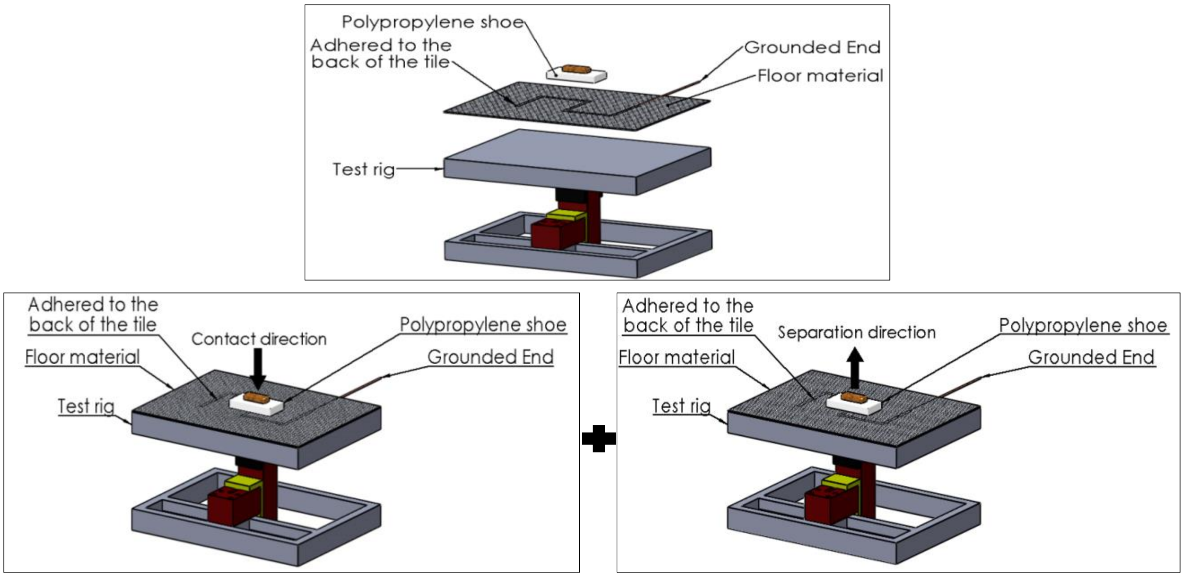

Fig. 4 Arrangement of the experimental test.

RESULTS AND DISCUSSION

Figure 4 illustrates that, the number of strips influenced ESC. The maximum voltage in floor material (A) free of strips was 142 volts while in floor material fitted by one and two strips were 120 and 130 volts respectively; this behavior was due to that the copper area in one and two strips was limited to increase the conductivity of floor material or increase ESC generated. Although, when increasing the number of strips to three, four, five and six stripes the voltage increased slightly to 155, 167, 190, and 196 volts respectively as a maximum values. Where increasing of copper area facilitated the intensity of ESC generated of the floor material to increase, Fig. 5. On the other hand, it can be observed that voltage increased by increasing the normal applied load where the intensity of ESC depended on the value of pressure.

The floor material as insulator contains a distribution of charges which are conserved, once the floor material being in contact with polypropylene shoe, the double layer ESC generated on the contact area and consequently the electric filed generated increased, This is due to the phenomenon of triboelectrification. Presence of copper strips adhered to the back of the floor material generated extra ESC on the contact surface which leading to increase the ESC. So it can be noticed that the ESC increased by increasing the number of strips, Fig. 6.

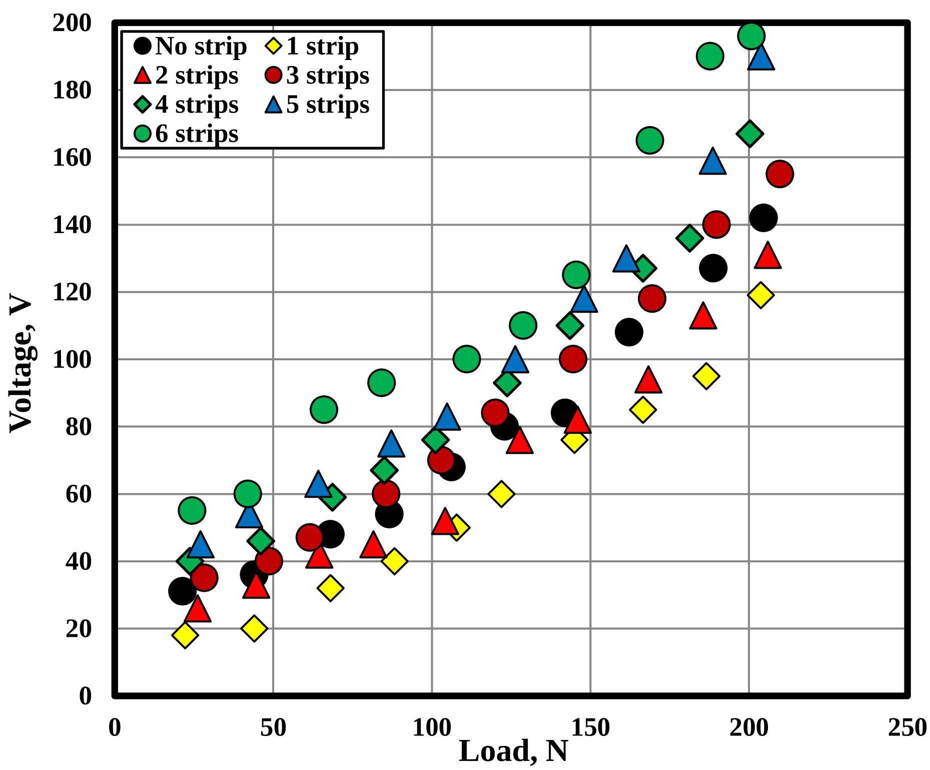

Fig. 5 Effect of number of strips on electrostatic charge on floor material (A) at dry condition and ungrounded.

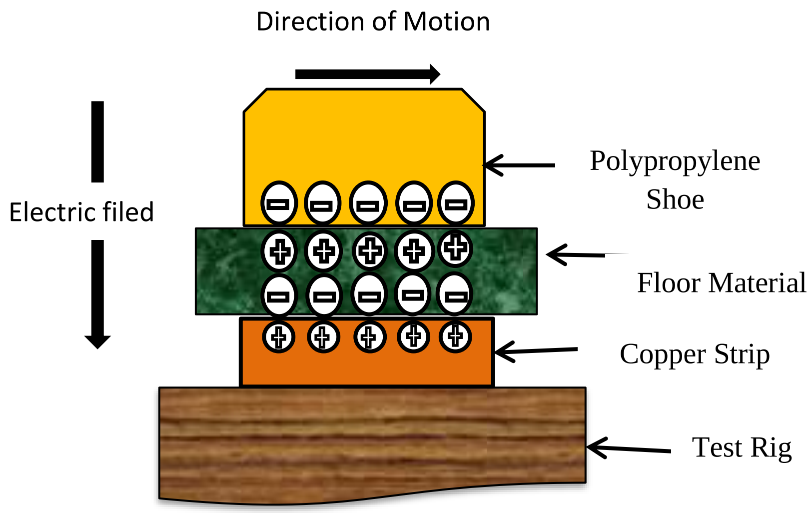

Fig. 6 Schematic illustration of ESC generated on floor material and polypropylene at ungrounding system.

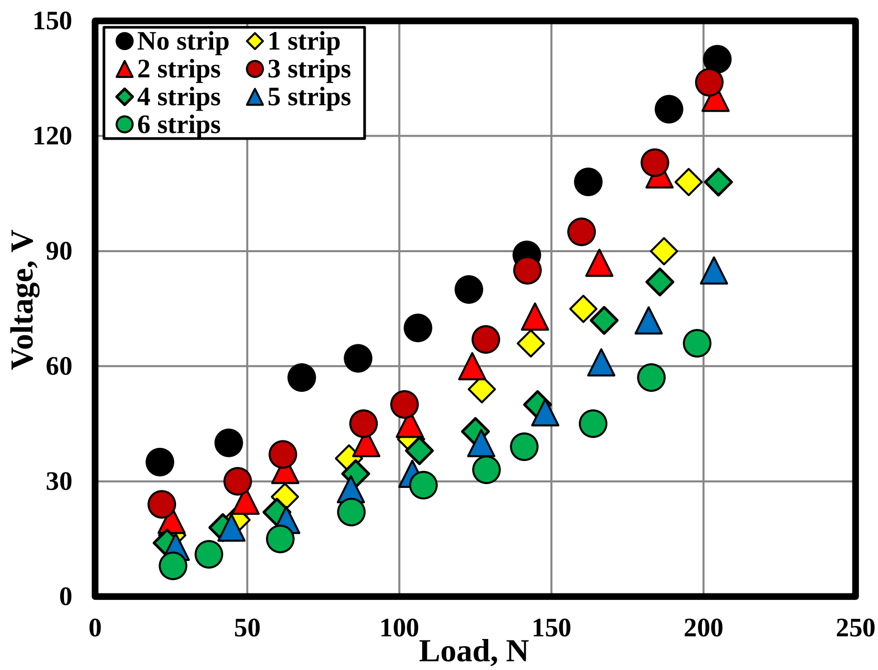

Fig. 7 Effect of number of grounded strips on ESC on floor material (A) at dry condition and.

Figure 7 illustrates that, the maximum value was 140 volts in floor material (A) free of strips and 66 volts in floor material (A) fitted by six strips. This value is lower than that observed in ungrounded test in Fig. 5. 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

electrostatic charge. Thus, because the grounding design facilitated the leakage of voltage which is collected by adding the copper strips as discussed in Fig. 8. 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.

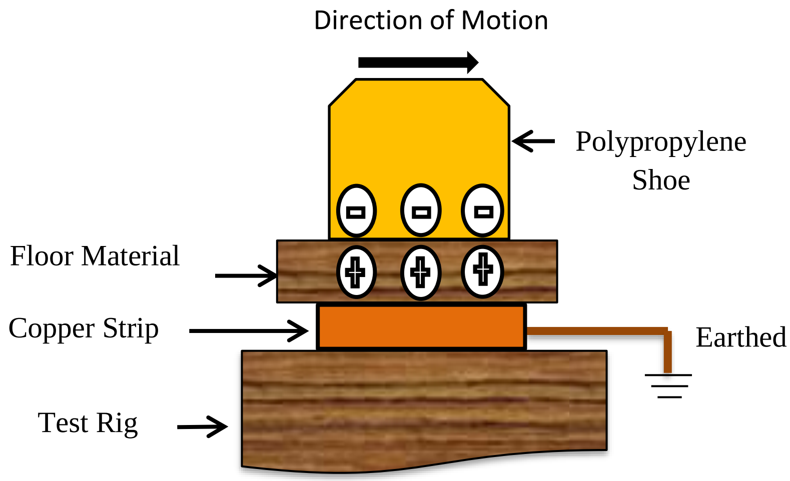

Fig. 8 Schematic illustration of electric static charge generation between floor material and polypropylene at grounding system.

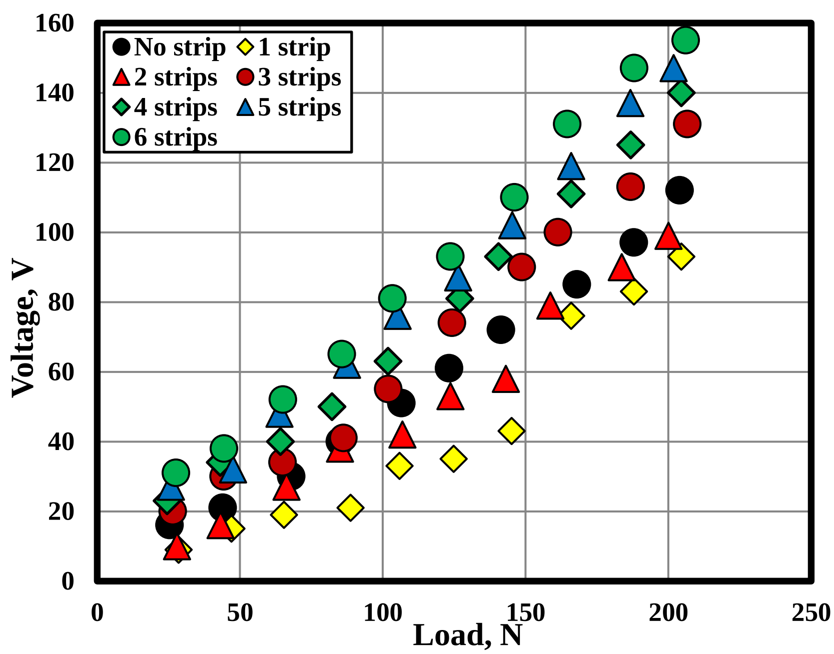

Fig. 9 Effect of number of ungrounded strips on ESC on floor material (B) at dry condition.

The floor material had an effect on generated voltage where floor material (B) helped to insulate the charge compared to floor material (A). The voltage decreased from 196 volts in Fig. 5 to 155 volts in Fig. 9 when the floor material was fitted by six of strips as a maximum value. This reduction was discussed in table 1 where the electrical resistance

of material (B) was higher than material (A) and therefore, the ESC generated in floor material (B) was lower than that generated in floor material (A). Similarly, the material (B) free of strips generated 93 volts, while material (A) generated 142 volts under the same load.

The existence of grounded system facilitated leaking an amount of electrostatic charge. The voltage decreased from 155 in ungrounded condition, as shown in Fig. 9, to 44 volts in floor (B) fitted by six strips in grounded condition as illustrated in Fig. 10 under the normal applied load. The presence of chlorine in water caused a high reduction of the electrostatic charge more than in dry condition. This is illustrated in Fig. 11, where the maximum value was 30 volts in floor material (A) fitted by six of strips. It seems that, water leaked the generated charge out of the floor material.

The grounding design was applied in the presence of chlorine/water dilution. This is illustrated in Fig. 12. Whereas the maximum value was 32 volts in floor material (A) that was free of strips and was 6 volts in the specimen fitted by six strips. Figure 13 illustrates that, the floor material (B) caused a relatively higher reduction of ESC than floor material (A) in the presence of chlorine/water dilution where the maximum value was 22 volts in specimen fitted by six strips. Generally the ESC increased by the increase of load, which increased the contact area and consequently the transmission of electrons between the surfaces increased.

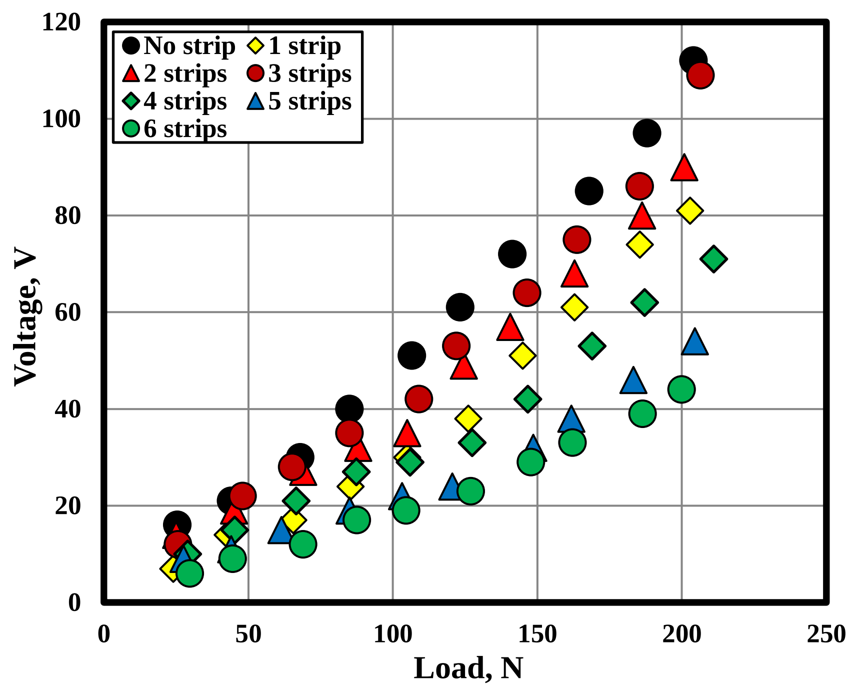

Fig. 10 Effect of number of grounded strips on ESC on floor material (B) at dry condition.

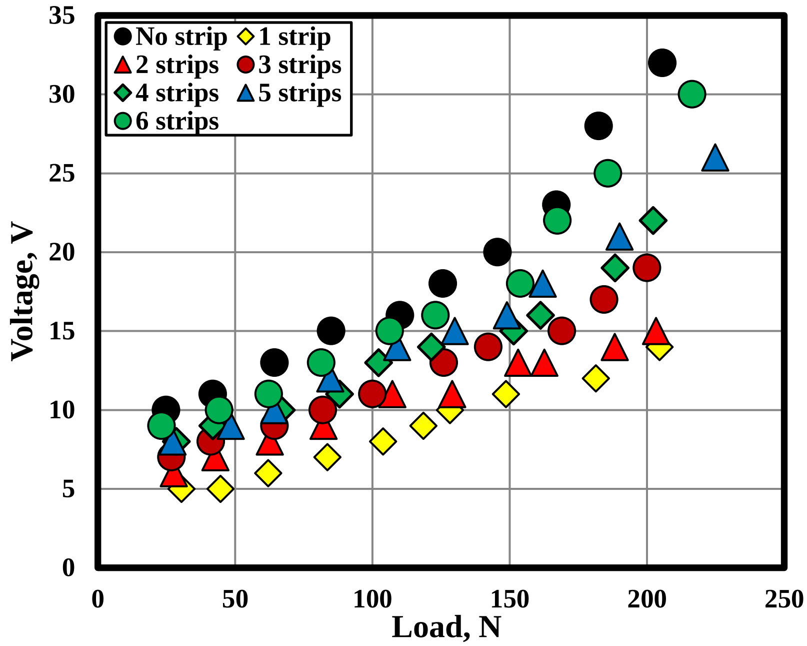

Fig. 11 Effect of number of ungrounded strips on ESC on floor material (A) at chlorine wet condition.

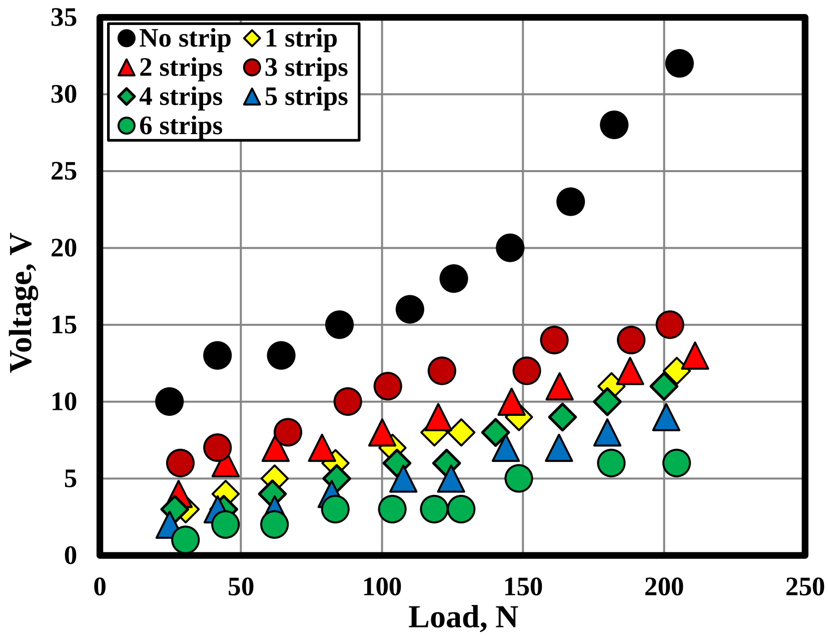

Fig. 12 Effect of number of grounded strips on ESC on floor material (A) at chlorine wet condition.

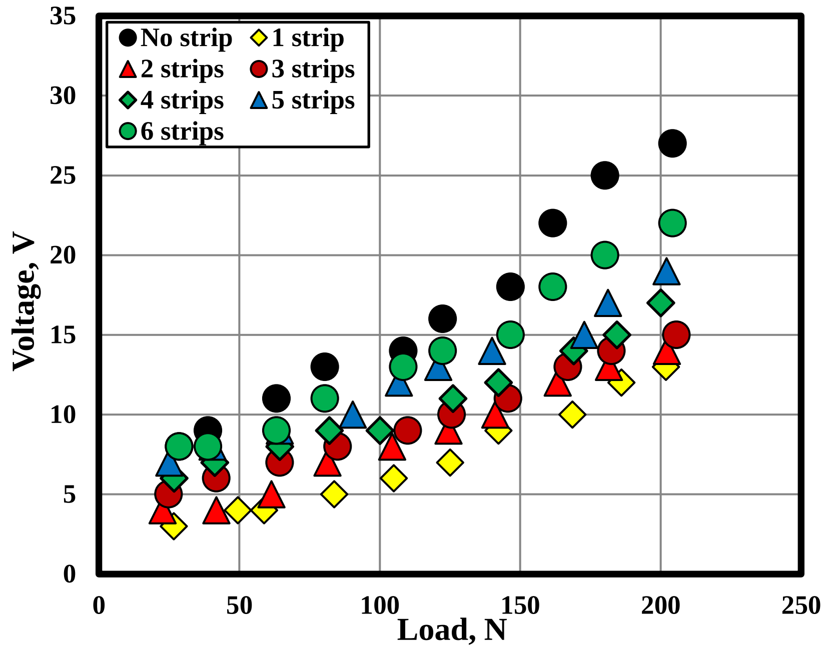

Fig. 13 Effect of number of ungrounded strips on ESC on floor material (B) at chlorine wet condition.

Figure 14 shows the minimum voltage when using floor material (B) and grounding test, where the voltage was 4 volts in the floor material fitted by six strips, while it was lower than that generated in floor material free of strips.

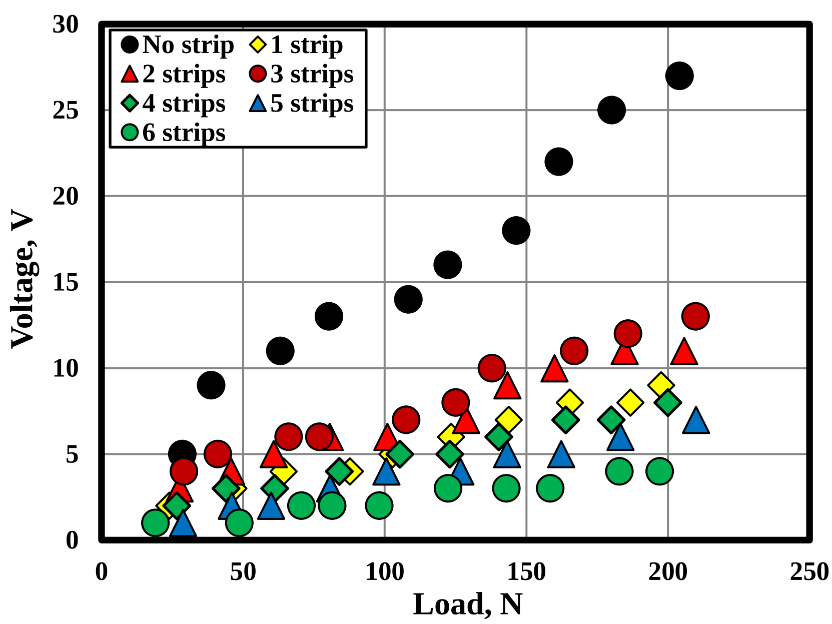

Fig. 14 Effect of number of grounded strips on ESC on floor material (B) for chlorine wet condition.

Grounding of copper strips enhances leaking an amount of (ESC) generated for the same number of strips and applied load. This behaviour can be observed in Fig. 15, where the voltage decreased from 196 to 66 volts in floor material (A) fitted by six strips.

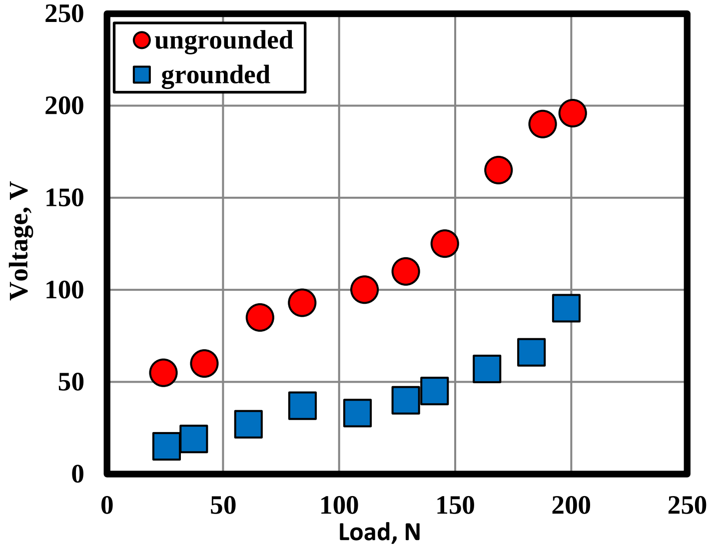

Fig. 15 Effect of type of conduction on ESC on floor material (A) at dry condition.

Figure 16 shows that presence of chlorine/water dilution at the surface of grounding design system facilitates the leakage of generated ESC, where the voltage decreases down from 66 volts at dry condition to 6 volts at chlorine condition.

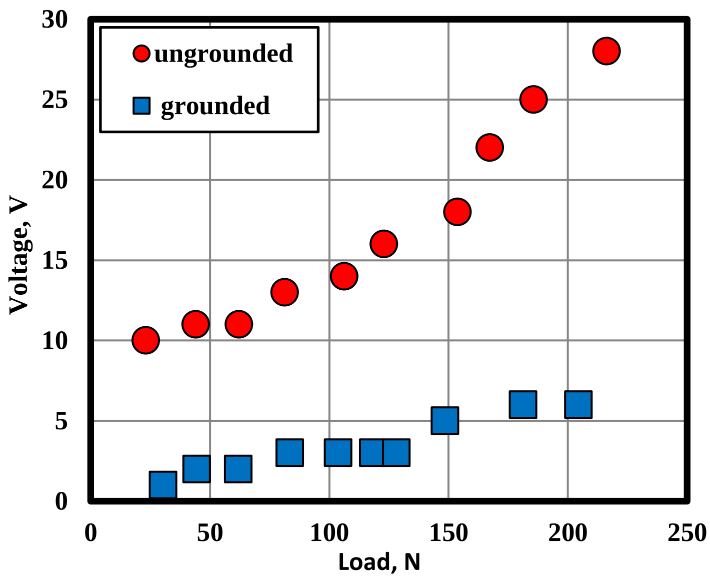

Fig. 16 Effect of type of conduction on ESC on floor material (A) at chlorine wet condition.

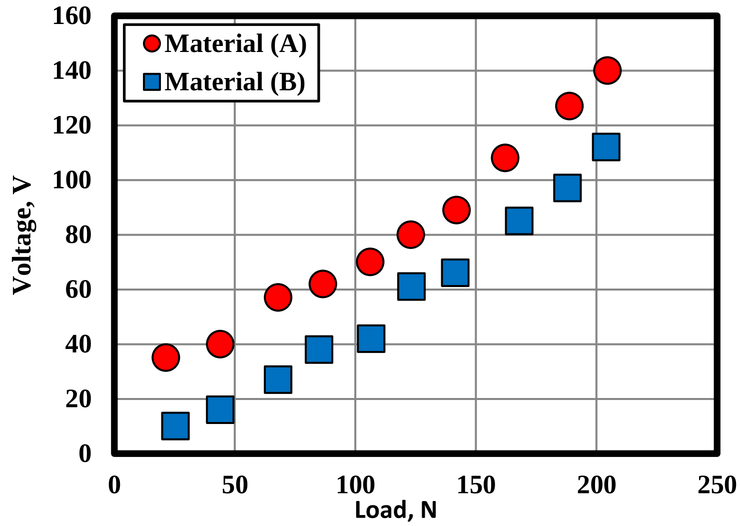

Fig. 17 Effect of type of flooring material on ESC at dry condition and free of strips.

The conductivity of the floor material influenced the generated voltage, whereas the floor material (B) generated voltage lower than that observed in floor material (A) under the same load. This reduction was showed in table 1 where the electrical resistance of material (B) was higher than material (A) and therefore, the ESC generated in floor material (B) was lower than that generated in floor material (A). Figure 17 illustrates that behaviour.

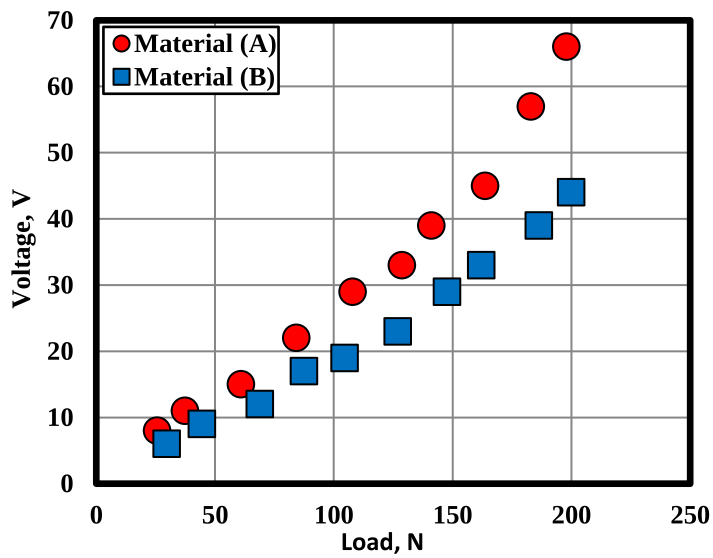

Fig. 18 Effect of type of flooring material on ESC at dry condition.

Figure 18 illustrates that minimum voltage occurred at dry contact, while the voltage decreased to 66 volts on using floor material (A) and 44 volts on using floor material (B), when using the specimen fitted by six strips which collected amount of generated charge then the grounded wire leaks that voltage.

CONCLUSION

1. At dry contact, voltage significantly increased by increasing normal load due to the increase of the contact area.

2. Increasing the number of strips increased the copper area which collected double layer of ESC generated on the floor material higher than that observed during using floor material free of strips.

3. The grounding conduction is the best way to leak ESC out of the contact surfaces.

4. The floor material (B) generated ESC lower than that observed when using floor material (A). This is due to the electrical resistance of the floor material.

5. Chlorine wet floor material facilitated the distribution of the ESC. Generally, chlorine wet floor material displayed values of voltage lower than that observed at dry condition.

6. It can be recommended to use the grounded floor material (B) that fitted by six strips due to its generation of the minimum ESC.

REFERANCES

1. Alphalab, Inc. (Trifield.com), Salt Lake city (USA), Ph.D. Physics, p. 9, (2009).

2. Crawford R. J., "Plastics engineering" Third Edition, Butterworth - Heinemann, pp. 28-33, (2002).

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

4. Chul H. P., Jai K. P., Ho S. J. and Byoung C. C., "Triboelectric series and charging properties of plastics using the designed vertical-reciprocation charge" Journal of Electrostatics, Vol. 66, pp. 578-583, (2008).

5. 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, April 2015, pp. 55 - 68, (2015).

6. George L. Trigg; Edmund H. Immergut. "Encyclopedia of applied physics. Vol. 4: Combustion to diamagnetism", VCH Publishers, pp. 267-272, (1992).

7. Hammond C. R., "The Elements, in handbook of chemistry and physics 81st edition", CRC press, (2004).

8. El-Sherbiny Y. M., Samy A. M. and Ali W. Y., "Electric static charge generated from bare foot and foot wear sliding against flooring materials", Journal of the Egyptian Society of Tribology, Vol. 11, No. 1, January 2014, pp. 1 – 11, (2014).

9. 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", Journal of the Egyptian Society of Tribology, vol. 12, No. 3, July 2015, pp. 28 – 39, (2015).

10. Gabriel P., Thomas A. G., Busfield J. J. C., "Influence of Interface Geometry on Rubber Friction", Wear 268, pp. 747 – 750, (2010).

11. Heinrich G., Kluppel M., "Rubber friction, tread deformation and tire traction ", Wear 265, pp. 1052 – 1060, (2008).

12. Liu L., Li K. W., Lee Y. H., Chen C. C., Chen C. Y., "Friction measurements on ''anti-slip" floors under shoe sole, contamination, and inclination conditions", Safety Science 48, pp. 1321 – 1326, (2010).

13. El-Sherbiny Y. M., Samy A. M. and Ali W. Y., “Friction Coefficient of Rubber Sliding Against Dusty Indoor Flooring”, Journal of the Egyptian Society of Tribology, Vol. 7, No. 4, October 2010, pp. 11 – 25, (2010).
14. El-Sherbiny Y. M., Mohamed M. K., Ali W. Y., “Friction Coefficient Displayed by Footwear Walking Against Rubber Floorings Fitted by Cylindrical Treads”, Journal of the Egyptian Society of Tribology, Vol. 8, No. 1, January 2011, pp. 1 – 12, (2011).
15. Mohamed M. K., Samy A. M., Ali W. Y., “Friction Coefficient of Rubber Shoes Sliding Against Ceramic Flooring”, KGK – April 2011, pp. 44 – 49, (2011).
16. Kai W. L., Horng H. W., Yu-Chang L., “The effect of shoe sole tread groove depth on the friction coefficient with different tread groove widths, floors and contaminants”, Applied Ergonomics 37, pp. 743 – 748, (2006).
17. Li K. W., Yu R., Han X. L., “Physiological and psychophysical responses in handling maximum acceptable weights under different footwear–floor friction conditions”, Applied Ergonomics 38, pp. 259 – 265, (2007).
18. Miller J. M., ‘‘Slippery’’ work surface: toward a performance definition and quantitative coefficient of friction criteria”, J. Saf. Res. 14, pp. 145 - 158, (1983).
19. Grönqvist R., "Mechanisms of friction and assessment of slip resistance of new and used footwear soles on contaminated floors", Ergonomics 38, pp. 224 - 241, (1995).
20. 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).