EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 14, No. 3, July 2017, pp. 18 - 33 ISSN 2090 - 5882
(Received January 17. 2017, Accepted in final form June 15. 2017)

REDUCING ELECTROSTATIC CHARGE GENERATED ON POLYMERIC FLOOR IN HOSPITALS

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ABSTRACT
The aim of this study is to develop a new material for reducing electrostatic charge (ESC) generated from the walking of polypropylene shoes against polymeric floor in hospitals. Stainless steel strips have been adhered to the back of two proposed polymeric floor materials (A & B). It has been observed that the ESC increased by increasing the number of stainless steel strips. Although the strips were grounded, ESC has increased, due to charging by induction. On other hand the grounded strips decreased the friction coefficient by 4 % and 5 % in dry sliding and water/chlorine wet sliding respectively.

KEYWORDS
Electrostatic charge (ESC), polyvinyl chloride (PVC), floor material, friction coefficient, grounded stainless steel strips.

INTRODUCTION
Electrostatic discharge (ESC) results from the separation of static charge, and there are several ways of producing such separation. Rubbing two kinds of insulating materials together can cause static charge to be transferred from one material to another, similar to walking across a carpet on a dry day and touching a metallic doorknob. Additionally, discharges can occur between metal objects, such as chairs and tables, in the proximity of equipment. As two materials are separated, the charge separation creates strong electric fields, and thus voltage differences between the materials will occur, [1 - 4]. When a conductor is connected to the Earth by means of conducting wire or pipe, it is said to be grounded. The Earth can then be considered an infinite "skin" to which electric charges can easily migrate. To understand induction, consider a neutral (uncharged) conducting sphere insulated from ground. When a negatively charged rubber rod is brought near the sphere, the region of the sphere nearest the rod obtains an excess of positive charge while the region farthest from the rod obtains an equal excess of negative charge, [5].

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, [6].

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, [7 - 9]. Investigators have concentrated on the friction coefficient measurements on liquid contaminated floors because most slip/fall incidents occur on the surfaces of such floors, [10].

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, [11 - 18]. Slip resistance of flooring materials is one of the major environmental factors affecting walking and materials handling behavior. Floor slipperiness may be quantified using the static and dynamic friction coefficient. Certain values of friction coefficient were recommended as the slip-resistant standard for unloaded, normal walking conditions, [19 - 21]. The ESC increases by increasing the number of copper strips, because the double layer of the ESC generated on the sliding surfaces causes an E-field that generates an extra ESC. The increase of the ESC has a pronounced effect on adhesion force between the contact surfaces leading to an increase in the friction coefficient. The grounding facilitates the leakage of 78 % of the generated ESC and consequently decreases the friction coefficient by 35 %. The triboelectric series can be used to determine the charge polarity of the materials. This series can be used to evaluate the relative charging capacity of many polymeric materials, [22]. Stainless steels have a high modulus of elasticity (200 MPa, or 30 ksi) that is nearly twice that of copper alloys. Also, it has a very high thermal conductivity and the corrosion resistance is frequently the most important characteristic of a stainless steel. General corrosion resistance to pure chemical solutions is comparatively easy to determine, but actual environments are usually much more complex, [23].

The aim of this study is to reduce electrostatic charge and enhances the friction coefficient during walking by polypropylene shoes against floor materials A and B in hospitals. The effect of adhering different numbers of grounded or ungrounded stainless steel strips to the back of the floor materials on ESC and friction coefficient is investigated.

EXPERIMENTAL WORK

The test specimens (polyvinyl chloride floor PVC) were adhered by stainless steel strips (0, 1, 2, 3, 4, 5 and 6 strips) as illustrated in Fig. 1. They were added in the back of polyvinyl chloride floor material sheets (A & B) of 300 × 400 mm^2 area and 5 mm thickness. The mechanical and electrical properties of PVC are shown in table 1.

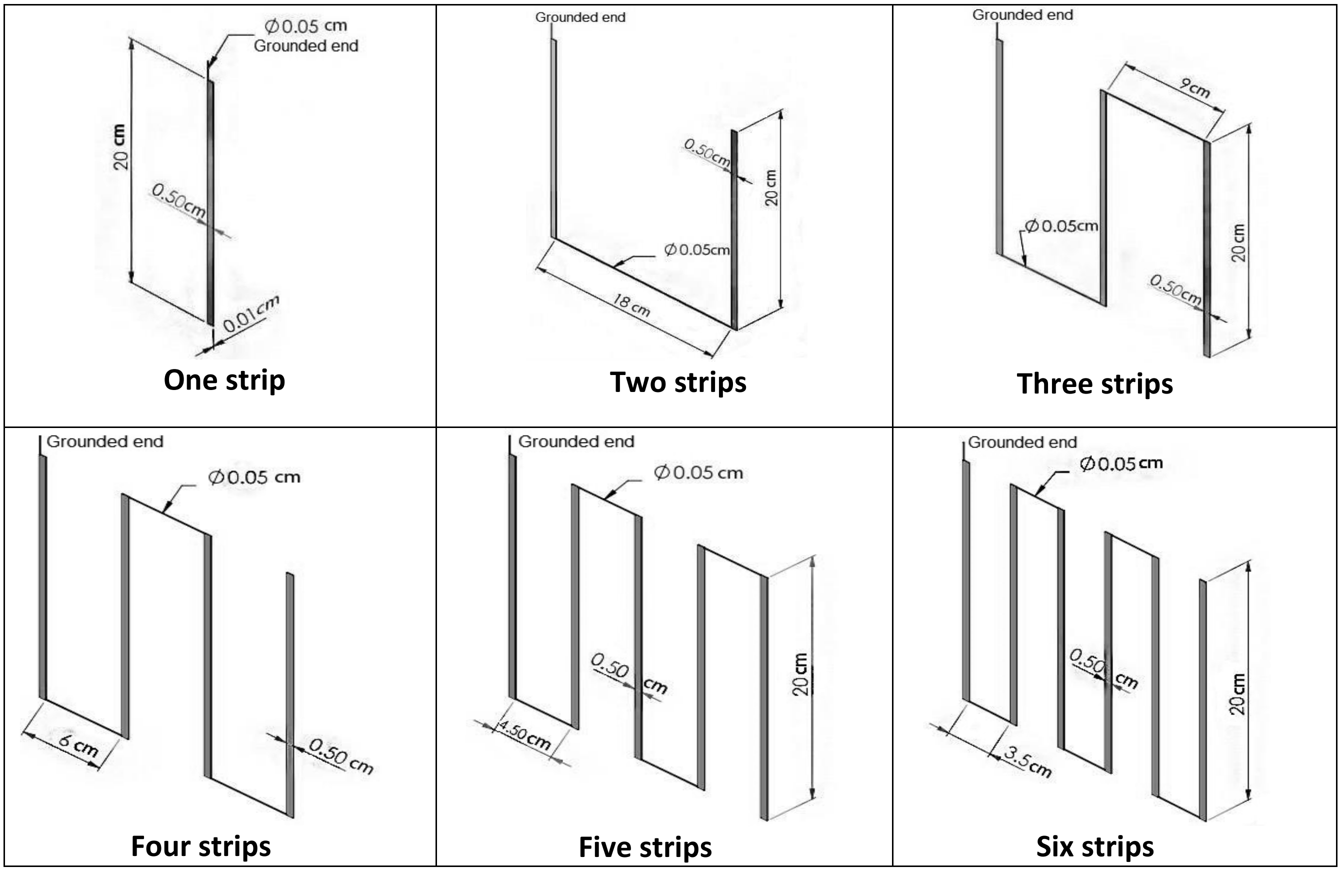

Fig.1 Distribution of the copper strips.

Table 1 The properties of the tested 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**

Ultra Stable Surface DC Voltmeter device was used to measure ESC (electrostatic field). It measures down to 1/10 volt on a surface, and up to volts (20 kV). Readings are normally performed by the sensor 25 mm apart from the surface being tested, Fig. 2. The friction coefficient was calculated by dividing the horizontal force (friction force) on the vertical force (normal force) which measured by using a test rig device, as illustrated in Fig. 3.

Fig. 2 Electrostatic charge (voltage) measuring device.

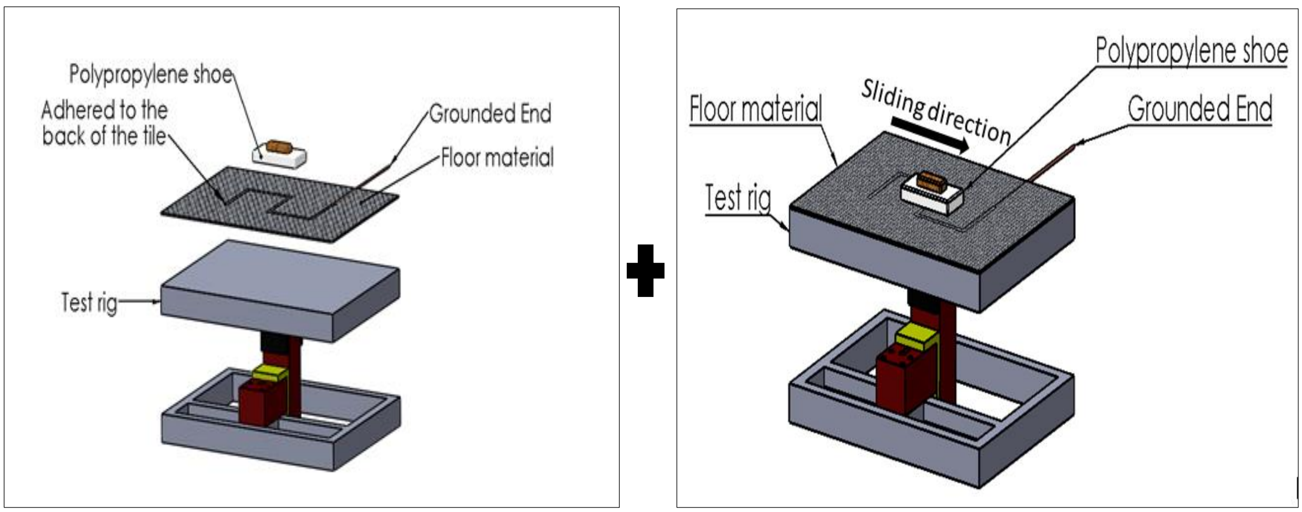

Fig. 3 Arrangement of the experimental test.

RESULTS AND DISCUSSION

After sliding to 200 mm against floor material (A), it was observed that, ESC slightly increased by increasing the normal load up to 459, 512, 538 volts in floor material fitted by four, five and six ungrounded strips respectively. These values were higher than floor material without strips due to the ability of strips to generate extra amount of ESC as illustrated in Fig. 4. It was also noted that the voltage increased with increasing applied normal load where the intensity of ESC depends on the pressure and time of sliding as illustrated in Fig. 5.

The floor material as insulator contains a distribution of charges that are conserved, when the polypropylene shoe slides against the floor material, the double layer of ESC is generated and consequently the generated electric field increases. Presence of stainless steel strips in the back of the floor material generates extra ESC on the sliding surface. Based on that observation, it can be noticed that ESC increases by increasing the number of strips, Fig. 5.

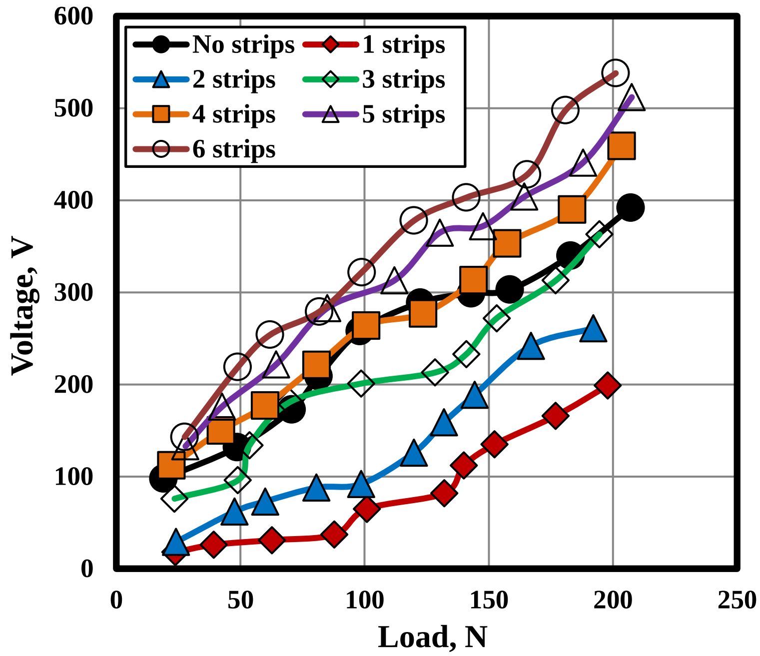

Fig. 4 Effect of number of ungrounded strips on ESC on material (A) at dry sliding.

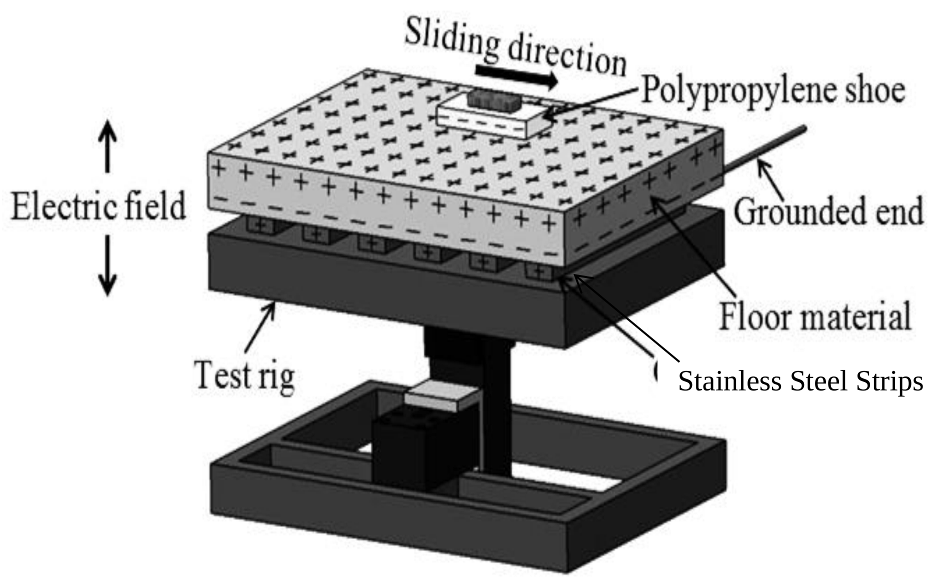

Fig. 5 Schematic illustration of ESC generated on floor material and polypropylene.

Figure 6 illustrates that, friction coefficient slightly increased by increasing the number of ungrounded strips. This behavior is attributed to due to ESC increase, Fig. 4, which consequently increases the adhesion force between surfaces, so that the friction coefficient was 0.81 in floor material fitted by six strips.

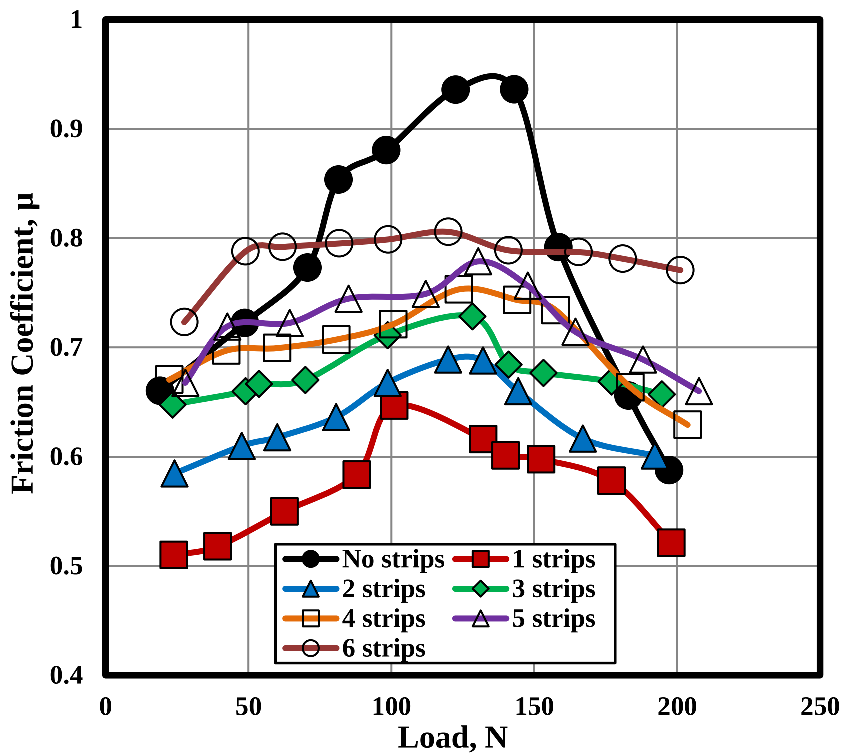

Fig. 6 Effect of number of ungrounded strips on friction coefficient on material (A) at dry sliding.

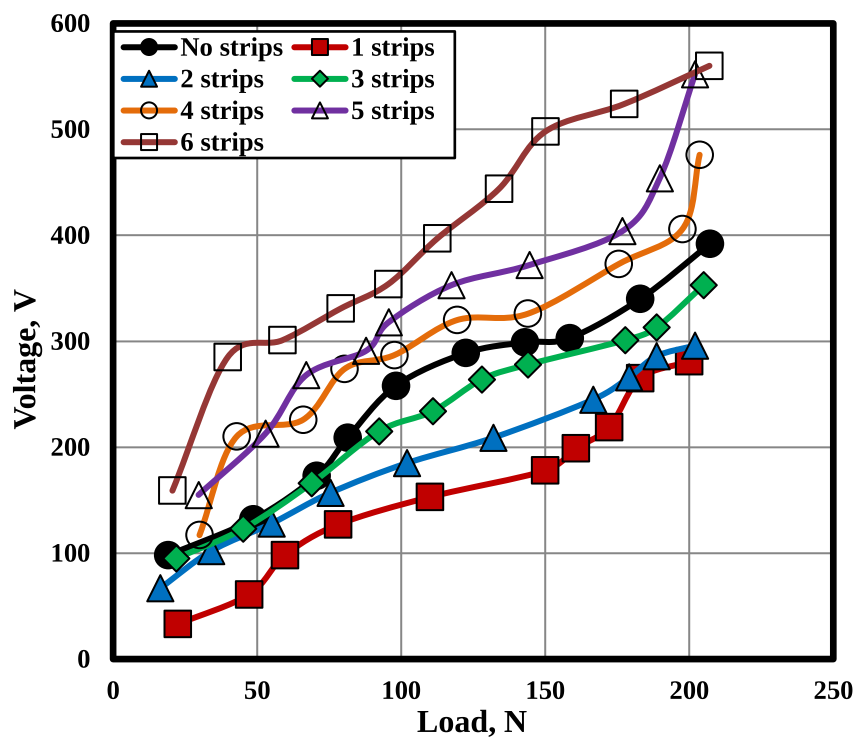

Fig. 7 Effect of number of grounded strips on ESC on material (A) at dry sliding.

Although the strips were grounded the charge has increased, this is due to charging by induction. The most of electrons escaped to the earth and left unbalance positive charge so that the strips have excess positive charge to balance the negative one. This discussion illustrates why ESC increased with increasing grounded strips in Fig. 7 up to 476, 552 and 560 volts in floor material fitted by four, five and six strips. These values were higher than that observed in Fig. 4 using ungrounded strips. Although ESC increased by increasing the number of grounded stainless steel strips in Fig. 8, friction coefficient decreased slightly to 0.77 compared to the data shown in Fig. 6.

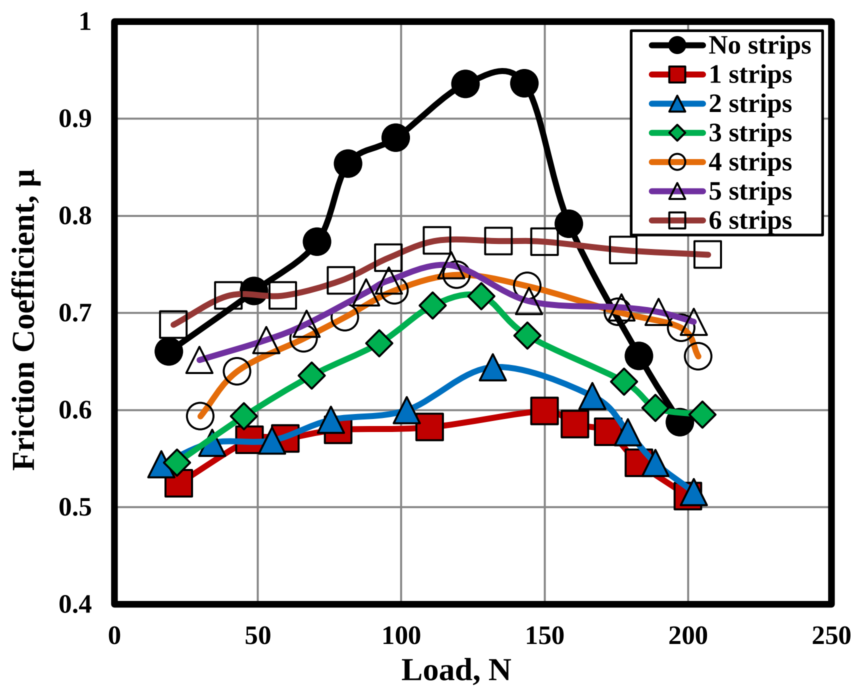

Fig. 8 Effect of number of grounded strips on friction coefficient on material (A) at dry sliding.

ESC slightly decreased down to 401, 420 and 486 volts in floor material fitted by four, five and six strips respectively, Fig. 9. These values were lower than that noticed in Fig. 4, because the electrical resistance of floor material (A) is higher than material (B) as illustrated in table 1. Consequently, the friction coefficient decreased also from 0.8057 in Fig. 6 to 0.74 in Fig. 10.

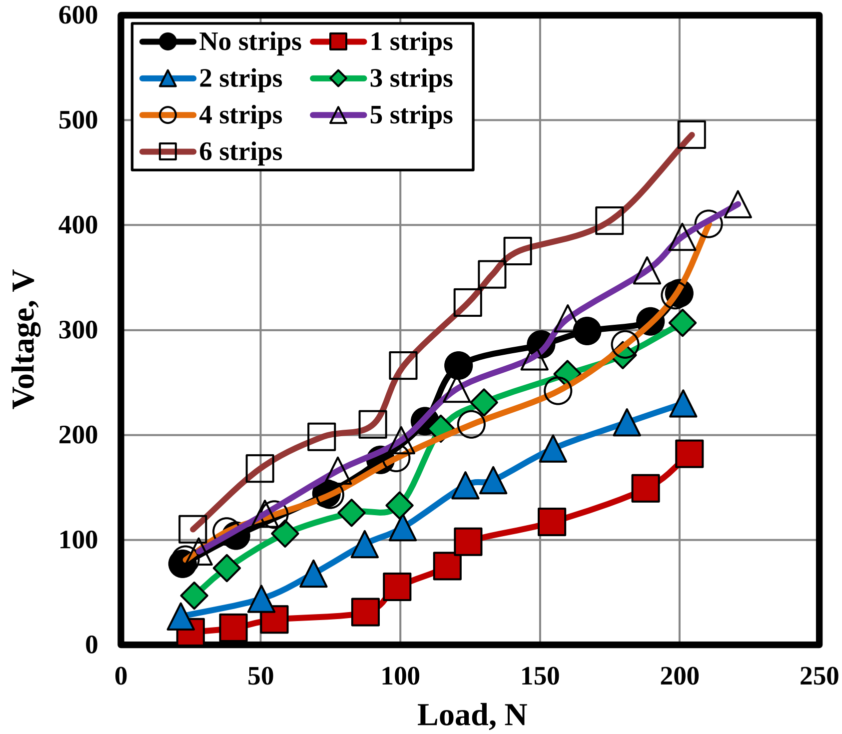

Fig. 9 Effect of number of ungrounded strips on ESC on material (B) at dry sliding.

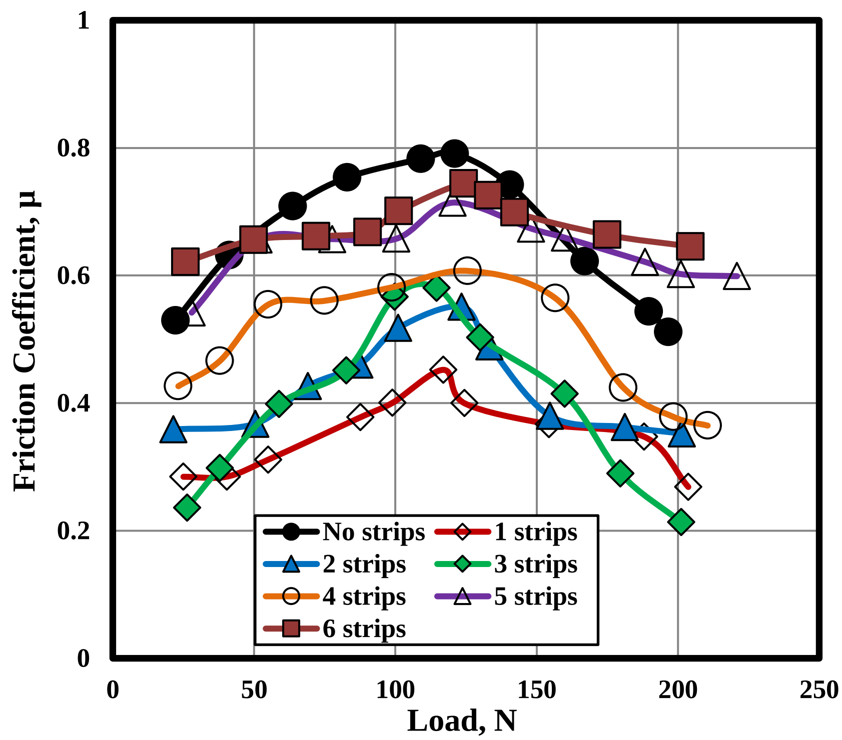

Fig. 10 Effect of number of ungrounded strips on friction coefficient on material (B) at dry sliding.

Grounding increased also ESC by increasing the number of strips, as illustrated in Fig. 7. The maximum value was 516 volts in floor material (B) fitted by six strips while it was 308 volts in specimen free of strips as illustrated in Fig. 11. On the other hand, it was observed that ESC increased by 3 % while friction coefficient decreased by 5 % as observed in Fig. 12.

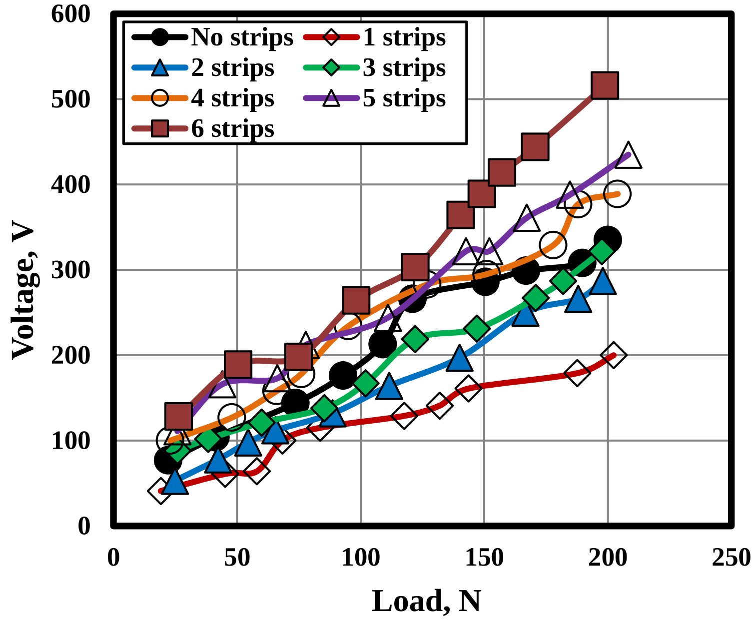

Fig. 11 Effect of number of grounded strips on ESC on material (B) at dry sliding.

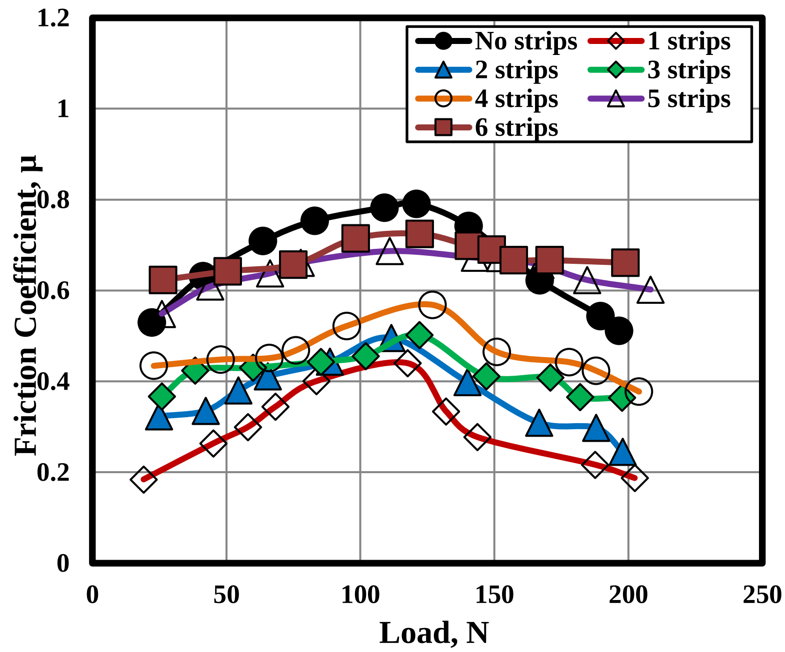

Fig. 12 Effect of number of grounded strips on friction coefficient on material (B) at dry sliding.

Figure 13 shows that, presence of water/chlorine dilution wet surface decreased ESC to 67, 81 and 98 volts in floor material fitted by four, five and six strips respectively. Those values were lower than that generated in dry sliding in Fig. 4. This behavior is attributed to the good conductivity of water which facilitates leaking the generated charge out of the contact area. Consequently friction coefficient decreased down to 0.79 in the specimen fitted by six strips, while it was 0.82 in the specimen free of strips at the same condition, Fig. 14. That behavior confirms the necessity of adding stainless steel strips, in the back of floor material, to enhance friction coefficient during walking against water/chlorine wet floor.

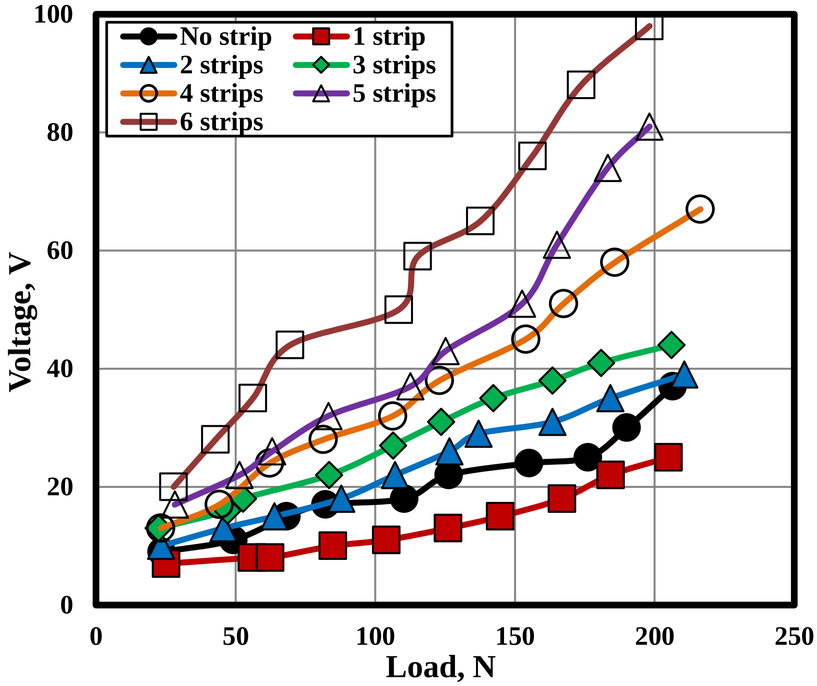

Fig. 13 Effect of number of ungrounded strips on ESC on material (A) at wet chlorine sliding.

ESC increased by increasing the number of grounded strips due to charging by induction, Fig. 15. When the strips were grounded, some of their electrons leave through the ground wire and the strips have excess positive charge. The voltage was 77, 98 and 117 in floor material (A) fitted by four, five and six grounded strips besides, this values were higher than that noticed in Fig. 13. On other hand, the friction coefficient increased by increasing grounded strips to (0.753) and (0.817) in floor material fitted by six and without strips respectively, as illustrated in Fig. 16.

The floor material (B) generated ESC lower than that observed in material (A), Fig. 17, where ESC was 47, 52 and 65 volts in floor material fitted by four, five and six stainless steel strips respectively. These values were lower than that observed in Fig. 13. This reduction influenced also friction coefficient that decreased to 0.7 and 0.8 in floor material fitted by six and without strips respectively, Fig. 18.

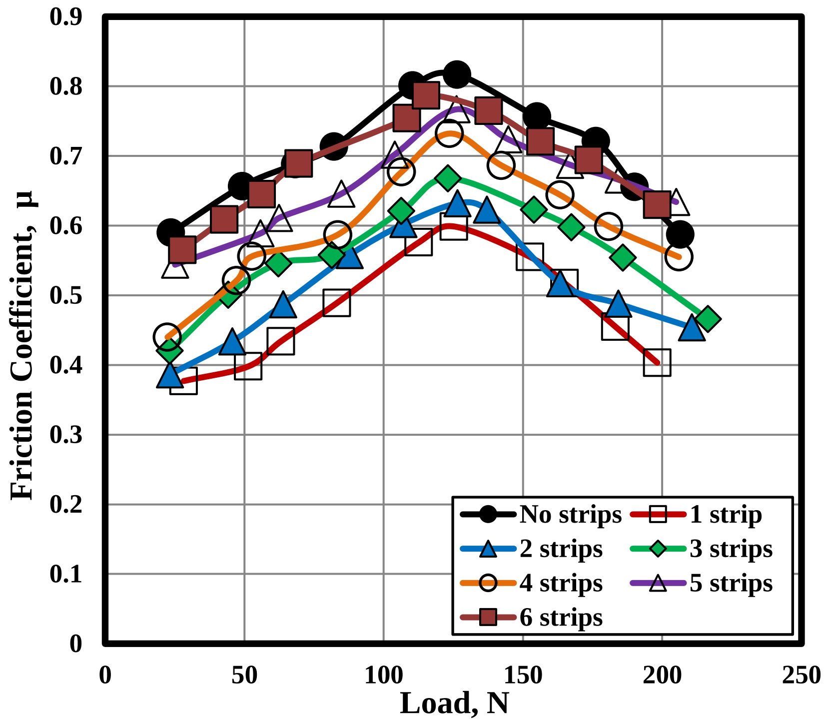

Fig. 14 Effect of number of ungrounded strips on friction coefficient on material (A) at wet chlorine sliding.

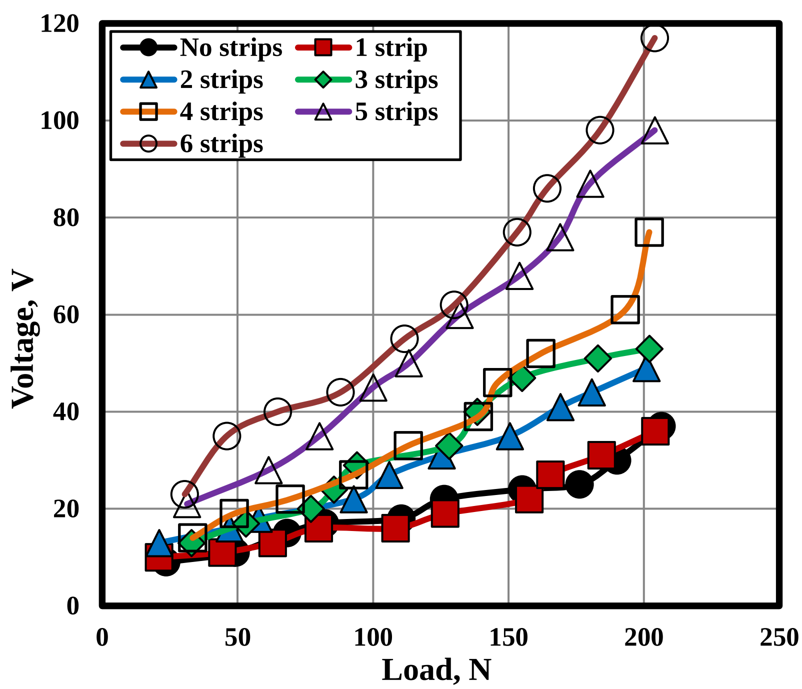

Fig. 15 Effect of number of grounded strips on ESC on material (A) at wet chlorine sliding.

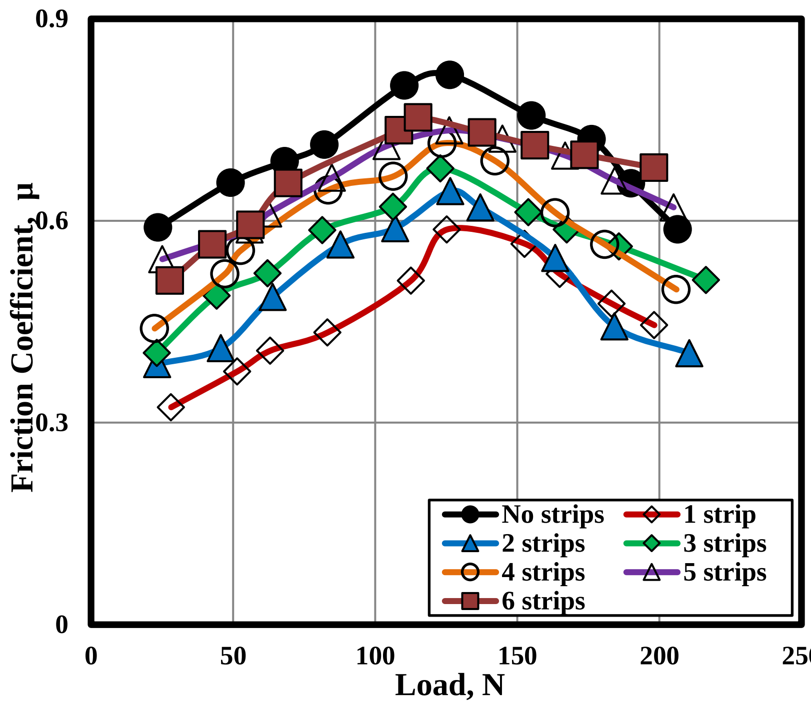

Fig. 16 Effect of number of grounded strips on friction coefficient on material (A) at wet chlorine sliding.

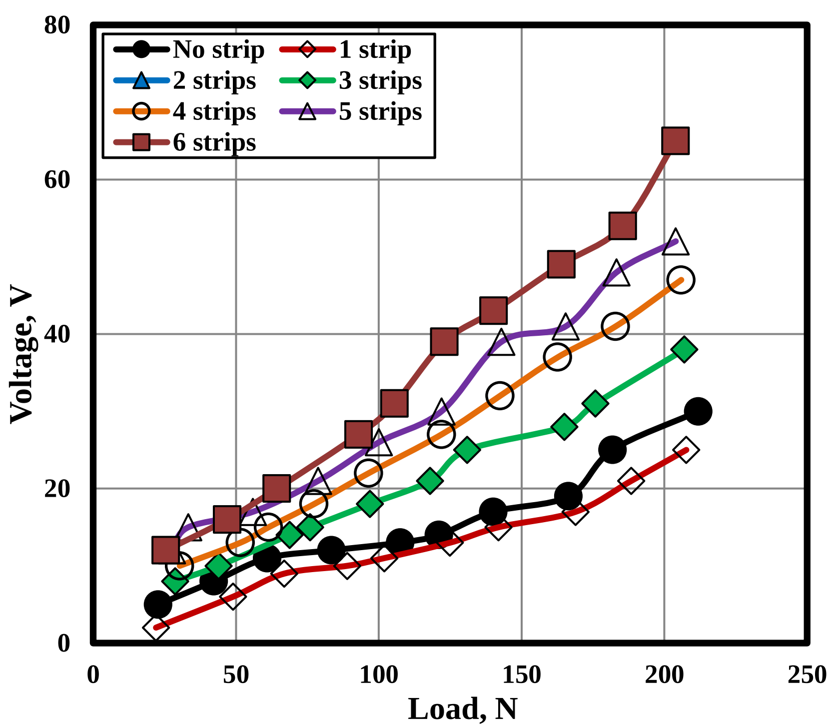

Fig. 18 Effect of number of ungrounded strips on ESC on material (B) at wet chlorine sliding.

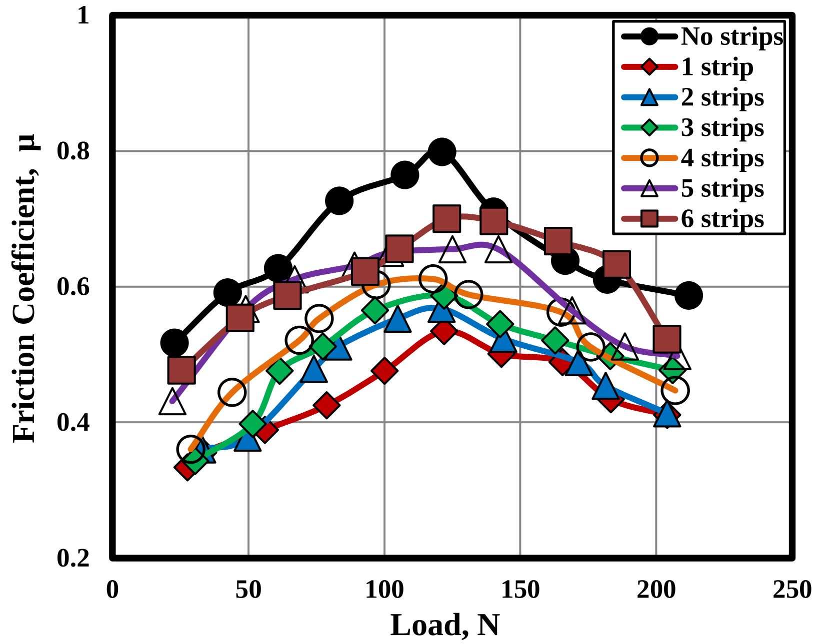

Fig. 19 Effect of number of ungrounded strips on friction coefficient on material (B) at wet chlorine sliding.

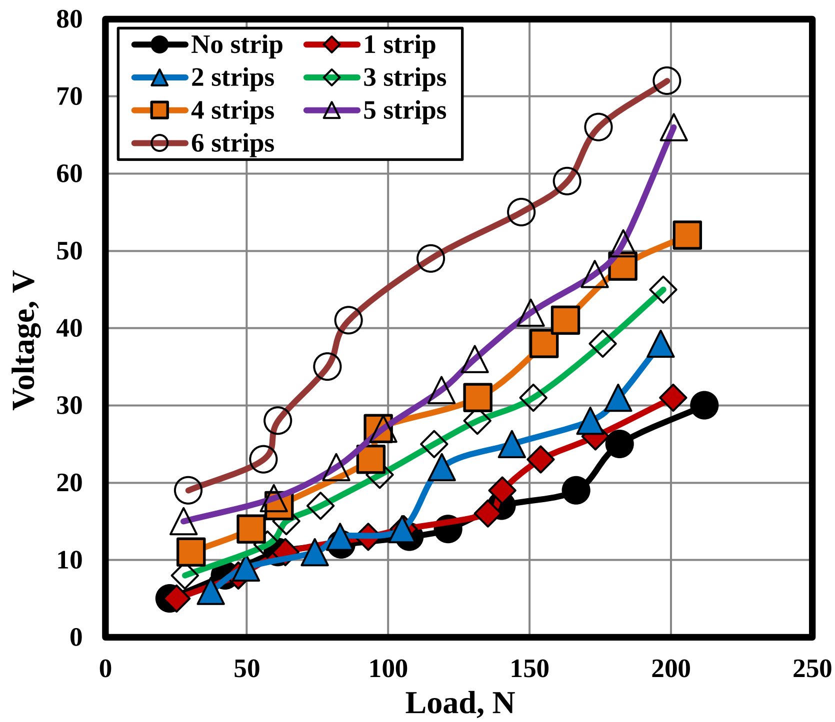

Fig. 20 Effect of number of grounded strips on ESC on material (B) at wet chlorine sliding.

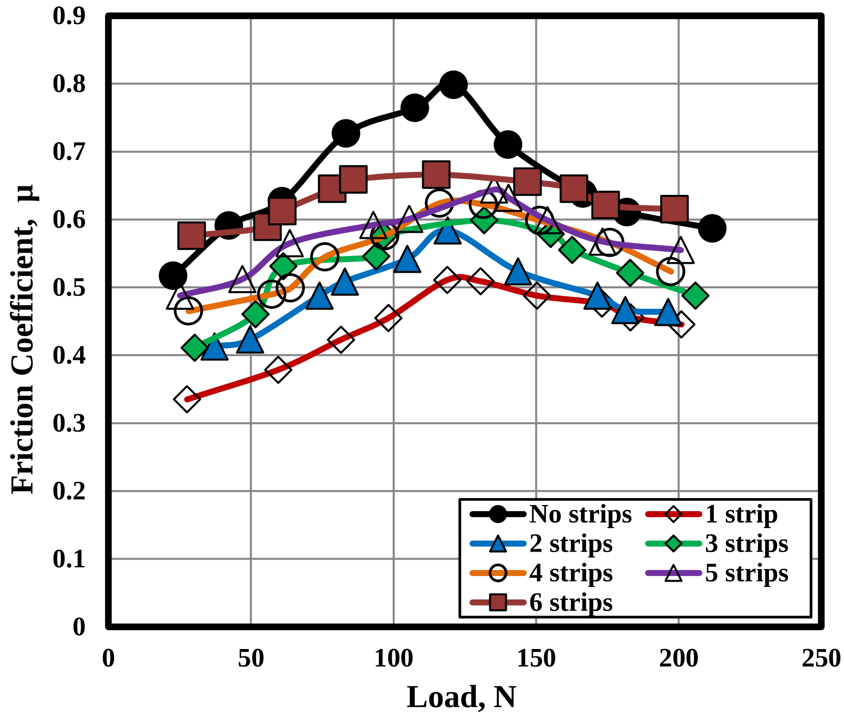

Fig. 20 Effect of number of ungrounded strips on friction coefficient on material (B) at wet chlorine sliding.

At water/chlorine dilution wet surface, the voltage decreased to 72 volts, Fig. 20, which was lower than that observed in Fig. 11. The voltage was 516 volts in floor material fitted by grounded six strips. This behavior is attributed to the presence of water film that leaks amount of generated ESC. On the other hand, the voltage increased up to 72 volts in the floor material fitted by six grounded strips, Fig. 19, due to charging by induction. Friction coefficient decreased down to 0.67 in floor material fitted by six grounded strips, Fig. 20, which was lower than that displayed in Fig. 18.

CONCLUSIONS

1. ESC increased by increasing the number of strips, where the double layer of the ESC generated on the sliding surfaces causes an E-field that generated extra amount of ESC.
2. Increasing ESC has a pronounced effect on adhesion force between the contact surfaces leading to an increase in the friction coefficient and consequently increases safety of walking.
3. ESC increased by 3 % in the presence of grounded stainless steel strips, while friction coefficient decreased by 4 - 5 %.
4. Floor material (B) generated ESC lower than that observed in floor material (A).
5. At dry sliding, ESC was higher than that generated at water/chlorine dilution wet sliding. On the other hand, the friction coefficient decreases only by 5 %, confirming the increased ability of the tested floor to avoid slip accidents due to excessive movement, especially at wet sliding.

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