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TRIBOELECTRIFICATION OF SHOE SOLES AND FLOOR IN HOSPITALS

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ABSTRACT

Electric static charges generated from friction of engineering materials have a negative effect in their applications. The increased use of polymeric materials raised the importance of studying that effect. Electric static charges building up on human skin and or clothes in direct contact with human body are very harmful and can create serious health problems. The present study investigates the electric static charge generated from the dry and water wetted sliding of shoe sole against floor for people who are working in hospitals.

It was found that friction coefficient displayed by dry sliding of polypropylene shoe sole against epoxy floor decreased with decreasing normal load, where the values were reasonable to avoid the foot slip. Friction values at light loads guaranteed the good adhesion of the shoe sole against floor. They are enough for safe use at dry sliding condition. Sliding of shoe against floor at dry condition generated much higher electric static charge measured on the shoe. This observation can confirm the necessity to develop new materials to be applied as shoe sole of low electric static charge. At sliding, the charge value was higher than that recorded for contact and and separation.At water wetted contact, the values of friction and electric static charge were lower than that observed for dry contact. It seems that the low values of electric charge were from the ability of water to conduct the charge from the contact surfaces.

KEYWORDS
Electric static charge, contact and separation, sliding, dry, water wetted, shoe, floor, hospitals.

INTRODUCTION
Static charge includes potentially dangerous electrical shocks which can cause fires and explosions. It can also cause severe damage to sensitive electronic components. Triboelectric charging is the transfer of electrons which occurs when two materials are in contact and are then separated. One material gains an excess of negative ions and the other an excess of positive ions. The charge generated can be more than 25,000 volts. It is well known that when two different materials contact each other, they may get charged. This tribocharging phenomenon is also known as triboelectrification when

materials rub against each other, [1 - 3]. The mechanism of charge transfer in tribocharging can be explained by three mechanisms: electron transfer, ion transfer, and material transfer, [4 – 6]. The metal to metal contact electrification successfully explained by electron transfer mechanism. When two different materials come to contact, electrons transfer happens until their Fermi level equals. Difference in work functions between them is the main driving force, [7]. As for insulators, the electron transfers only happen on the surfaces of insulators, where electrons move from the filled surface of one insulator to the empty surface of the other insulator, [8 – 10]. Few researchers have drawn up triboelectric series to predict the polarity of the charge that is transferred from one surface to another, [11]. When two kinds of materials contact each other, the upper one in the triboelectric series will get positively charged and the other one will be negatively charged. It is becoming increasingly evident that more than one of these mechanisms may occur simultaneously, [12].

The electrostatic charging of unstrained and strained latex rubber sheets contacted with a series of materials such as polytetrafluoroethylene (PTFE), polyurethane (PU) and stainless steel (SS) was studied, [13]. For SS, strain reduces the frequency of electrical discharges occurring. It was found that material strain can strongly influence triboelectric charging. Besides, straining a material can produce ions, electrons, and radicals that can react to form charged species. Silicon carbide is electrically semiconducting. The friction and wear behaviour of silicon carbide based materials may be influenced by electric potentials applied to the tribological system, [14 – 17]. Also, it was found that the surface state of SiC ceramics can be influenced by electric potentials.

Triboelectrification and triboluminescence were measured from the sliding or rolling frictional contacts between polymers of PA66, POM, ABS, PET, PP, PVC, PE, and PTFE in various humidity conditions, [18]. Triboluminescence intensity was higher in sliding friction. The saturation charges of all the sliding couples showed their maxima at the humidity from 10 to 30%. It was found that the humidity enhanced charge transfer which resulted in the increase or decrease of electrification, [19]. The contact and separation process leads to the charge transfer between dissimilar materials. When charges are accumulated, they are measured as triboelectrification.

Charge and discharge associated with the rubbing between shoes and carpet are less experienced in summer rather than in winter. It indicates that the charge is suppressed in higher humidity. Experimental data have exemplified this tendency [20 - 22]. However, other data show that water molecules on the surfaces convey charges in the form of ions to enhance charge separation between two surfaces [23, 24]. These contradictory results require precise measurement of the effect of humidity on charge generation.

Dielectric and friction behaviour of unidirectional glass fibre reinforced epoxy (GFRE) were studied, [25]. It was found that the glass fibre/matrix interfaces allow the trapping of electric charges. The diffusion of electric charges through the fibre–matrix interfaces permits a stabilization of the friction coefficient and a limitation of the wear, where a localized trapping of charges on the interfaces is a source of damage and wear. The importance of fibre/matrix interface on the trapping/diffusion of the electric charges was previously discussed, [26]. Tribological studies to correlate friction coefficient and wear with the role of the electric charges were carried out. Polymers are characterized by a low mobility leading to a strong localization of the electric charges, and consequently to

their trapping on structural defects inducing local variations of the dielectric susceptibilities, [27]. Then, an external stress can permit the detrapping of trapped charges, [28], and, consequently, the release of the stored polarization energy, inducing catastrophic effects, such as dielectric breakdown, rupture or wear.

It was found that voltage generated by the contact and separation of the tested upholstery materials of car seat covers against the materials of clothes showed great variance according to the type of the materials, [29]. The materials tested showed different trend with increasing load. The contact and separation of the tested against polyamide textiles generated negative voltage, where voltage increased down to minimum then decreased with increasing load. The behaviour can be interpreted on the fact that as the load increased the two rubbed surfaces, charged by free electrons, easily exchanged the electrons of dissimilar charges where the resultant became relatively lower voltage. High density polyethylene displayed relatively lower voltage than cotton and polyamide textiles, while polypropylene textiles displayed relatively higher voltage than that shown for high density polyethylene. The variance of the voltage with load was much pronounced. Remarkable voltage increase was observed for contacting synthetic rubber. This observation can limit the application of synthetic rubber in tailoring clothes. Materials of high static electricity can be avoided and new materials of low static electricity can be recommended.

The wide use of polymer fibers in textiles necessitates to study their electrification when they rubbing other surfaces. The electric static charge generated from the friction of different polymeric textiles sliding against cotton textiles, which used as a reference material, was discussed, [30]. Experiments were carried out to measure the electric static charge generated from the friction of different polymeric textiles sliding against cotton under varying sliding distance and velocity as well the load. It was found that increase of cotton content decreased the generated voltage. Generally, increasing velocity increased the voltage. The voltage increase with increasing velocity may be attributed to the increase of the mobility of the free electrons to one of the rubbed surfaces. The fineness of the fibers much influences the movement of the free electrons. The electrostatic charge generated from the friction of polytetrafluoroethylene (PTFE) textiles was tested to propose developed textile materials with low or neutral electrostatic charge which can be used for industrial application especially as textile materials, [31]. Research on electrostatic discharge (ESD) ignition hazards of textiles is important for the safety of astronauts. The likelihood of ESD ignitions depends on the environment and different models used to simulate ESD events, [32]. Materials can be assessed for risks from static electricity by measurement of charge decay and by measurement of capacitance loading, [33].

Less attention was considered for the triboelectrification of the textiles. Friction coefficient and electrostatic charge generated from the friction of hair and head scarf of different textiles materials were measured, [34]. Test specimens of head scarf of common textile fibres such as cotton, nylon and polyester were tested by sliding under different loads against African and Asian hair. Electric static charge measured in voltage represented relatively lower values. This behaviour may be attributed to the ranking of the rubbing materials in the triboelectric series where the gap between human hair and nylon is smaller than the gap between hair and cotton as well as hair and polyester.

Little attention has been devoted so far to the electrostatic properties of hair although these properties are very sensitive to the friction between hair and head scarf textiles. Hair has a tendency to develop static charge when rubbed with dissimilar materials like human skin, plastic and textiles. Human hair is a good insulator with an extremely high electrical resistance. Due to this high resistance, charge on hair is not easily dissipated, especially in dry environments. Many macroscale studies have looked at the static charging of human hair, [35, 36]. Most of these studies include rubbing hair bundles with various materials like plastic combs, teflon, latex balloons, nylon, and metals like gold, stainless steel and aluminum. Hair in these cases is charged by a macroscale triboelectric interaction between the surface and the rubbing element.

The present study investigate the friction coefficient and electric static charge generated from the contact and separation as well as sliding of polypropylene shoe against epoxy floor for people who are working in hospitals at dry and water wetted working conditions.

EXPERIMENTAL

The present work investigated the measurement of electric static charge generated by the contact and separation as well as dry sliding of shoe (polypropylene) against floor (epoxy) of people who are working in hospitals. The electrostatic fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens, Fig. 1. It measures down to 1/10 volt on a surface, and up to 20 000 volts (20 kV). Readings are normally done with the sensor 25 mm apart from the surface being tested. The tested textiles were adhered to the wooden block of 50 × 50 mm^2. Tests were carried out at room temperature under varying normal loads. The epoxy floor tiles of 400 × 200 mm^2 were placed in a base supported by two load cells, the first can measure the horizontal force (friction force) and the second can measure the vertical force (normal load), Fig. 2. The shoe was pressed to epoxy tile by foot. Friction coefficient was determined by the ratio between the friction force and the normal load.

Fig. 1 Electrostatic field measuring device.

During test running, horizontal and vertical load cell connected to two monitors read normal and friction load respectively. Friction coefficient is the ratio between friction load and normal load. Each run was replicated five times, and the mean value of the friction coefficient was considered. Friction test were carried out at different forces (loads) ranging from 0 -100 N. The tested shoe and floor are shown in Fig. 3, 4.

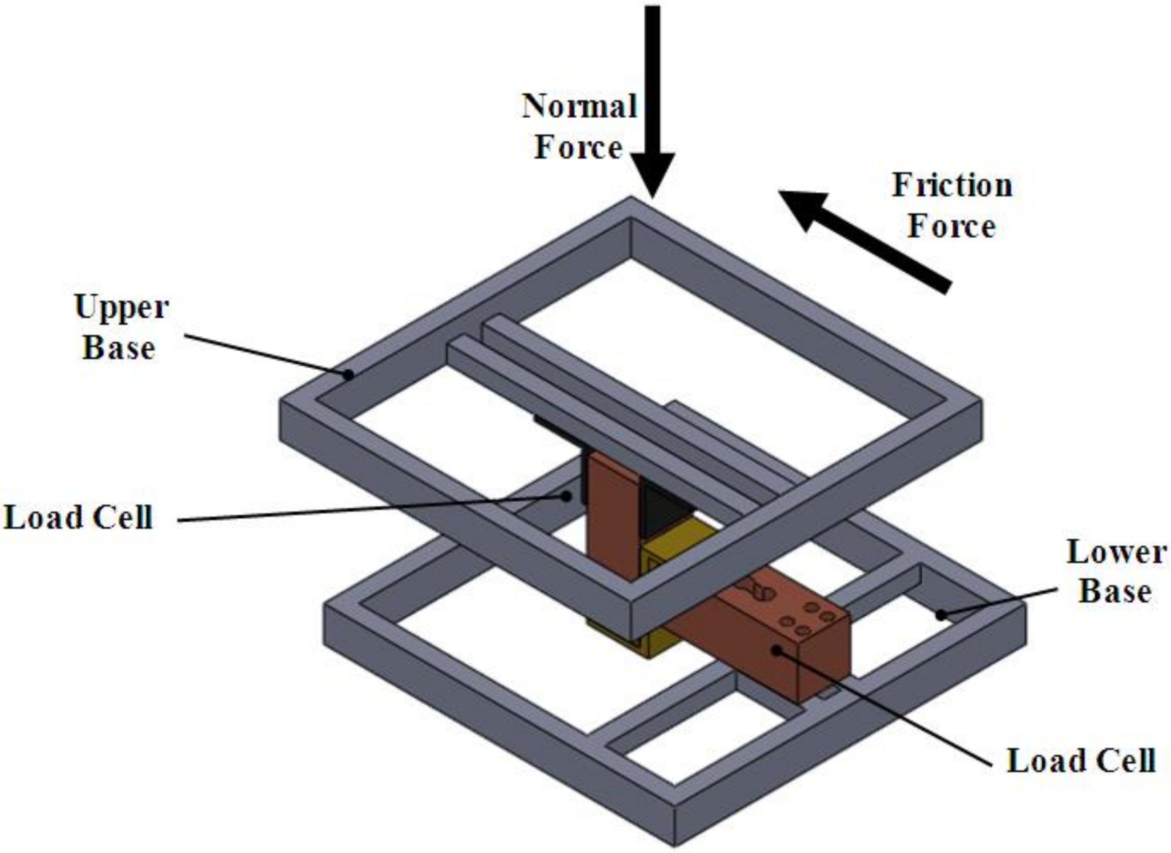

Fig. 2 Arrangement of the test rig.

Fig. 3 Shoe against floor.

RESULTS AND DISCUSSION

The results of the experiments carried out to test the friction coefficient and electric static charge generated at the dry contact and separation as well as sliding of shoe sole against floor are shown in Figs. 4 – 8. Friction coefficient displayed by sliding of polypropylene shoe sole against epoxy floor at dry condition, Fig. 4, decreased with decreasing normal load. It is necessary that friction coefficient should have reasonable values so that the foot slip should be avoided to prevent accidents. The lowest and highest friction values were 0.43, 1.02at 350 and 850 N load respectively. As the load increased, friction coefficient drastically decreased. The friction values at light loads guaranteed the good adhesion of the shoe sole against floor. They were enough high for safe use at dry sliding condition.

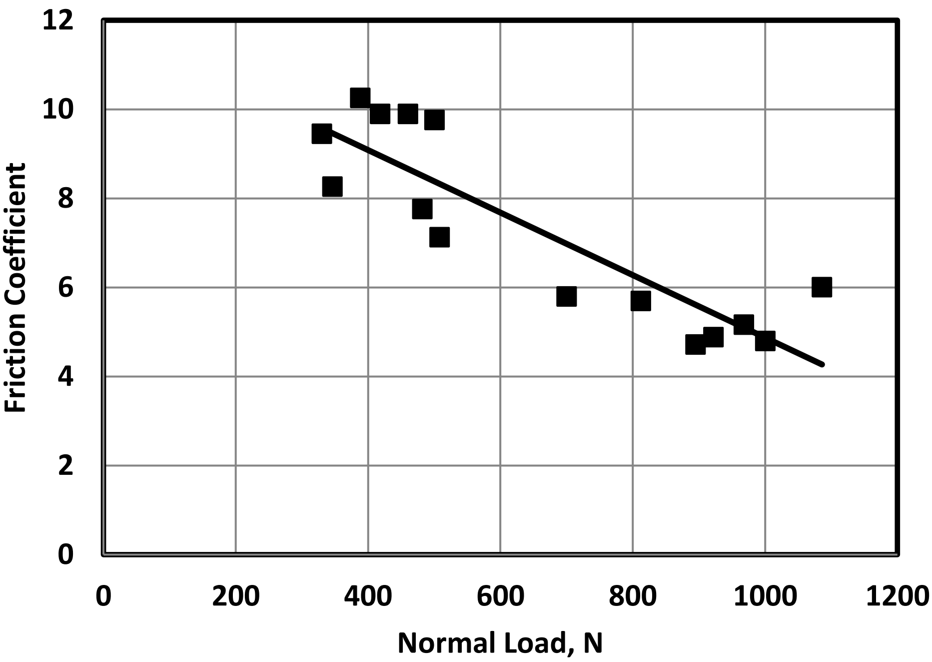

Fig. 4 Friction coefficient displayed by sliding of shoe against dry floor.

Electric static charge generated on the shoe sole from contact and separation against dry floor is shown in Fig. 5. The values were ranged between -48 and -155 volts distributed on the shoe sole. As the load increased the charge decreased. This behaviour might be attributed to increase of the contact area with increasing load. The electric static charge generated on the epoxy floor, Fig. 6, showed positive values ranging from 35 to 78 volts. As the load increased, electric static charge slightly decreased due to the increased interference between the shoe and floor, where the charge transfer became easier. Due to the nature of the electric static charge the scatter in the values measured during experiments was relatively high.

Dry sliding of shoe against floor generated much higher electric static charge measured on the shoe, Fig. 7. The highest voltage reached -4400 volts, while the lowest was -250 volts. This observation can confirm the necessity to develop new materials to be applied as shoe sole of low electric static charge. As the load increased, the negative voltage remarkably increased. Electric static charge generated on the floor surface recorded very low voltage value of 220 volts at 720 N, Fig. 8. As the load increased the positive voltage increased. It seems that friction coefficient critically depended on the value of the generated voltage. This behaviour can be explained on the basis that, generation of

equal electric static charges on the sliding surfaces of different signs would increase the attractive force between the two surfaces and consequently the adhesion increased leading to friction increase.

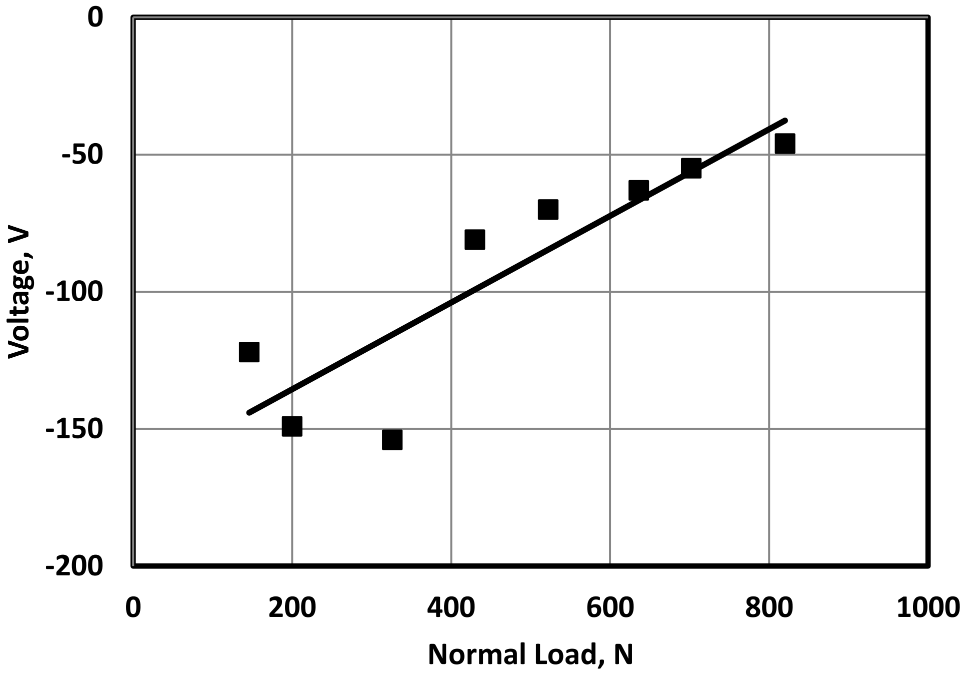

Fig. 5 Electric static charge of shoe generated from its contact and separation against dry floor.

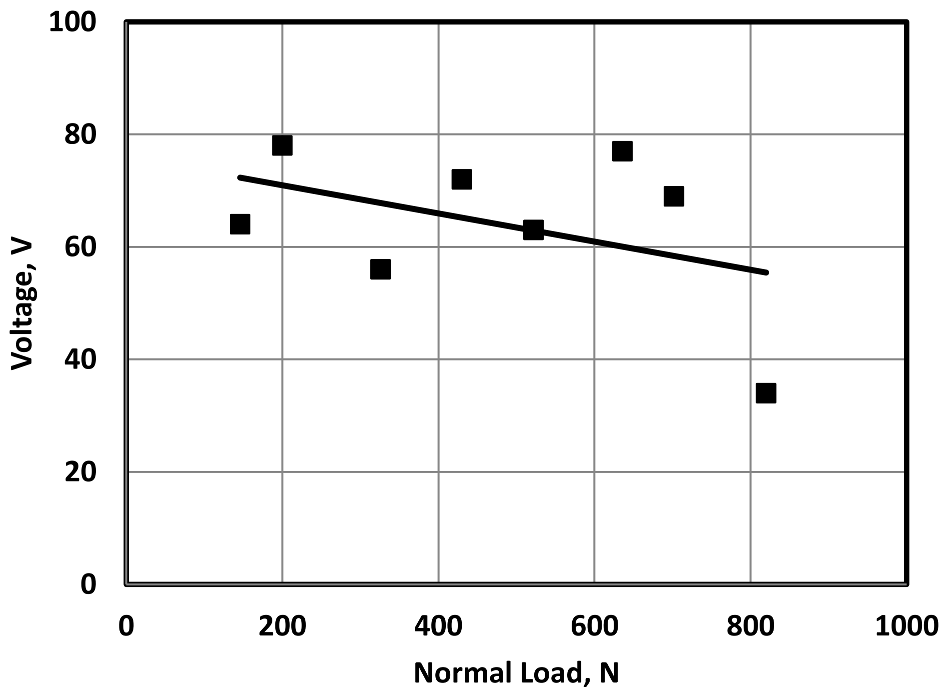

Fig. 6 Electric static charge of floor generated from its contact and separation against dry shoe sole.

It was observed that, at sliding, the charge value was higher than that recorded for contact and and separation. Based on this observation, it can be concluded that material of shoe sole generated very high electric static charge values. When two materials contact each other, the upper one in the triboelectric series will get positively charged and the other one will be negatively charged. As the difference in the rank of the two materials increases the generated voltage increases. It is known that shoe sole (polypropylene) is ranked as negative charged material, while epoxy is above propylene so it is positive charged. It is therefore necessary to select the materials based on their triboelectric charging.

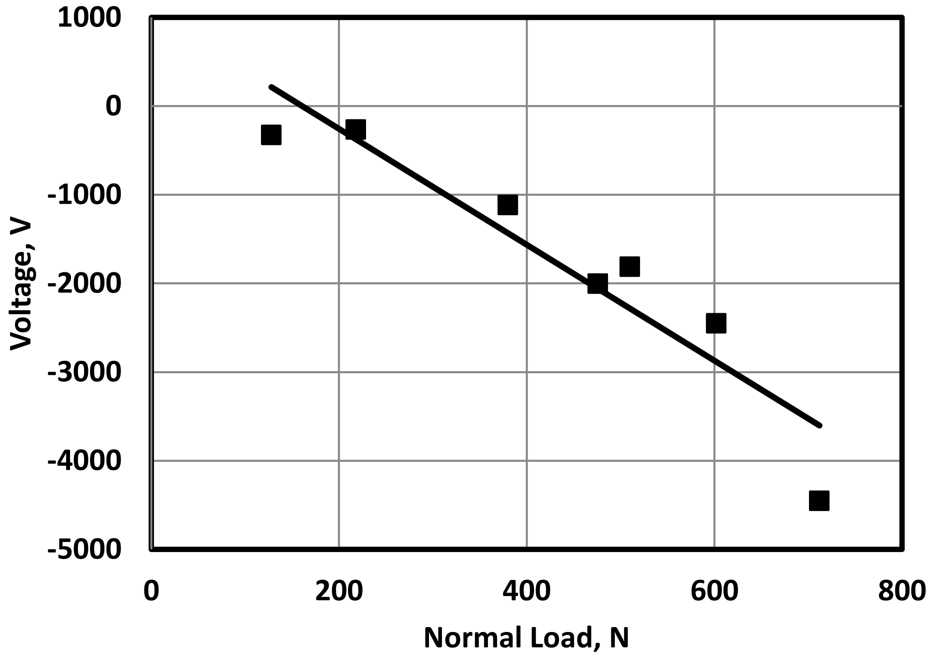

Fig. 7 Electric static charge of shoe generated from its sliding against dry floor.

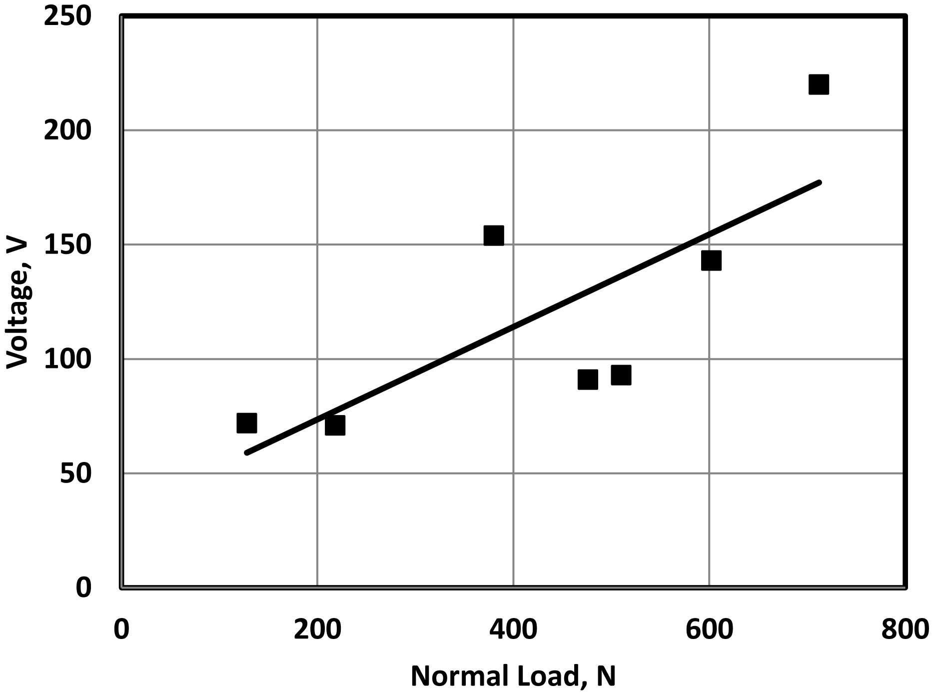

Fig. 8 Electric static charge of floor generated from its sliding against dry shoe sole.

The results of experiments measuring friction coefficient and electric static charge at water wetted contact are illustrated in Figs. 9 – 13. Friction coefficient is considered as the main factor in evaluation contacting materials. The measure of the safety is the friction coefficient displayed between the shoe and the floor. As the friction coefficient increased, the safety of walking increased. Friction coefficient displayed by sliding of shoe against epoxy floor at water wetted condition is shown in Fig. 9. Friction coefficient slightly decreased with increasing the load. The lowest friction value was 0.42, while the maximum value was 0.56. The values of friction were lower than that observed for dry contact.

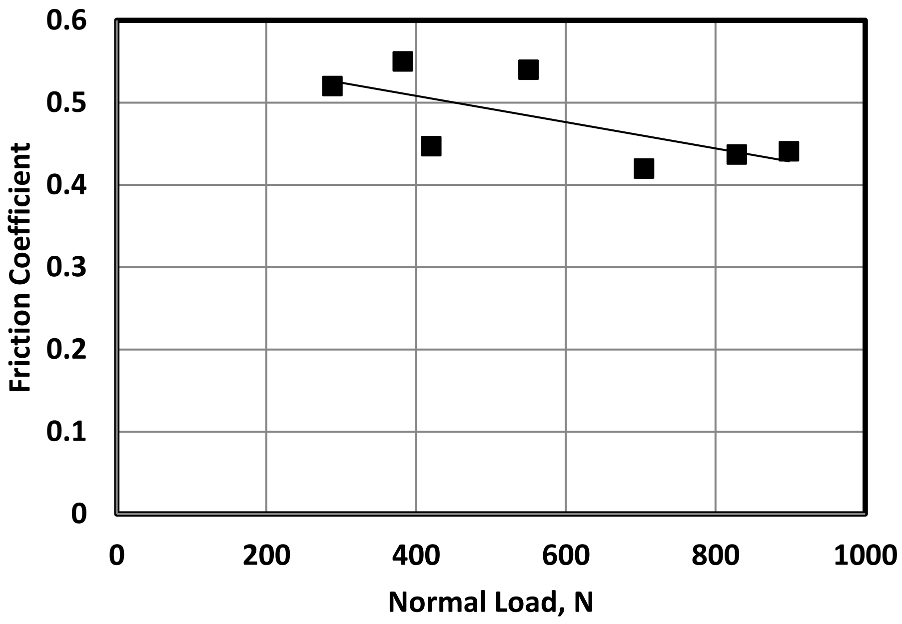

Fig. 9 Friction coefficient displayed by sliding of shoe against water wetted floor.

Voltage generated on the shoe sole from its contact and separation against epoxy floor is shown in Fig. 10. Voltage values were -92 and -25 volts at 220 and 850 N load respectively. This observation confirmed that, the amount of electric static charge depended on the load. The contact and separation of the sole with floor, Fig. 11, displayed positive voltage reached 78 volts. The values of electric static charge were approximately similar to that shown for the opposite side (shoe). It seems that, the low values of charge were from the ability of water to conduct the charge from the contact surfaces. It is recommended to measure the charge simultaneously on the two opposing surfaces.

Voltage generated on sole from its sliding against floor is shown in Fig. 12. The maximum voltage value was -88 volts at 250 N. The electric static charge generated on the floor from its sliding against sole is shown in Fig. 13. The voltage observed was in positive sign with relatively low values.

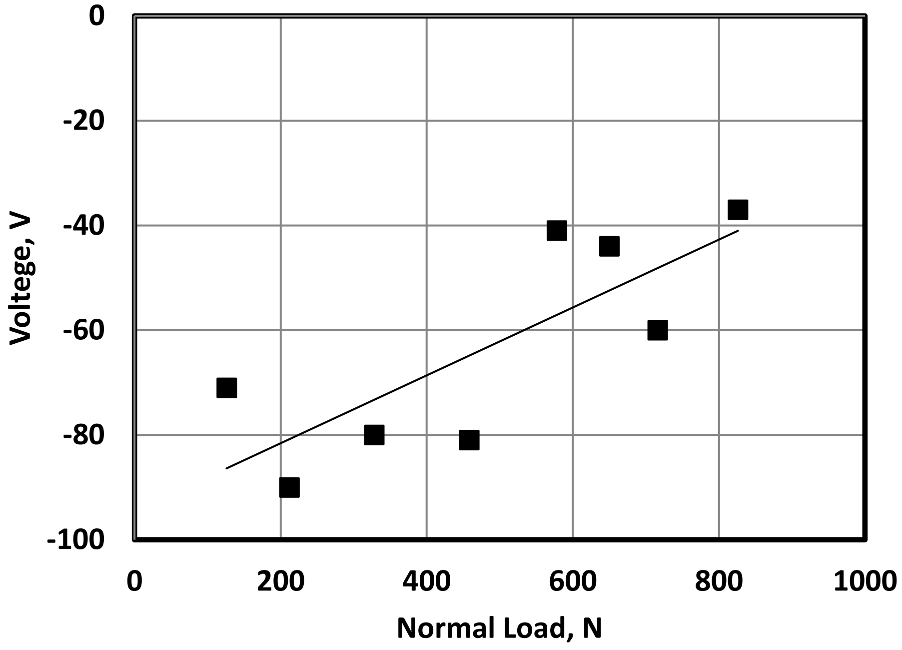

Fig. 10 Electric static charge of shoe generated from its contact and separation against water wetted floor.

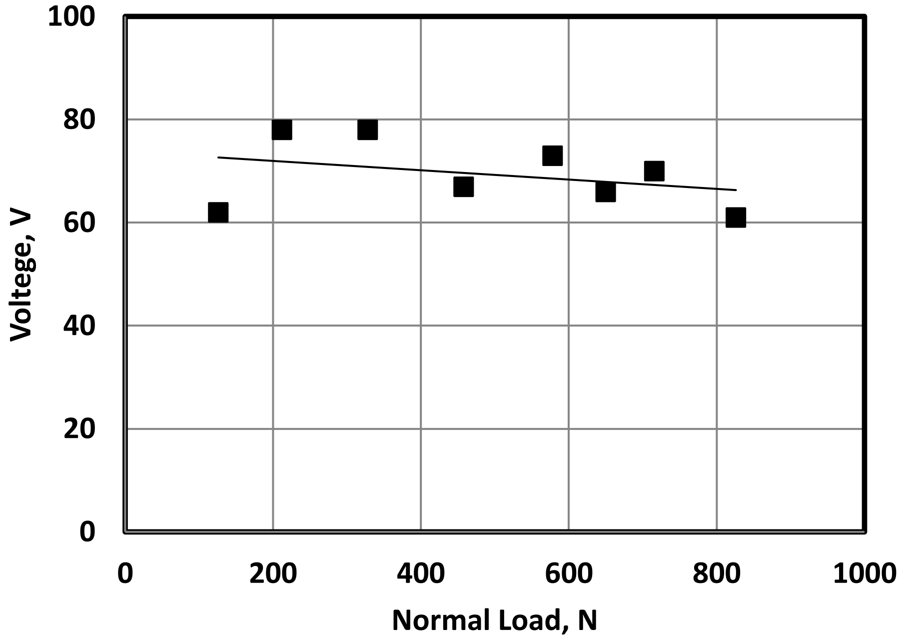

Fig. 11 Electric static charge of floor generated from its contact and separation against water wetted shoe sole.

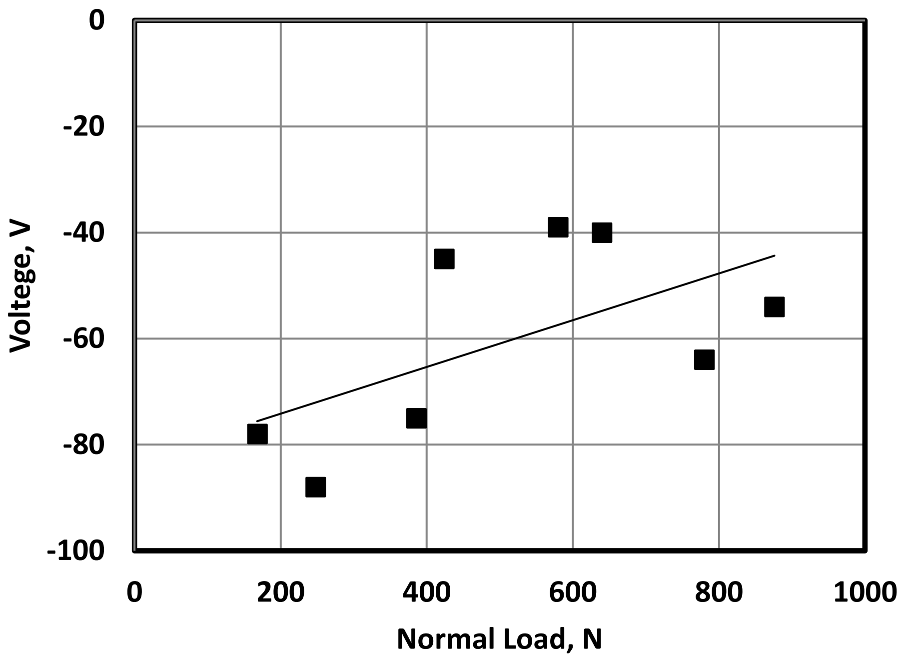

Fig. 12 Electric static charge of shoe generated from its sliding against water wetted floor.

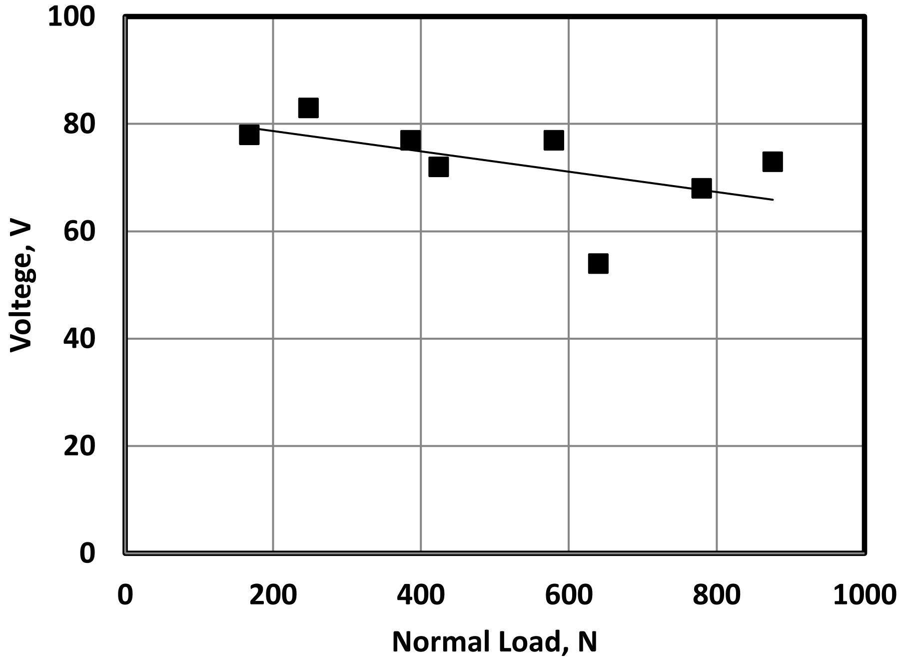

Fig. 13 Electric static charge of floor generated from its sliding against water wetted shoe sole.

CONCLUSIONS

1. Friction coefficient displayed by dry sliding of polypropylene shoe sole against epoxy floor decreased with decreasing normal load. As the load increased friction coefficient drastically decreased. The friction values at light loads guaranteed the good adhesion of the shoe sole against floor. They are enough safe for use at dry sliding condition.

2. Electric static charge generated on the shoe sole from dry contact and separation against floor showed negative sign, while the electric static charge generated on the epoxy floor showed positive values. As the load increased, electric static charge slightly decreased due to the increased interference between the shoe and floor, where the charge transfer became easier.
3. Dry sliding of shoe against floor generated much higher electric static charge measured on the shoe. The highest voltage reached -4400 volts, while the lowest was -250 volts. This observation can confirm the necessity to develop new materials to be applied as shoe sole of low electric static charge.
4. Friction coefficient displayed by sliding of shoe against epoxy floor at water wetted condition slightly decreased with increasing the load. The values of friction were lower than that observed for dry contact.
5. Electric static charge generated at the water wetted surfaces generated relatively low values due to the ability of water to conduct the charge from the contact surfaces.

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