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ELECTROSTATIC CHARGE GENERATED FROM CONTACT/SEPARATION AND SLIDING OF FOOT ON INSOLE OF POLYPROPYLENE SHOES IN HOSPITALS

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ABSTRACT
Electrostatic charges (ESC), generated from contact/separation and sliding of foot and insole of polypropylene (PP) shoes used by people of medical care in hospitals are discussed in the present work. ESC built up on human skin are harmful and can cause serious health problems. The harmful effect too is from the electric field generated from ESC that can influence the operation of the electronic appliances used in hospitals. It is aimed to investigate friction coefficient and ESC generated from the dry and wet sliding of bare foot as well as foot wearing cotton and polyester (PET) on insole of PP shoes.

The slipperiness of foot in contact with the insole of the PP shoes influences the safe walking. Besides, generation of ESC built up on human bodies causes serious health problems. It was revealed that bare foot displayed the highest friction values followed by foot wearing cotton socks, while PET socks showed the lowest values at dry and water wet sliding. PET socks displayed very low values of friction coefficient increasing the danger of slip. Bare foot generated the highest ESC values followed by foot wearing cotton and PET socks. The experimental observations confirmed the dependency of friction coefficient on the magnitude of ESC due to the increase of the adhesion between foot and PP. It is recommended to carefully select the materials of shoe insole and socks materials.

KEYWORDS
Friction coefficient, electrostatic charge, contact/separation, bare foot, foot wearing socks, cotton, polyester, insole, polypropylene, shoes, hospitals.

INTRODUCTION
The used of polymeric materials in the medical clothes of people working in hospitals necessitates to increase the interest in studying triboelectrification. Measurement of potential by gained by human body was made to avoid the drawbacks of electrostatic charges (ESC) by selecting the proper materials, [1, 2]. ESC of the human body after walking on polymeric floors was discussed, [3 - 5]. It was recommended to carefully select the proper materials of floor and the footwear outer soles of relatively higher electrical conductivity to avoid the increase of body voltage to be lower than 100 V.

It was revealed ESC may damage electronic appliances of monitoring the healthy condition of patients in hospitals, where ESC up to 25,000 volts. When two dissimilar materials contact each other, they get charged. This process is defined as triboelectrification, [6 - 8]. ESC transfer includes ion transfer, electron transfer and material transfer. Triboelectric series controls the prediction of the polarity of the ESC generated on the contacting surfaces, [9 - 17], where the material in the upper position in the triboelectric series will be positively charged while the other will be negatively charged.

It was found that ESC generated from walking on the carpet may be more dangerous, [18 - 20]. To leak ESC out of the contact surfaces, water was sprayed on the carpet, [21, 22], confirming the influence of humidity on reducing ESC. It was observed that polymers had localized and trapped ESC, [23]. ESC can be released by applying external stress, rupture and wear, [24]. It was proved thar PP textiles showed higher ESC than that observed for high density polyethylene (HDPE).

The present study investigates the triboelectrification of the bare foot and foot wearing socks due to contact/separation and sliding on PP insole of shoes of people working in hospitals.

EXPERIMENTAL

The measurement of ESC generated by the contact/separation and sliding of bare foot and foot wearing cotton as well as polyester socks against insole of the PP shoes that the people of medical care in hospitals are wearing. The measuring device (Ultra Stable Surface DC Voltmeter) was applied to measure ESC. The PP insole in form of sheet of 500 × 500 mm^2 and 0.5 mm thickness was adhered to the wooden table of the test rig, Fig. 1. Load was applied by pressing the PP sheet in two conditions. The first was contact/separation and the second was sliding at dry and water wet PP surface.

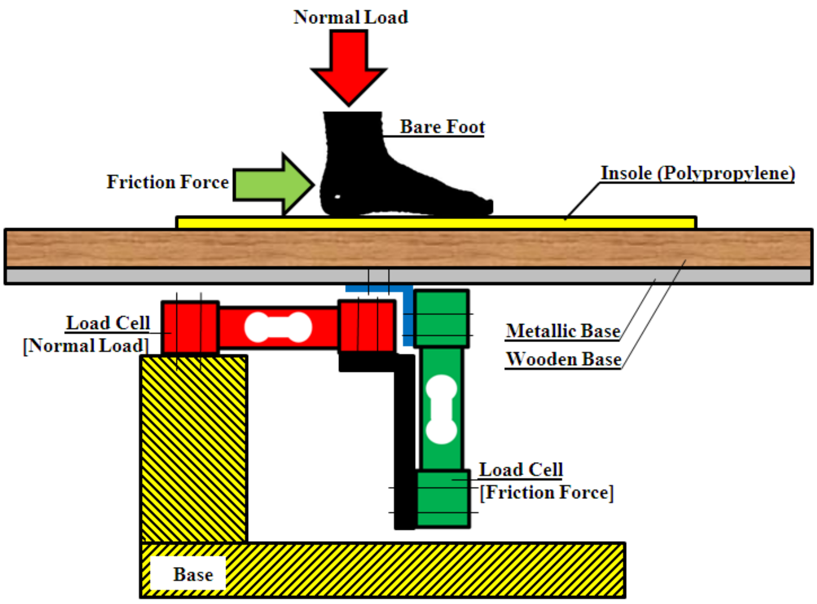

Fig. 1 Arrangement of the test rig.

Fig. 2 PP shoe.

The foot pressed the PP sheet for 5 second then ESC was measured. In condition of sliding, foot was permitted to slide during loading. ESC was measured on the PP surface, where the experiments were repeated five times. Bare foot and foot wearing polyester as well as cotton socks were tested. Tests were carried out at varying load up to 900 N. Besides, friction coefficient between the foot and PP sheet, where the base of the test rig is supported by two load cells to measure the friction force and the normal load. The value of friction coefficient was calculated by dividing the value of friction force on the value of normal load. The two load cells were connected to two monitors to register both the normal and friction force. Each run was replicated five times, and the mean value of the friction coefficient was considered. The tested PP shoe is shown in Fig. 2.

RESULTS AND DISCUSSION

The slipperiness of foot on the insole of the shoe is evaluated by the static friction coefficient. Slip resistance of floor is the major factor influencing walking. Floor slipperiness may be quantified using the static and dynamic friction coefficient. The values of friction coefficient were recommended for unloaded and normal walking conditions, [13]. In the present work, friction coefficient displayed by bare foot as well as foot wearing cotton and PET socks sliding on dry and water wet PP was tested, Figs. 3, 4. It is shown that that friction coefficient decreased with increasing normal load. Bare foot showed the highest friction values followed foot wearing cotton socks, while PET socks measured the lowest values. It seems that the adhesion of bare foot to the PP sheet was relatively high. At wet sliding condition, friction coefficient displayed relatively low values that do not guarantee safe walking, Fig. 4, especially at higher normal loads. PET socks gave very low values of friction coefficient that permit the slip of the foot on the PP sheet. The lowest friction value displayed by PET was 0.11 at 734 N at dry sliding, while the highest value was 1.1 at normal load of 103 displayed by bare foot. As the load increased friction coefficient drastically decreased. The experimental observations confirmed that socks influence friction coefficient between the foot and shoe insole. Application of both cotton and PET socks reduced the shear between the foot and PP, [27, 28]. This behavior is favorite to avoid abrasion of the foot skin.

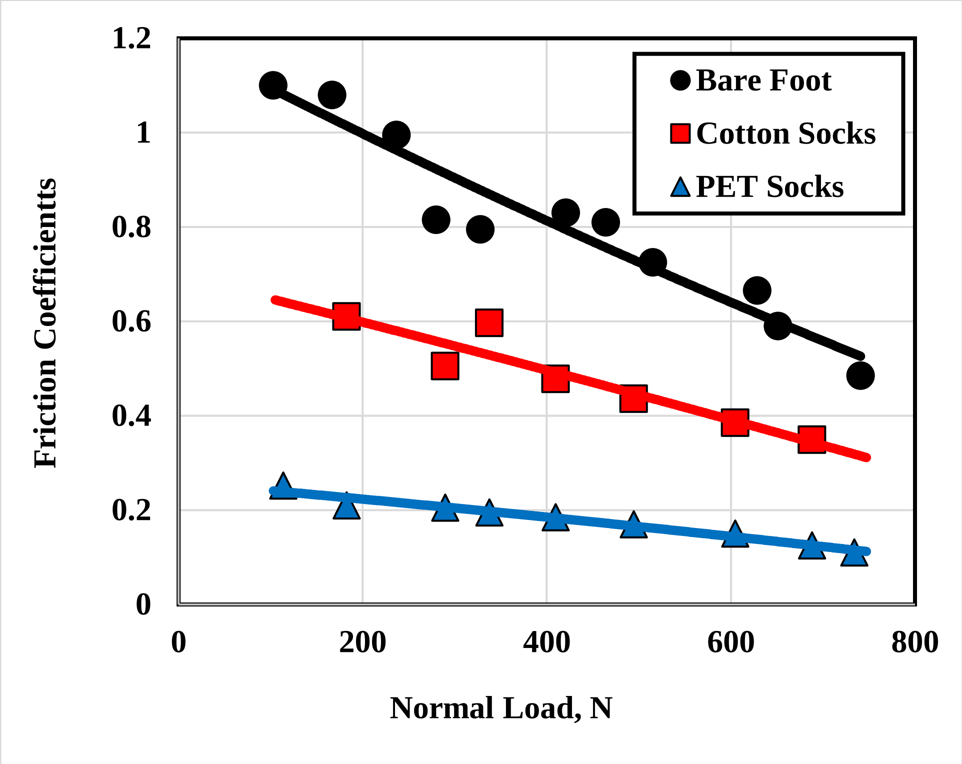

Fig. 3 Friction coefficient displayed by sliding of foot on PP insole.

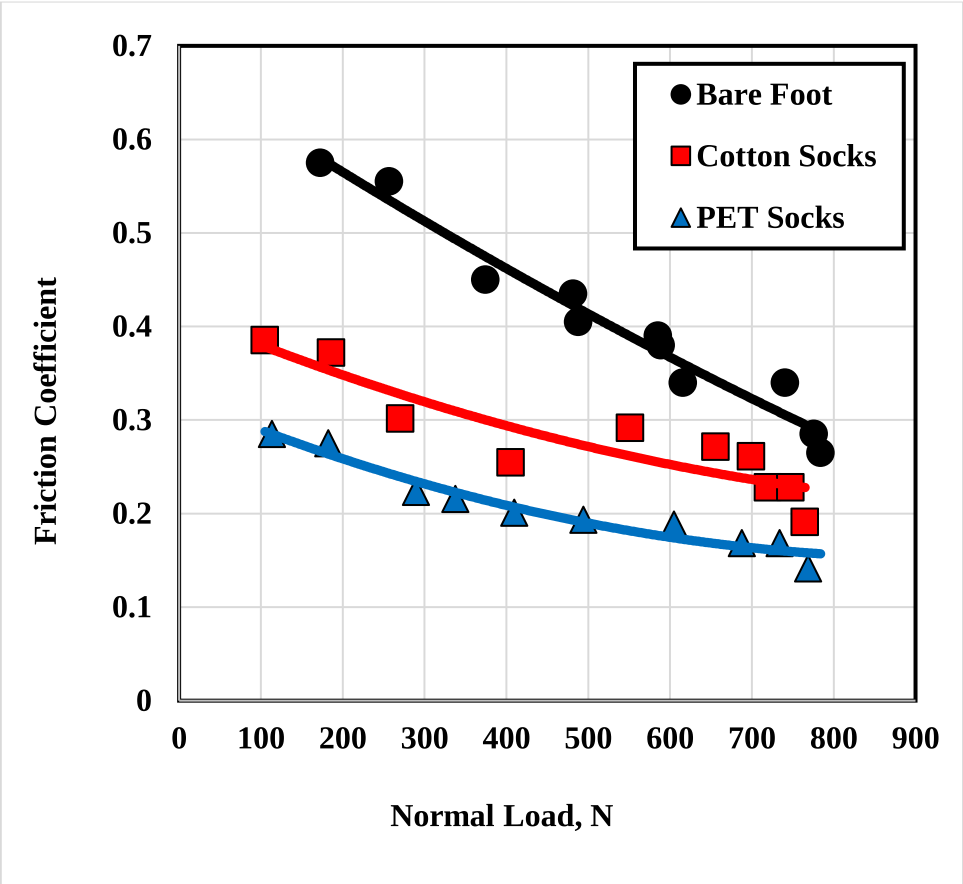

Fig. 4 Friction coefficient displayed by water wet sliding of foot on PP insole.

The frictional behavior of the tested surfaces can be explained on the bases of ESC. Little attention has been considered to the triboelectrification of foot after contact/separation and sliding on the insole of the shoes. Bare foot develops ESC when rubbed PP insole. Because PP is a good insulator and has high electrical resistance, ESC gained by PP cannot easily dissipated in dry air. Several researches were conducted to study the dependency of friction coefficient on the generated ESC, [29 – 32]. PTFE composites reinforced by carbon fibers (CF), copper and iron wires were tested. It was revealed that ESC generated on the surface of the tested composites strengthened the dependency of friction coefficient on ESC. The ESC value can control friction coefficient. It is known that increasing ESC value increases the adhesion between the two contacting surfaces so that the friction coefficient increases. In addition to that insulating the sliding surfaces affects the friction coefficient, where the insolated surfaces displayed lower friction coefficient than that measured for the connected ones.

ESC generated on the foot from its contact/separation against dry PP insole is shown in Fig. 5. ESC significantly increased with increasing the normal load. Bare foot gained the highest values of ESC followed by foot wearing cotton and PET socks. The highest values -2350, -1340 and -635 volts gained by bare foot and foot wearing cotton and PET socks respectively. At water wet, drastic decrease in the ESC values were observed the highest value was -736 volts for bare foot, Fig. 6. ESC generated from sliding of bare foot on PP sheet at dry condition generated much higher values reached to -5350 volts, Fig. 7, while cotton and PET recorded -3340 and -1235 respectively. The load had significant effect on the value of ESC. Wet contact showed lower values of ESC due to the conductivity of water that leaks the charge from one surface to the other, where the highest ESC recorded -720 volts displayed by bare foot, Fig. 8. The dependency of friction coefficient on the ESC is confirmed in the present work, where bare foot showed the highest friction when slid on PP followed by cotton and PET socks. The same order was observed in ESC gained by the tested surfaces, where bare foot gained the highest ESC while PET gained the lowest values.

Triboelectrification generates ESC that built up on human skin and clothes that are in direct contact with human body causing serious health problems. ESC generated during contact/separation and sliding of insulating materials can be from the trapping of charges during friction. Because ESC occurs during contact or sliding on the surface, they control the adhesion and affect friction due to the trapped charges. During, Surface deformation due to sliding generates local variations of the atomic polarizability, [33, 34], and lead to an electric field. In addition, the moving charges can be trapped the increasing the surface charge. Friction moves the charged particles by triboelectrification, [35], to be trapped followed by the relaxation of the polarisation energy that induces electric field. Besides, it is expected that friction induces dislocations, [36]. Based on that, the internal electric field prevails.

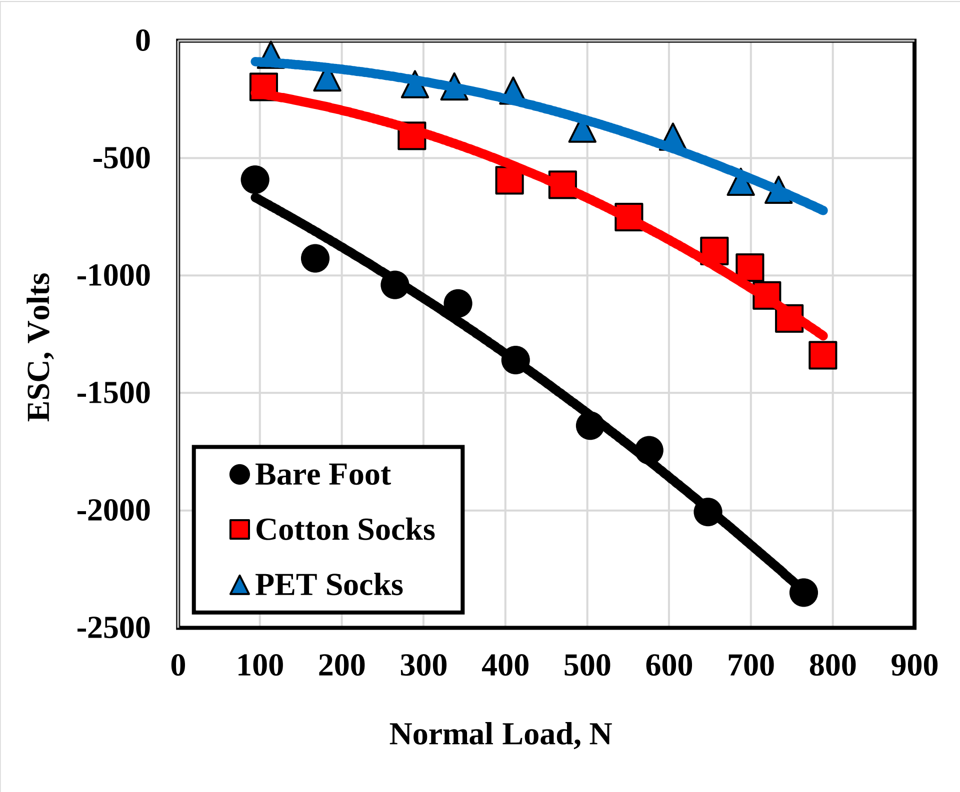

Fig. 5 ESC generated from contact/separation of foot on dry PP insole.

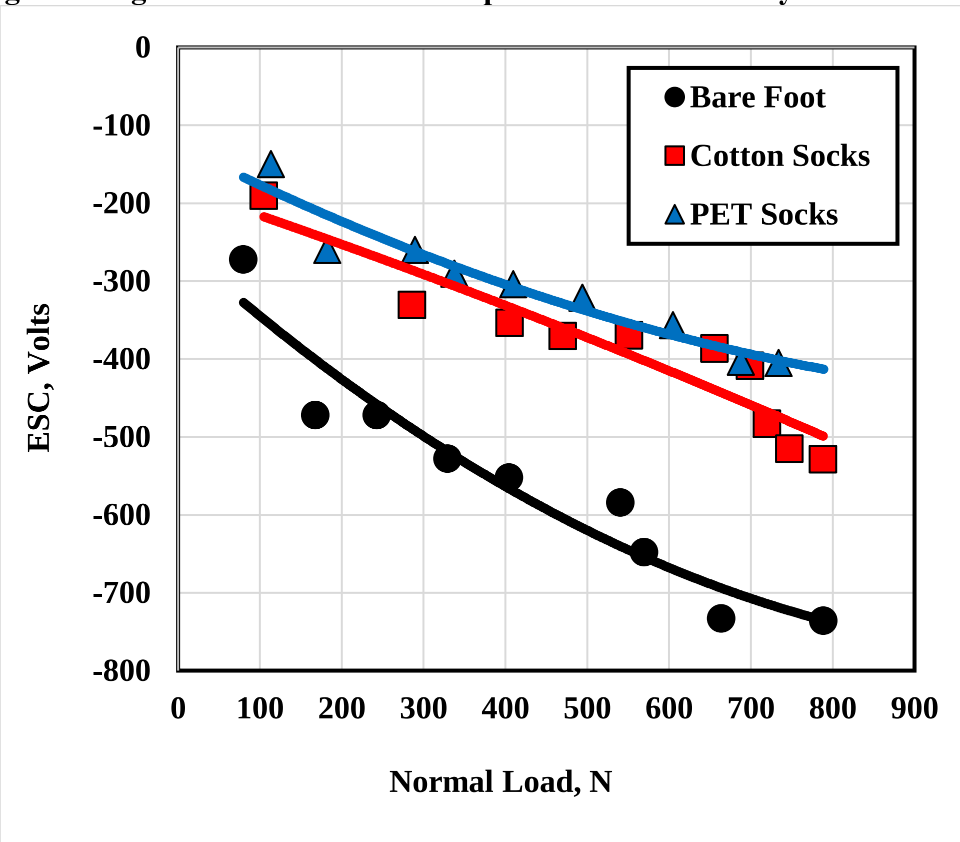

Fig. 6 ESC generated from contact/separation of foot on water wet PP insole.

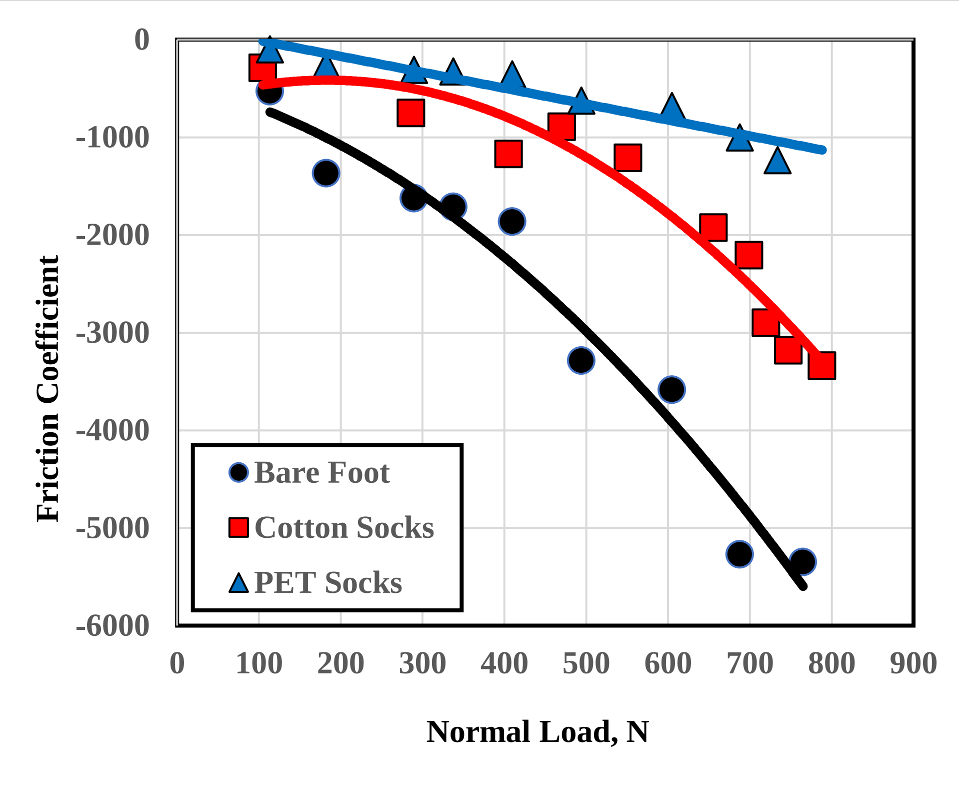

Fig. 7 ESC generated from sliding of foot on dry PP insole.

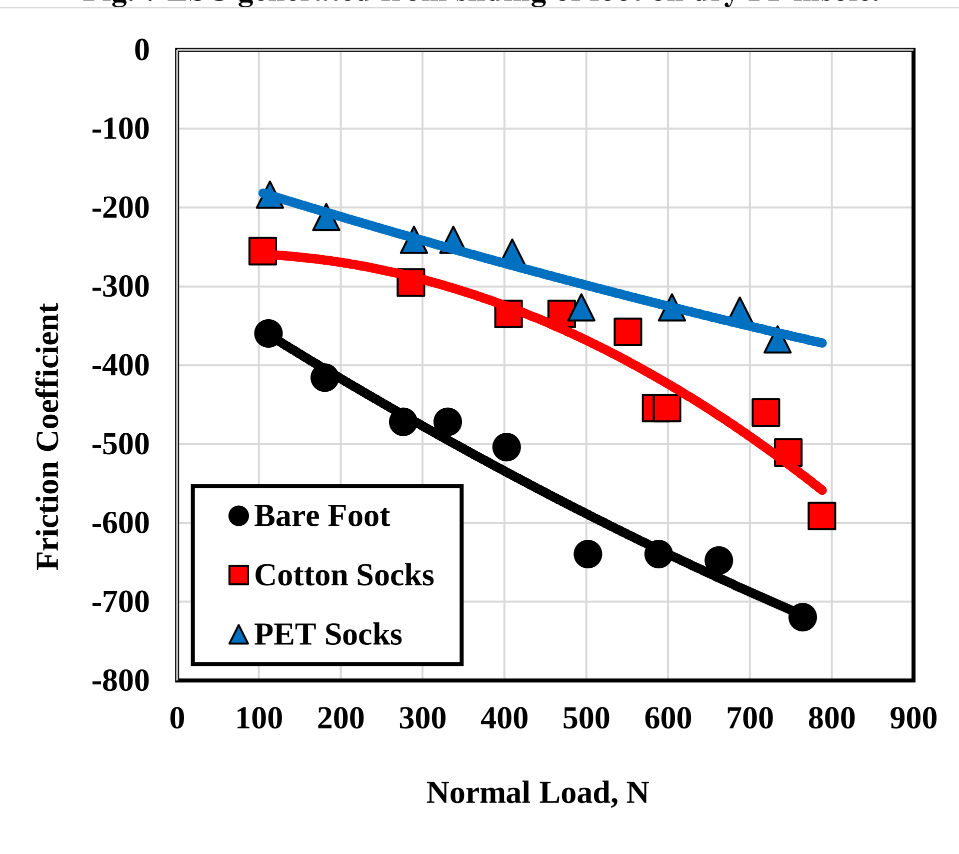

Fig. 8 ESC generated from sliding of foot on water wet PP insole.

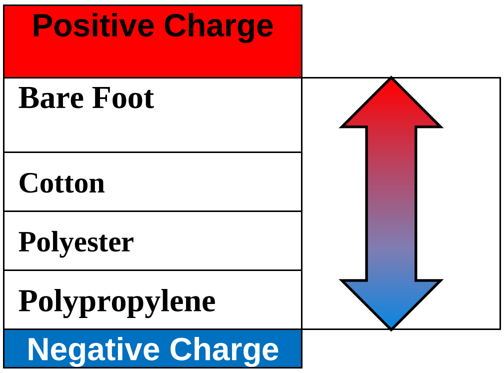

Fig. 9 Triboelectric series of the tested materials.

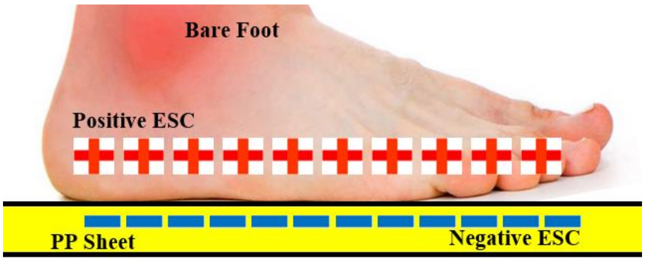

Fig. 10 Illustrating the distribution of electrostatic charge on the surfaces of bare foot and PP sheet.

Triboelectric series evaluates the ability of the materials to generate ESC. When two dissimilar materials contact and separate each other, one gets positively charged and the other gets negatively charged. As the distance of the two materials in the triboelectric series increases, the magnitude of ESC increases, Fig. 9. According to that, it is expected that shoe insole (PP) has negative charge when contacts or rubs bare foot that acquires positive charge, Fig. 10, where the distribution of ESC on both the surfaces of bare foot and PP sheet is illustrated. It is expected that the generation of equal ESC of different charges would increase the attractive force between the two contacting surfaces increasing the adhesion that increases the friction.

CONCLUSIONS

1. At dry sliding, bare foot displayed the highest friction values followed by foot wearing cotton socks, while PET socks showed the lowest values.
2. At water wet sliding, friction coefficient displayed relatively lower values than that observed for dry sliding.
3. PET socks gave very low values of friction coefficient increasing the danger of slip.
4. Friction coefficient drastically decreased with increasing the load.
5. Use of both cotton and PET socks reduced friction coefficient between the foot and PP sheet.
5. Bare foot acquired the highest values of ESC followed by foot wearing cotton and PET socks.
6. Water wetted PP caused drastic decrease in ESC.
7. Friction coefficient depends on the magnitude of ESC.

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