TRIBOELECTRIFICATION OF SLIDING OBJECTS AGAINST FLOOR IN HOSPITALS

El-Sherbiny Y. M. 1, Ali A. S. 2 and Ali W. Y. 3
1Department of Civil and Architectural Engineering, National Research Center, Dokki, Giza, Egypt
2Petrojet Company, Cairo, Egypt
3Faculty of Engineering, Minia University, El-Minia, Egypt
Email: yassershr@hotmail.com

ABSTRACT

The increased use of polymeric materials in hospital floorings raised the issue of electrostatic charges and its implications. Electrostatic charges generated from friction of engineering materials show a negative effect on their applications particularly in health related issues. Electrostatic charges accumulating on human skin are dangerous and cause serious health problems. The present work investigates the electrostatic generated charge from dry and wet rubbing of disposable - Anti-Skid polypropylene shoe covers “Non Slip Medical”, and rubber against polymeric flooring materials. Decreasing normal load in dry rubbing of polypropylene against epoxy floor decreased measured friction. Friction values at light loads maintained good adhesion of the sliding objects against floor µ = 0.5. It was enough for safe use at dry rubbing condition. Sliding of hospital foot wear on dry floor generated higher electrostatic charge. Wet rubbing, however, generated charge values higher than these measured for repeated alternate contact and separation. Water wetted contacts resulted in lower values of friction and electrostatic charge relative to those obtained in dry contact situations. Water molecules in wet contacts facilitated the conduction of generated electrostatic charges at the contact interfaces, thereby resulted in lower measurements for wet contacts. Accordingly it was recommended to look for new materials and coatings maintaining values µ = 0.5 to prevent slip and fall, with lower electrostatic charges.

Keywords: electrostatic, repeated contact and separation, sliding, dry and wet, floor, hospitals.

INTRODUCTION

Architects and designers usually face difficulties in selecting proper flooring materials for hospitals. In hospitals most handling trolleys for food, medications and treatments have rubber or polymeric thick coatings to suppress noise and maintain steady rolling or sliding during motion. Rubber and polymers are very susceptible for electrostatic charges (ESD). Antistatic flooring materials can still get ESD from friction with different type of shoes. Doctors, nurses and assisting staff wear polypropylene hygienic foot wear within the hospitalization zones. Such foot wear and hygienic covers should supress the generation of ESD and maintain good friction for walking stability.

Preventing slip and falls of all moving objects in hospitals is of prime importance. Static charge causes potentially serious electrical shocks, which may ignite fires and explosions. It also causes damage to sensitive electronic equipment and components. When two different and dissimilar materials in contact are separated electrons are generated by the potential difference are transferred and the phenomenon is called Triboelectric charging. In such case, one surface gains excess negative ions and the mating gain excess positive ions. The generated charge can create more than 25 kV.

It is a known practice that when two different and dissimilar materials are in repeated direct contact its surfaces are charged. Tribocharging phenomenon caused by repeated sliding or alternate contact and separation is known as triboelectrification, [1 - 3]. In tribocharging, the charge transfer mechanism is taking place due to electron, ion, and material transfer [4-6]. The electrification process during metal to metal contacts can be fully understood by electron transfer mechanism. The ultimate result is obtained when the two different and dissimilar materials come into contact, where electrons transfer takes place on the mating surfaces until the Fermi levels equalize. The potential difference in work functions is the main driving force, [7].

The electron transfers for contacting insulators, takes place on the surfaces only, where electrons migrate from the surface of one insulator (the filled one) to the surface of the other (the empty one), [8 – 10]. Researchers draw up Triboelectric chain to predict the polarity of charge transferred from one surface to the other, [11]. When two dissimilar different materials come into contact, the lower one in the Triboelectric chain will have negative charge while the other material will show positive charge. It is evident that more than one mechanism act and occur simultaneously, [12]. The electrostatic charging of strained and unstrained rubber sheets in contact with polyurethane (PU), polytetrafluoroethylene (PTFE), and stainless steel (SS) was investigated, [13]. Strain in SS reduces the frequency of occurrences of electrical discharges. Material strain was found to strongly influence Triboelectric charging.

Besides, straining a material proved to produce ions, electrons, and radicals which may react and form charged species. The Tribological (friction and wear) properties of the semiconducting silicon carbide based materials were influenced by the electric potentials imposed on the tribological systems, [14 – 17]. Surface state of SiC ceramics was also found to be affected by the electric potentials. Triboelectrification as well as triboluminescence was investigated for sliding and rolling contacts between polymeric materials of ABS, PA66, PE,
PET, POM, PP, PTFE, and PVC in different humidity conditions, [18]. Triboluminescence intensity was found to be higher in sliding friction as compared with alternate contact and separation. The saturated charging showed its maximum within humidity range 10 to 30% for all the sliding couples.

The humidity was found to enhance charge transfer thereby resulting in either increase or decrease of electrification, [19]. When dissimilar materials are in repeated contact; the charge transfers between surfaces at the contact interface of the dissimilar materials. Accumulated charges are measured indicators for triboelectrification, [20 - 22]. Charge and discharge associated with the rubbing between footwear and carpet were less pronounced in winter. It implied that the charge is suppressed in humid environments. Experimental data [20 - 22] showed such tendency. However, other data, [23, 24] show that the water molecules wetting the surfaces convey charges in the form of ions and enhance charge transfer and separation between the two mating surfaces. Accordingly measurement of the effect of humidity on charge generation needs more precise measuring facilities to conclude decisive trends.

Friction behavior and dielectric characteristics of glass fiber reinforced epoxy (GFRE) were studied, [25]. The results showed that unidirectional fiber / matrix interaction permit trapping the present electric charges. The diffusion of such electric charges through the fibre-matrix interfaces permitted stabilization of the coefficient of friction and reduction of wear, whilst localized trapping of charges at the interfaces were a source of damage and subsequent wear.

The importance of fiber/matrix interface on the trapping and diffusion of the electrostatic charges was previously discussed, [26]. Tribological studies aiming at correlating friction coefficient and associated wear with the surface electrostatic charges were carried out. Polymers are known for low mobility causing strong localization of ESD, and accordingly to its trap within the material structure [27]. It follows that external stress permits de-trapping of charges, [28], thereby releasing the stored energy, causing serious effects, such as dielectric breakdown, failure, rupture and tear. The voltage generated by repeated contact and separation of car seat materials against driver external wear showed considerable variations according to the materials used, [29]. The materials tested showed mixed mode trends with increasing load.

The repeated alternate contact of the materials against polyamide produced negative voltage, where voltage fell down to minimum then raised with load increase. This phenomenon is explained by the increase in free electron charging of the two rubbing with load increase; and hence surfaces easily exchanged the dissimilar charges; resulting in relatively lower voltage. High density polyethylene showed low voltage as compared with polyamide and cotton, while polypropylene generated higher voltage as compared with high density polyethylene. The voltage changes with load were more pronounced in the latter case. Remarkable voltage increase was also reported for synthetic rubber. This result limited its application in clothe industry.

Materials of high electrostatic properties should be replaced by new materials of low electrostatic properties. The wide use of polymer fibers in textile industry encouraged the study of its electrification when it rubs with other surfaces. The generated electrostatic charge from the rubbing of dissimilar polymeric and cotton textiles (a reference material), was discussed, [30].

Experiments were conducted to measure the generated electrostatic charge from the rubbing of different polymeric textiles against cotton under different rubbing conditions (distance, velocity and load). It was reported that the increase of cotton content decreased the generated voltage. Generally, increasing velocity increased the voltage.

The voltage increase with increasing velocity can be attributed to the increase of the mobility of the free electrons on one of the mating surfaces. The fineness degree of the used fibres significantly influenced free electrons movement. In order to develop and propose textile materials with low or neutral electrostatic potential, to be used for industrial application especially as textile materials, the electrostatic charge generated by friction of polytetrafluoroethylene (PTFE) textiles was tested, [31]. Research on ignition hazards of textiles by electrostatic discharge (ESD) is important for the safety in astronautics and hospitals. The possibilities of ESD ignitions depend on the environment whereas different models used to simulate ESD events, [32]. Risk assessments of materials with electrostatics are identified by measuring and monitoring the charge decay and by recording the measured capacitance loading, [33]. Less attention was given for the triboelectrification of the textiles. Electrostatic charge and generated coefficient of Friction from the rubbing between hair and head scarf made of different textiles materials were measured, [34]. Test specimens of scarf made of common textile fibers such as nylon, cotton, and polyester were tested by rubbing under different loads against Asian and African hair. Measured electrostatic charge in voltage was relatively of lower values, [34]. This phenomenon was attributed to the potential 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 and also between hair and polyester. Although the electrostatic properties of hair are very sensitive to the friction between hair and covering scarf textiles, little attention has been given so far to this application. Hair when rubbed with dissimilar materials like human skin, plastic and textiles show a tendency to develop electrostatic charge. Human hair is known to be a good insulator with a reasonably high electrical resistance. Charge on hair, therefore, is not easily dissipated because of such high resistance especially in dry environments. Macro-scale, [35, 36] studies looked at the electrostatic charging of human hair. Hair bundles were rubbed with different materials like combs, latex balloons, plastic, nylon, and Teflon, and also aluminum, gold and stainless steel metals. In such cases macro-scale Triboelectric
interaction between the hair surface and the rubbing element generates the charge.

The present study reports the results of an investigation on the friction coefficient and electrostatic charge generated from the repeated alternate contact and separation as well as rubbing of polypropylene coated objects with epoxy flooring materials used in hospitals at dry and wet working conditions.

EXPERIMENTAL

The present experiments investigate the measurement of electrostatic charge generated during alternate contact and separation in dry sliding condition of polypropylene body or coating against epoxy flooring materials used in hospitals. The electrostatic fields (voltage) were measured by Ultra Stable Surface DC Voltmeter device for test specimens, Figure-1. It measures up to 20 000 volts (20 kV) with a resolution down to 0.1 volt on a surface. The measuring head (probe) was usually placed with the sensor 25 mm apart from the surface being tested. The tested textiles were glue mounted onto the wooden block of 50 × 50 mm². Tests were conducted at room temperature under different normal loads. The epoxy floor tiles of 400 × 200 mm² were placed in a frame supported by two load cells, the first measures the horizontal friction force (F) and the other measures the vertical normal load (N). The tribotester was described in earlier works [31, 34]. The mating object was pressed to the epoxy tile by normal force. Friction coefficient was determined by the ratio of the friction force (F) and the normal load (N) i.e. \( \mu = \frac{F}{N} \).

RESULTS AND DISCUSSIONS

The results of the experiments for testing the friction coefficient and the generated electrostatic charge under alternate contact and separation, as well as sliding in dry conditions against floor material are shown in Figures 3-7.

Figure-1. Electrostatic field measuring device.

Figure-2. Test frame.
Friction coefficient obtained in dry sliding of polypropylene against epoxy flooring material, Figure-3, decreased with decreasing normal load. It is important that the friction coefficient should have reasonable values to avoid slip and to prevent accidents. The lowest and highest friction values were 0.43, 1.02 at 350 and 850 N loads respectively. As the load increased, friction coefficient drastically decreased.

The friction values at light loads guaranteed the good adhesion of the mating surfaces. It indicated safe use at dry sliding situations. Electrostatic charge generated by the alternate contact and separation with dry floor is shown in Figure-4. The values ranged between -48 and -155 volts distributed on the surface. As the load increased the charge decreased.

This trend can be reasoned by the increase of the contact area with increasing load. Positive values ranging from 35 to 78 volts were detected for the generated electrostatic charge on the epoxy floor, Figure-5. As the load increased, electrostatic charge slightly decreased due to the increased interference between the mating bodies, where the charge transfer became easier. Due to the nature of the electrostatic charge, the scatter in the measured values during experiments was relatively high.

![Image of friction coefficient graph](image)

Figure-3. Friction coefficient for sliding against dry epoxy floor.

Dry sliding against floor generated considerably higher electrostatic charge, Figure-6. The highest voltage reached -4400 volts, while the lowest was -250 volts. This observation shows the importance of developing new materials of low electrostatic charge to be applied and used in hospital applications. As the load increased, the negative voltage remarkably increased. Generated electrostatic charge on the floor surface recorded very low voltage value of 220 volts at 720 N, Figure-7.

\[ y = -0.007x + 11.891 \]

\[ R^2 = 0.7703 \]
As the load increased the positive voltage increased. It was evident that the friction coefficient partially depends on the value of the existing voltage. This characteristic can be explained on the basis that, the generation of equal electrostatic charges on the sliding surfaces of different signs would increase the attraction force between the two mating surfaces and accordingly the adhesion, leading to higher friction.
The electrostatic charge at sliding was higher when compared with that of repeated and alternate contact and separation of mating surfaces. Based on this observation, it can be concluded that polypropylene material generated high electrostatic charge values. When two materials are in contact with each other, the lower one in the Triboelectric chain will get negatively charged and the other will be positively charged.

As the difference in the order of the two materials increases the generated voltage increases. It is known that polypropylene is ranked as negative charged material, while epoxy is positively charged. It is therefore important to select the materials based on their triboelectric charging or location within the Triboelectric series.
The results of experiments measuring the electrostatic charge and friction coefficient in water wetted contacts are illustrated in Figures. 8-12. Friction coefficient is considered as the main factor in assessment of contacting material pairs.

The measure of the safety is directly related to and dependent on the friction coefficient of the sliding pair. As the coefficient of friction increases, the no slip and walking safety increases. Friction coefficient measured when sliding against epoxy floor in water wetted condition is presented in Figure-8.

Increasing the load slightly decreased the coefficient of friction. The lowest friction value was 0.42, while the maximum value was 0.56. The values of friction in wet conditions were lower than those observed at dry contact. Voltage generated due to repeated alternate contact and separation with epoxy floor material is shown in Figure-9.

Voltage values were -92 and -25 volts at 220 and 850 N load respectively. This observation confirms that, the value of electrostatic charge depends on the load. The contact and separation with floor, Figure-10, showed positive voltage approaching 78 volts. The values of electrostatic charge are approximately similar to those shown for the opposite rubbing surface.

The low values of charge were attributed to the ability of water to permit charge conduction from and between the contact surfaces. It is therefore recommended to measure the charge simultaneously on the two mating surfaces.

![Graph](image-url)

**Figure-8.** Friction coefficient when sliding against water wetted floor.

Voltage generated by sliding against floor is shown in Figure-11. The maximum voltage value was -88 volts at 250 N. The generated electrostatic charge on the floor during sliding is shown in Figure-12. The voltage observed was in positive sign with relatively low values.
**Figure-9.** Electric static charge for contact and separation with water wetted floor.

**Figure-10.** Electric static charge of floor in contact and separation with water wetted polypropylene.
CONCLUSIONS

a) Friction coefficient measured in dry sliding of polypropylene against epoxy floor decreased with increasing normal load. As the load increased friction coefficient drastically decreased. The friction values at light loads facilitated a good adhesion against floor.

b) They are safe enough for use at dry sliding condition. Electrostatic charge generated from dry repeated contact and separation against floor showed negative sign, while the generated electrostatic charge on the epoxy floor showed positive values.

c) As the load increased, electrostatic charge slightly decreased due to the increased interference between the mating surface and the floor, where the charge transfer had less resistance. Dry sliding against floor generated considerably higher electrostatic charge measured on the counter face. The highest negative
voltage reached -4400 volts, whilst the lowest negative was -250 volts.

d) This observation confirms the importance of developing new materials for lower electrostatic charge. Friction coefficient generated by sliding against epoxy floor at water wet conditions slightly decreased with increasing the load. The friction values were lower than values observed in dry contacts.

e) Generated Electrostatic charge at the water wet surfaces was relatively of low values due to the promotion of charge electro-conduction in the presence of water. Accordingly it was recommended to look for new materials and coatings maintaining values $\mu = 0.5$ to prevent slip and fall, with lower electrostatic charges.

REFERENCES


