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FRICTION BEHAVIOR OF EPOXY FLOOR TILES FILLED BY SAND NANOPARTICLES

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ABSTRACT

Proper selection of floor materials can reduce slip accidents. The present work proposes epoxy floor tiles filled by sand nanoparticles. Friction coefficient and electrostatic charge (ESC) generated from sliding of bare foot, foot wearing socks and rubber footwear on the proposed composites are investigated.

It was observed that filling epoxy by sand nanoparticles increased friction coefficient at dry sliding. While at water, detergent and oil wet sliding, friction coefficient showed relatively higher values than that recorded for unfilled epoxy. It seems that sand particles could break the fluid film adhered on both rubber and epoxy surfaces leading to the increase in friction values. Besides, the interaction of the sand particles in rubber surface might contribute extra friction increase. Sliding of bare foot on dry epoxy composites displayed lower friction coefficient than that recorded for rubber shoe. Cotton socks showed the highest friction values followed by polyester and wool. Besides, ESC generated on rubber surface sliding on dry epoxy composites showed the highest values at 1.0 wt. % sand content. Wool socks slid against epoxy showed significant increase in ESC, compared to that observed for cotton and polyester socks. ESC generated on bare foot sliding on dry epoxy composites represented very low values relative to rubber shoe due to the good electrical conductivity of the human body.

KEYWORDS

Epoxy composites, sand nanoparticles, friction coefficient, electrostatic charge, slip accidents.

INTRODUCTION

There is an increasing demand to avoid slip accidents indoor through paying attention to the proper selection of floor materials. The effect of reinforcing epoxy by carbon fibres (CFs) on the friction coefficient displayed by contact and separation as well as sliding of bare foot and foot wearing rubber contacting epoxy was investigated, [1, 2]. It was observed that electrostatic charge (ESC) increased with increasing CFs content. Besides, as the CFs are close to the sliding surface ESC increases. It is known that the strength of the electric field inside the epoxy matrix is proportional to how much charge

is generated on the friction surface. The significant ESC increase when the CFs were close to the surface confirmed the presence of a magnetic field around the CFs that is directly proportional to the current value and inversely proportional to the distance from the conductor. ESC generated during contact and separation as well as sliding of insulating materials can play a major role in adhesion energy and alter friction.

The effect of the cotton content of socks on the frictional behaviour of foot during walking was investigated, [3 – 5]. It was found that friction coefficient increased with increasing the cotton content in socks, where polyamide socks displayed the lowest friction and cotton socks displayed the highest one.

Slip resistance of flooring materials is one of the major environmental factors affecting walking and materials handling behaviors. Floor slipperiness may be quantified using the static and dynamic friction coefficient, [7]. Certain values of friction coefficient were recommended as the slip-resistant standard for unloaded, normal walking conditions, [8, 9]. Relatively higher static and dynamic friction coefficient values may be required for safe walking when handling loads. The subjective ranking of floor slipperiness was compared with the static coefficient of friction (μ) and found that the two measures are consistent, [10, 11]. Many state laws and building codes have established that a static μ ≥ 0.50 represents the minimum slip resistance threshold for safe floor surfaces. Furthermore, the Americans Act Accessibility Guidelines for Disabled, [12 - 15], contain advisory recommendations for static coefficient of friction of μ ≥ 0.60 for accessible routes (*e.g.* walkways and elevators) and μ ≥ 0.80 for ramps.

In the present work, friction coefficient and ESC generated from sliding of bare foot, footwear and foot wearing socks against epoxy filled by sand nanoparticles tiles are investigated.

EXPERIMENTAL

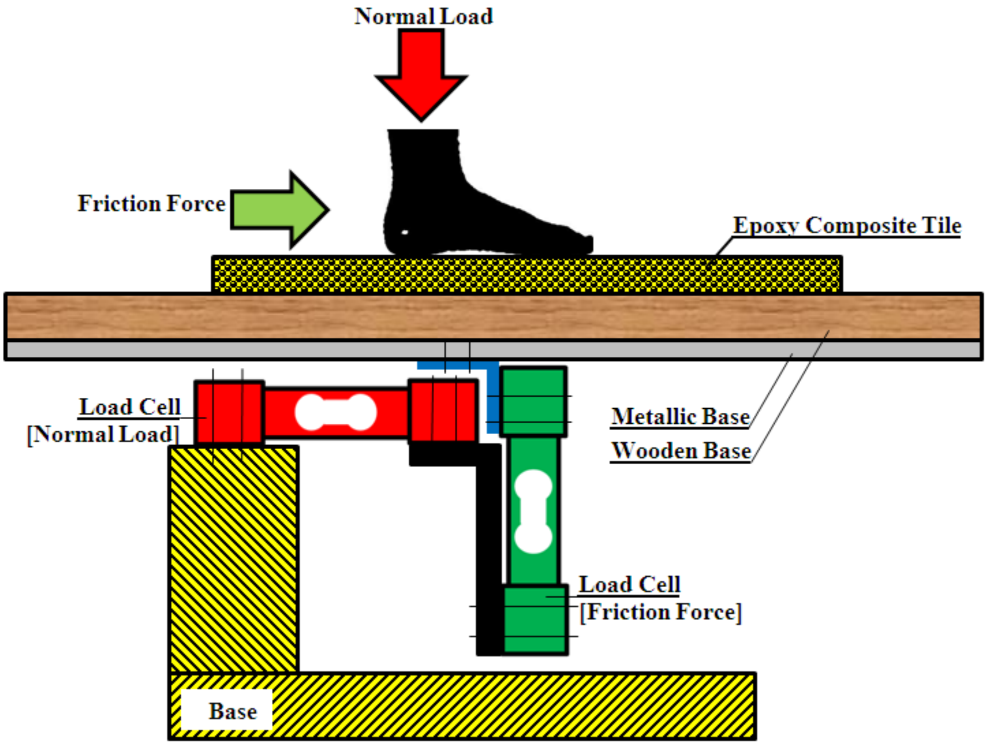

Fig. 1 Arrangement of the test rig.

Experiments were carried out using test rig designed and manufactured to measure friction coefficient through measuring the friction force and applied normal load, Fig. 1. The tested materials are placed in a base supported by two load cells, the first measures the horizontal force (friction force) and the second measures the vertical force (normal load) to measure friction coefficient. A handheld electrostatic meter is used to measure the magnitude and polarity of ESC generated on the sliding surfaces by a back sensor in a disc shape without contact, Fig. 2. It is typically held 25 mm from the test specimen surface.

The tested floor materials are in form of epoxy tiles filled by sand nanoparticles of 20 – 30 ηm particle size. The counterfaces are bare foot, rubber footwear as well as foot wearing cotton, polyester and wool socks. The tested floor tiles are prepared in square shape with area of 300 × 300 mm^2 and 5 mm thickness. The hardness of the rubber foot wear was 70 Shore A. Friction test was carried out under different applied normal loads ranging from 200 to 1000 N at dry, water, detergent (1.0 wt. %), oil (Paraffin oil) and oil/water dilution (5.0 wt. % oil) wet sliding conditions. The tested epoxy tiles were filled by sand nanoparticles of 0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt. % content. Tests were carried out by pressing and sliding the foot against tested tiles at different applied load.

Fig. 2 The electrostatic charge meter.

RESULTS AND DISCUSSION

Friction coefficient displayed by rubber shoe sliding on dry epoxy composites, Fig. 2, slightly increased up to maximum values then slightly decreased with increasing sand (SiO_2) content. The maximum friction values were observed at 0.6 wt. % sand. It is clearly shown that filling epoxy by sand nanoparticles increased friction coefficient.

At water wet sliding, friction coefficient showed relatively lower values than that recorded for dry sliding, Fig. 3. The highest friction values were observed at 0.6 wt. % sand content. The fluid film seems to be responsible for the friction decrease, while the presence of sand nanoparticles caused slight increase in friction. This behavior can be illustrated in Figs. 4 and 5. When unfilled epoxy contacted rubber, the contact could be classified as partially rubber/epoxy, fluid/epoxy and fluid/rubber, Fig. 4. The contact between rubber and sand nanoparticles filled epoxy surfaces during sliding, Fig. 5, is divided into rubber/epoxy, fluid/epoxy and fluid/rubber as well as the sand/rubber contact that strongly influenced the friction values.

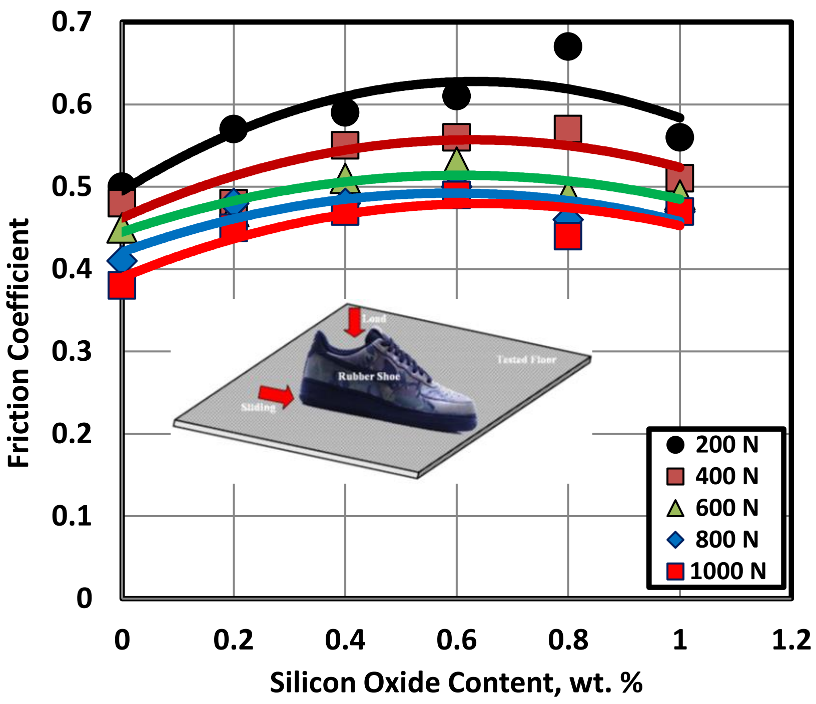

Fig. 2 Friction coefficient displayed by rubber shoe sliding on dry epoxy composites.

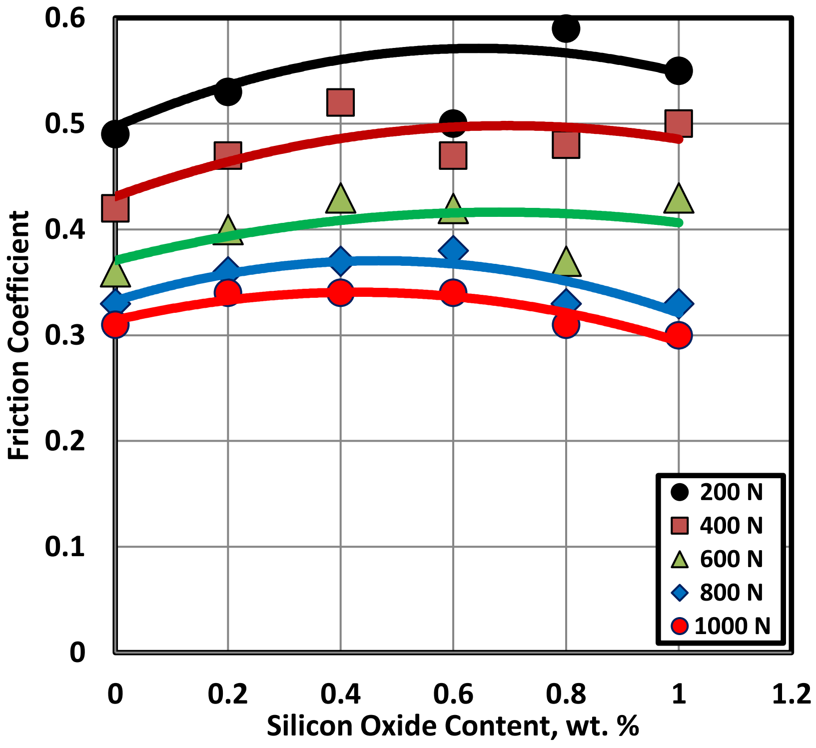

Fig. 3 Friction coefficient displayed by rubber shoe sliding on water wet epoxy composites.

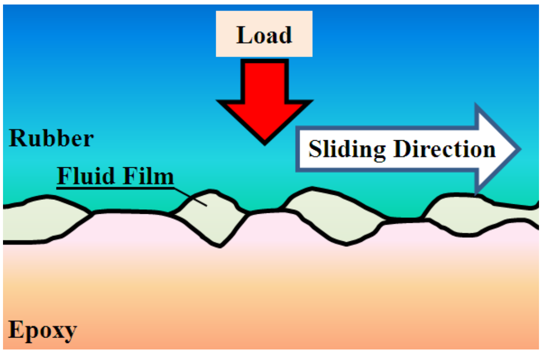

Fig. 4 Contact between rubber and unfilled epoxy surfaces during sliding.

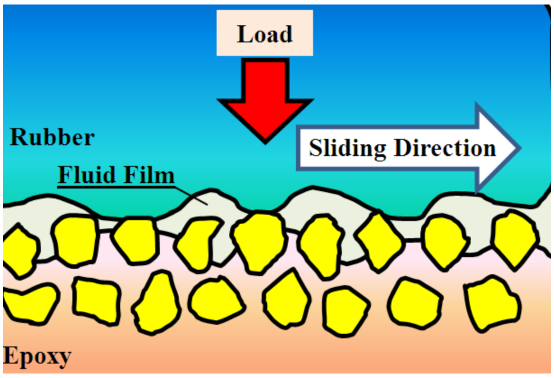

Fig. 5 Contact between rubber and sand nanoparticles filled epoxy surfaces during sliding.

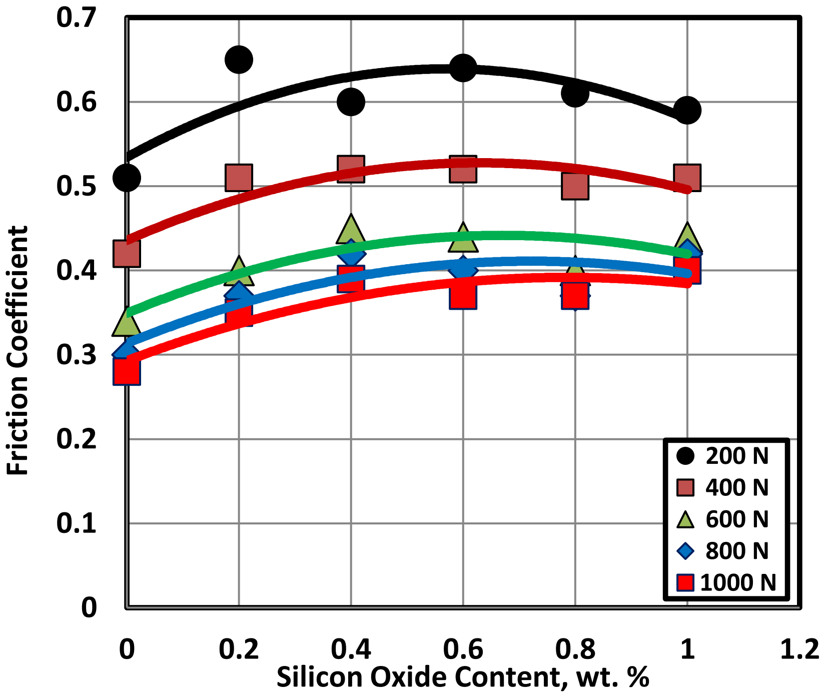

Fig. 6 Friction coefficient displayed by rubber shoe sliding on detergent wet epoxy composites.

Sliding at detergent wet epoxy composites displayed slight increase in friction coefficient compared to water wet surface, Fig. 6. That behavior can be useful in floors of bathrooms. Drastic friction decrease was observed for sliding of rubber shoe at oil lubricated epoxy composites, Fig. 7. Filling epoxy by sand nanoparticles significantly increased friction coefficient. It seems that sand particles could break the oil film adhered on both rubber and epoxy surfaces leading to the increase in friction values. Besides, the interaction of the sand particles in rubber surface might contribute friction increase. Friction coefficient displayed by rubber shoe sliding on oil/water dilution wet epoxy composites showed relatively higher friction than that observed for oil lubricated sliding, Fig. 8.

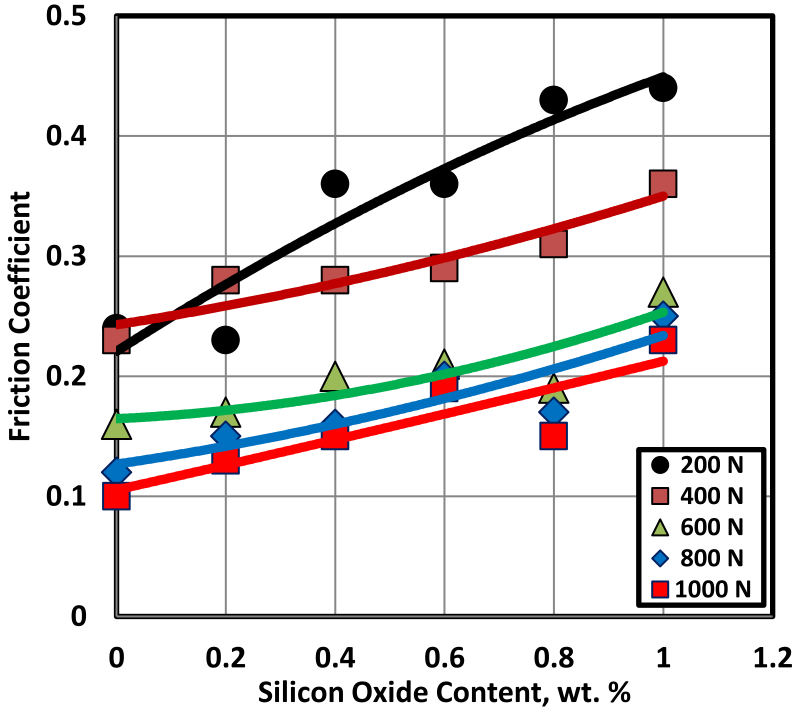

Fig. 7 Friction coefficient displayed by rubber shoe sliding on oil lubricated epoxy composites.

Sliding of bare foot on dry epoxy composites displayed lower friction coefficient than that recorded for rubber shoe, 9. At lower loads, friction slightly increases with increasing sand content. As the load increased, that effect vanished. Friction coefficient displayed by foot wearing socks sliding on dry epoxy composites is illustrated in Fig. 10. Friction coefficient decreased with increasing sand content. Cotton socks showed the highest friction values followed by polyester and wool. The friction decrease might be from the frictional behavior of textile sliding at epoxy.

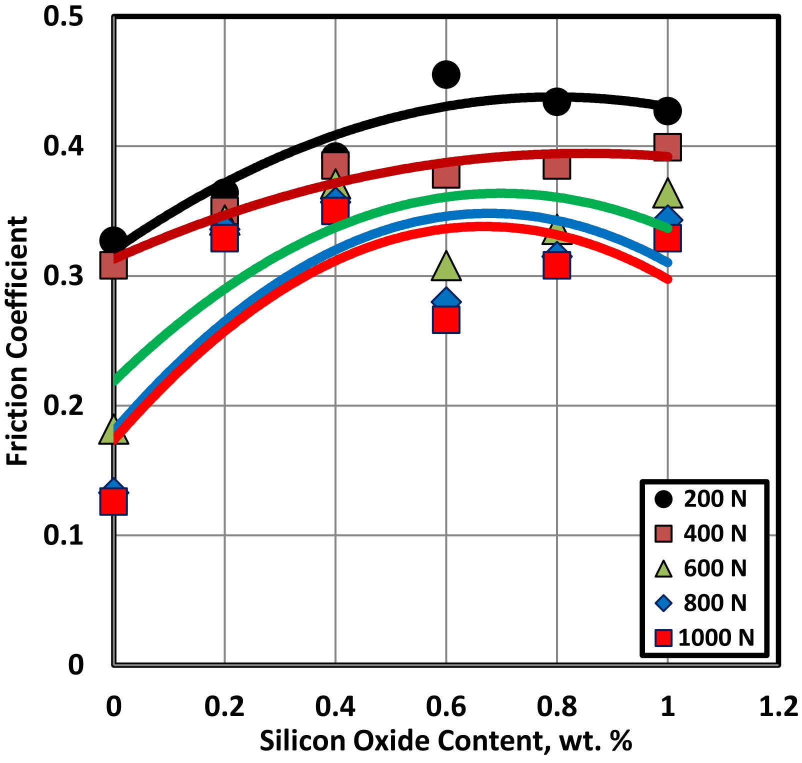

Fig. 8 Friction coefficient displayed by rubber shoe sliding on oil/water dilution wet epoxy composites.

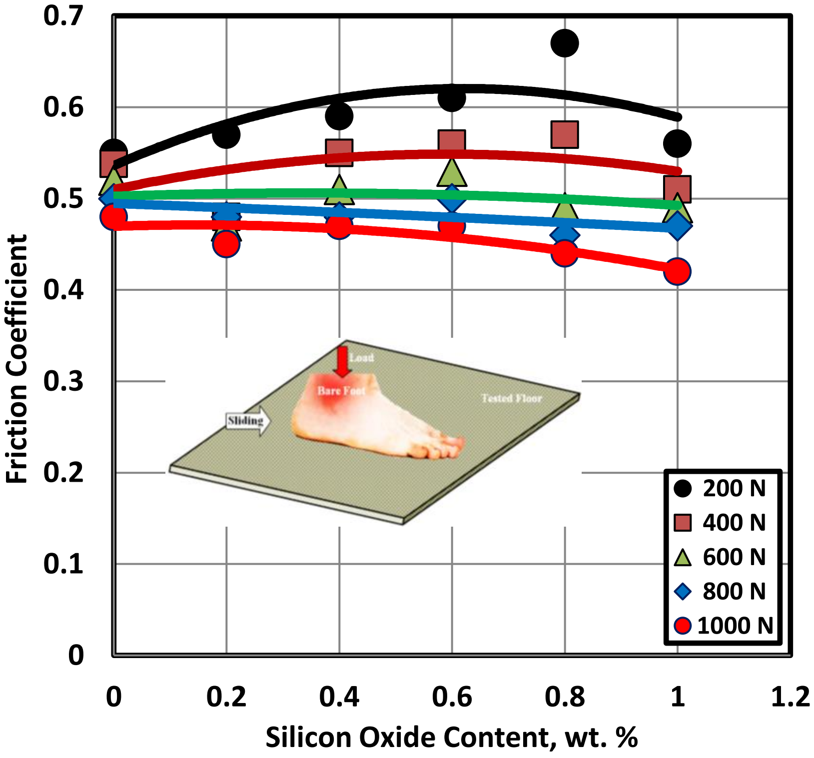

Fig. 9 Friction coefficient displayed by bare foot sliding on dry epoxy composites.

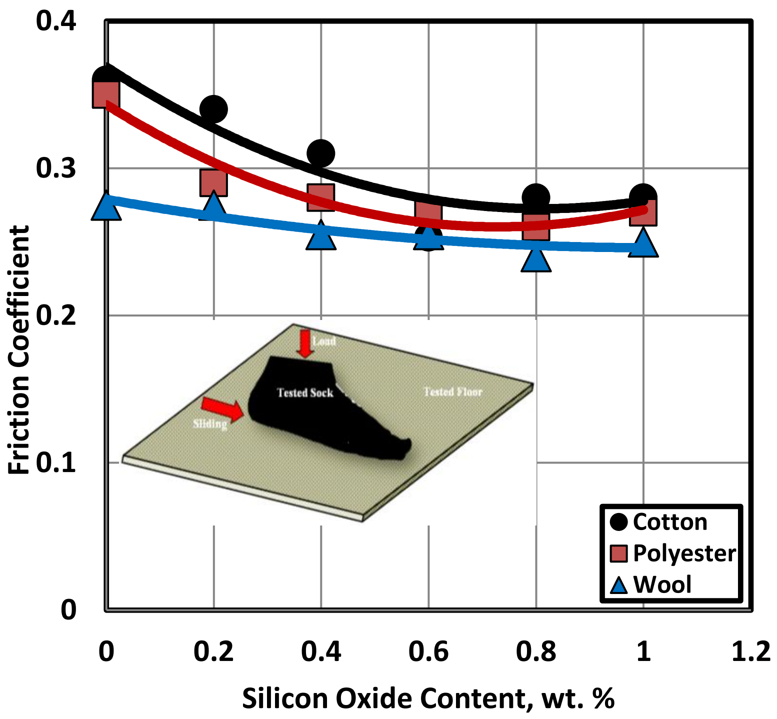

Fig. 10 Friction coefficient displayed by foot wearing socks sliding on dry epoxy composites.

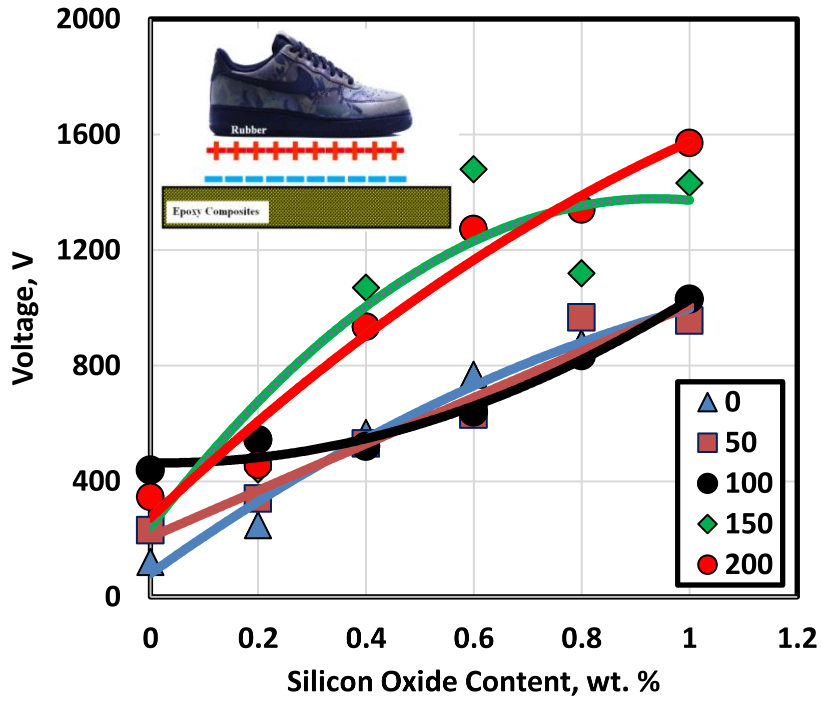

Fig. 11 ESC generated on rubber surface sliding on dry epoxy composites.

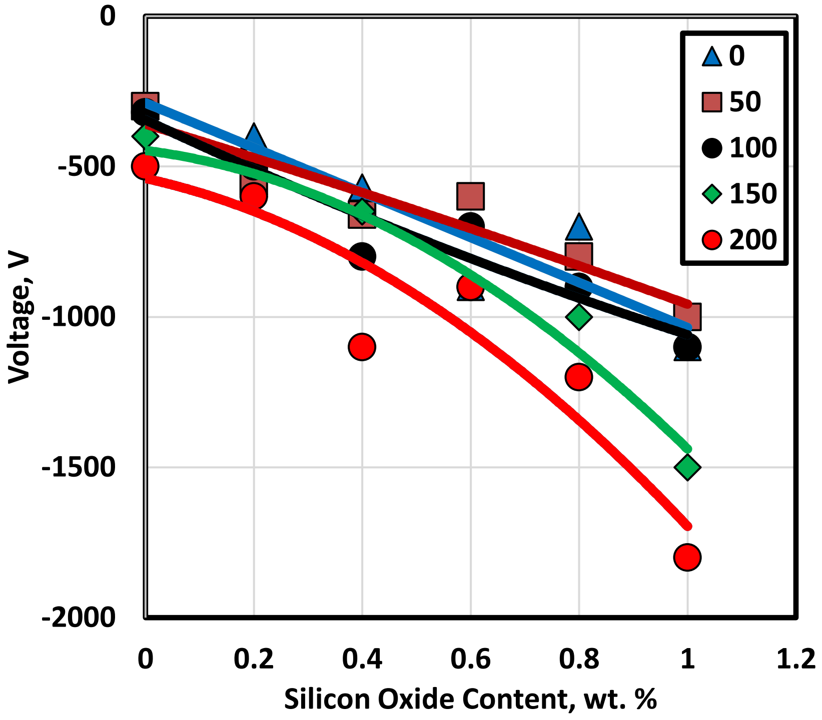

Fig. 12 ESC generated on dry epoxy composites when rubber surface slid on it.

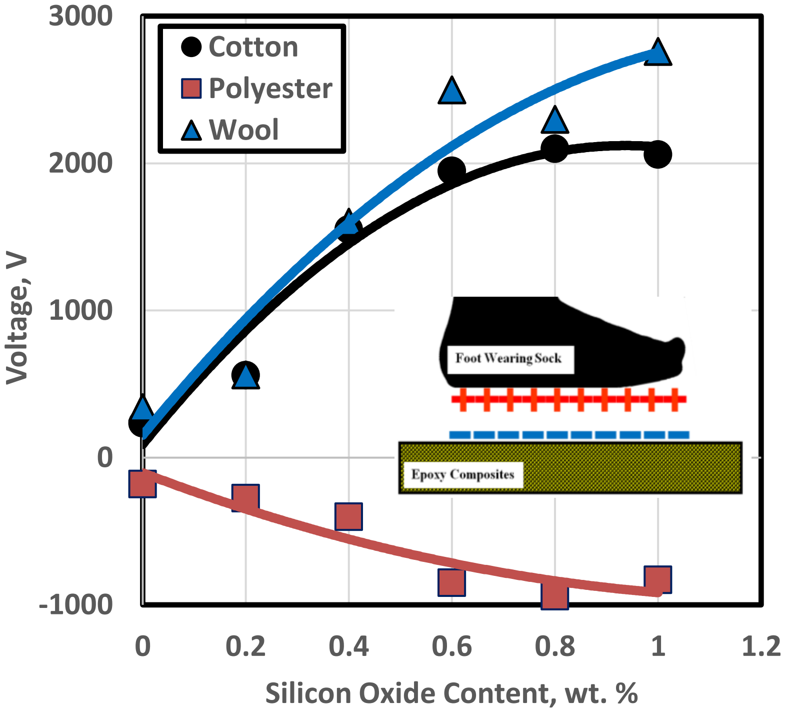

Fig. 13 ESC generated on foot wearing socks sliding on dry epoxy composites.

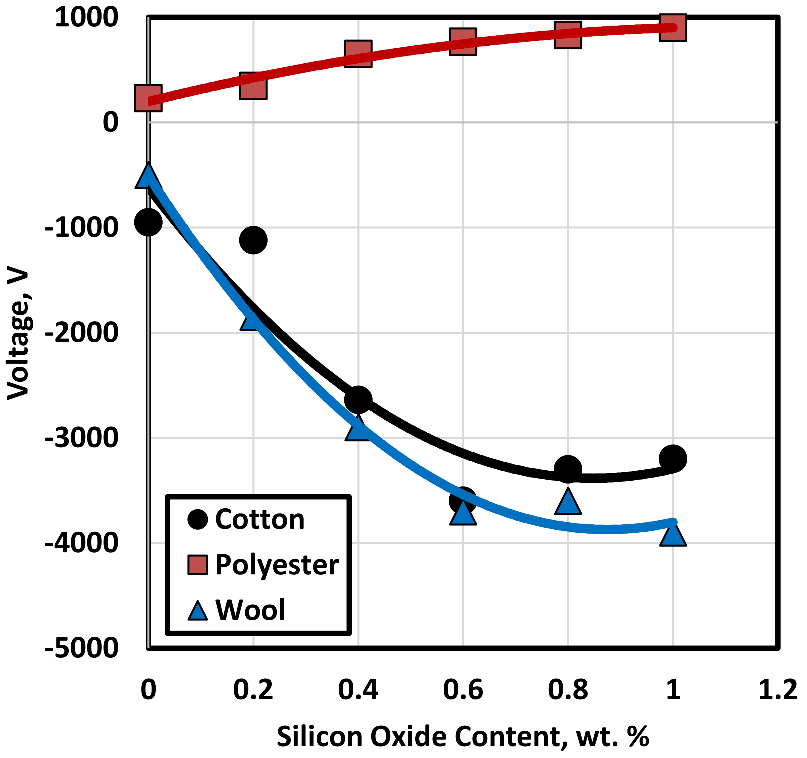

Fig. 14 ESC generated on dry epoxy composites when foot wearing socks slid on it.

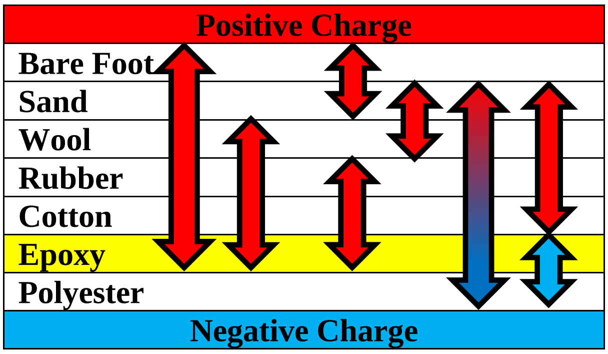

Fig. 15 Triboelectric series of the tested materials.

Illustration of the generation of ESC on the sliding surfaces is shown in Fig. 11, where the equal ESC generated of different signs on both the rubber shoe and epoxy composites. When two materials contact each other, the upper one in the triboelectric series will be 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. Therefore, it is necessary to select the materials based on their triboelectric ranking. ESC generated on rubber surface sliding on dry epoxy composites is shown in Fig. 11, where the highest intensity was observed after 200 mm sliding distance. ESC generated on dry epoxy composites after sliding is illustrated in Fig. 12. The highest ESC values (1600 and -1800 volts for rubber and epoxy respectively) were recorded at 1.0 wt. % sand content.

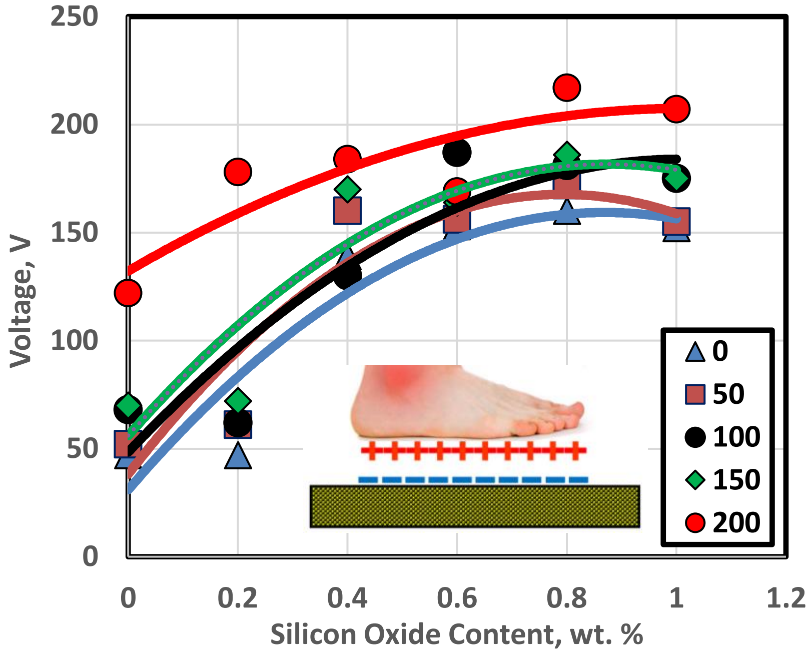

Fig. 16 ESC generated on bare foot sliding on dry epoxy composites.

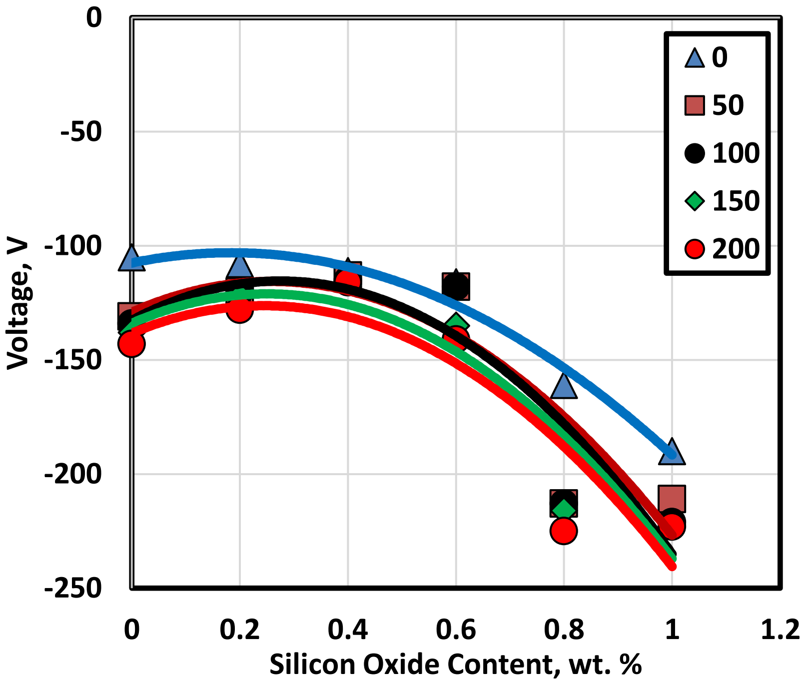

Fig. 17 ESC generated on dry epoxy composites when bare foot slid on it.

Wool socks slid against epoxy showed significant increase in ESC, Figs. 13 and 14, compared to that observed for socks made of cotton and polyester. It seems that the rank of wool in the triboelectric series was responsible for that behavior, Fig. 15. The arrows in the figure represent the gap between the tested material that is proportional to the intensity of ESC generated from friction as well as contact and separation. Extra

work should be done to determine the position of the floor materials in the triboelectric series in order to properly select the material of the socks to avoid generation of excessive electric static charge.

ESC generated on bare foot sliding on dry epoxy composites represented very low values relative to rubber shoe, Fig. 16, due to the good electrical conductivity of the human body. Although that the gap in the triboelectric series between bare foot and epoxy, Fig. 15, ESC was leaked out of the sliding surfaces. ESC generated on dry epoxy composites when bare foot slid on it displayed the same trend observed for the bare foot, Fig. 17, where the highest values could not exceed -230 volts.

CONCLUSIONS

Friction coefficient displayed by rubber shoe sliding on dry epoxy composites slightly increased up to maximum values then slightly decreased with increasing sand nanoparticles content. The maximum friction values were observed at 0.6 wt. % sand content. At water wet sliding, friction coefficient showed relatively lower values than that recorded for dry sliding. Sliding at detergent wet epoxy composites displayed slight increase in friction coefficient compared to water wet surface. That behavior can be useful in floors of bathrooms. Drastic friction decrease was observed for sliding of rubber shoe at oil lubricated epoxy composites. Filling epoxy by sand nanoparticles significantly increased friction coefficient. Sliding of bare foot on dry epoxy composites displayed lower friction coefficient than that recorded for rubber shoe.

ESC generated on bare foot sliding on dry epoxy composites represented very low values relative to rubber shoe due to the good electrical conductivity of the human body. The highest values of ESC generated on rubber surface and epoxy at dry sliding were recorded at 1.0 wt. % sand content. Wool socks slid against epoxy showed significant increase in ESC compared to that observed for cotton and polyester socks.

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