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INFLUENCE OF BLENDING POLYETHYLENE TURF BY COPPER TEXTILE ON GENERATION OF ELECTROSTATIC CHARGE

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ABSTRACT

The present study aims to decrease electrostatic charge (ESC) generated on polyethylene (PE) turf fibers by blending by suitable conductor such as copper (Cu) textile. Besides, the rubber counterface was replaced by conducting material such as aluminium (Al) film.

It was found that PE fibers blended by Cu textile showed drastic decrease in ESC generated on the surfaces of both rubber and PE fibers. The lowest ESC values were recorded when Cu substrate replaced PE substrate. Besides, when rubber was replaced by Al film, ESC generated on the mating surfaces recorded the lower values. It seems that, when PE fibers were charged by friction with rubber, Cu textile and Al film, the electrons from the rubbing surfaces are redistributed and transferred. This behavior could be assisted by the performance of Cu textile that conducted negative ESC generated on PE to the rubber surface and consequently decreased its gained positive ESC. On the other side, copper textile conducted the excess electrons and redistributed on PE fibers.

It is recommended to apply conducting material to coat rubber to transfer and redistribute ESC from PE fibers to Cu textile and reduce its accumulation on the rubber surface. This behavior can decrease the risk of ESC transmitted to the human body and avoid electric shock.

KEYWORDS

Polyethylene turf, copper textiles, aluminum film, electrostatic charge.

INTRODUCTION

The wide use of artificial PE turf should be accompanied by extra research to reduce the ESC generated from friction with the counterfaces. In recent study, [1], it was revealed that blending PE fibers by polyurethane (PU) decreased the intensity of ESC. When PE was replaced by polypropylene (PP) substrate significantly ESC, [2]. Using metallic substrates from steel and copper sheet influenced the intensity of ESC, where grounding the substrate caused drastic ESC decrease. Besides, grounding the metallic substrate

caused further ESC reduction, [3]. The experiments showed that PE fibers blended by PMMA yarns decreased ESC. PA textiles displayed extra reduction in ESC.

Materials selection should depend on their ability to minimize ESC generated from contact and separation as well as sliding with each other. Polymers as insulating materials do not allow ESC to flow through them and lead to be built up on the surface. ESC can cause serious problems to the health and safety of people, [1, 2]. Textiles accumulate ESC. To reduce that effect, conductive fibers and yarn are introduced to allow the generated ESC to dissipate. Triboelectric generator was investigated to harvest ESC generated from friction between shoe sole and ground during walking, [3]. The human body was employed as the electrode, where ESC can be obtained from any part of human body. It was found that addition of carbon black controlled ESC generated from nylon composites, [4]. The electrical resistances and mechanical properties of polymers blended by carbon black was studied, [5]. It was revealed that the several properties were gained after adding carbon black such as heat resistant, antioxidant and light filler, [6]. Besides, the composites possessed lower electrical resistivity, where carbon black worked as conductor filler, [7 - 10). The mechanism of action of carbon black filled nylon is to leak ESC from the charged surface by reducing the electrical resistivity.

The wide use of polymeric material in manufacturing artificial turf increased the attention to study the ESC effect. This effect is observed in the air gaps between the charged human body during contact with metallic grounded objects, [11 - 13]. Investigation of ESC can be useful tool to decrease ESC risks in artificial turf yards, where walking on synthetic turf causes electrification of the human body, [14 - 16]. It was revealed that ESC generated from rubbing of human skin and artificial turf of smooth surface generated relatively higher ESC values.

The present work aims to reduce the generation of ESC on polyethylene turf by blending by Cu textile. Besides, the rubber surface was coated by aluminum film. ESC was measured at contact and separation as well sliding of rubber on PE fibers at dry condition.

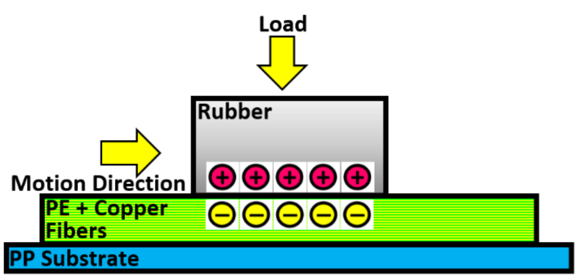
EXPERIMENTAL

The present work investigates ESC generated at contact and separation as well as sliding of rubber against PE turf blended by Cu textile. PE fibers were adhered to wooden block of 200 × 200 × 50 mm^3, where polypropylene as well as thin sheets of steel and copper (0.25 mm thickness) were used as substrates. The width and thickness of PE fiber were 2.0, 0.22 mm respectively. PE fibers were blended by Cu textile in form of ribbon of 4.0 mm wide, Figs. 1 - 3. The turf was tested using grounded and ungrounded steel and Cu substrates. The counterface was rubber of 60 Shore A hardness and 5 mm thickness adhered to a 40 × 40 × 40 mm^3 wooden cube. The rubber was coated by aluminum film (Al) of 0.25 mm thickness. The wooden cube, of both rubber and Al surfaces, was loaded at the tested turf adhered to the PP, Cu and steel substrates at 17.5 N load and moved horizontally. ESC generated on the surface of the tested turf and rubber was measured by surface DC Voltmeter, Fig. 4.

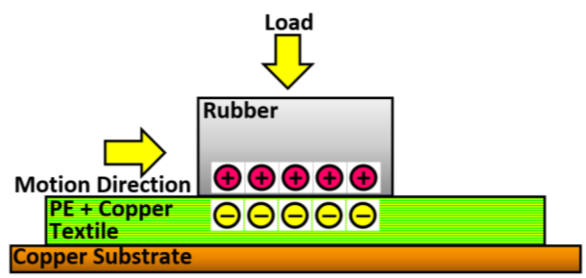
Fig. 1 PE turf on steel substrate.

Fig. 2 PE turf blended by Cu textile on Cu substrate.

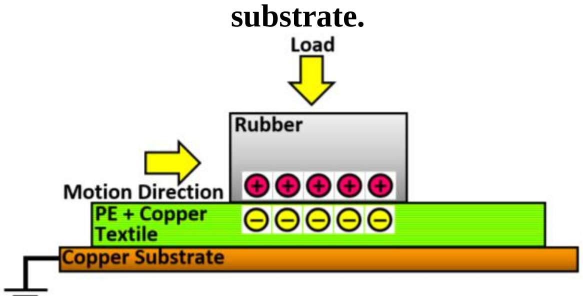
Fig. 3 PE turf blended by Cu textile on PP substrate.



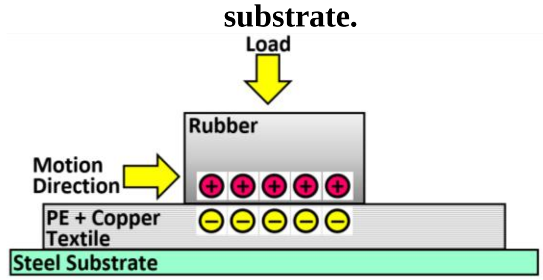
a. PE blended by Cu textile on PP substrate.



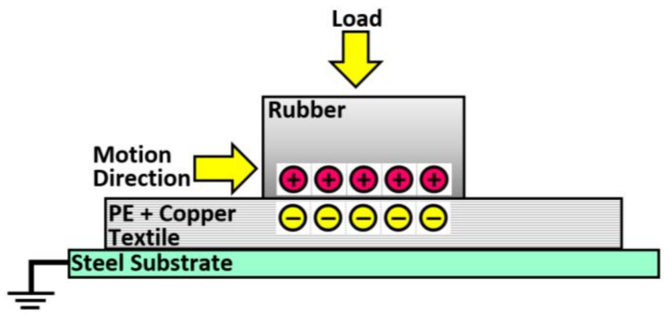
b. PE blended by Cu textile on Cu substrate.



c. PE blended by Cu textile on grounded Cu substrate.



d. PE blended by Cu textile on steel substrate.



e. PE blended by Cu textile on grounded steel substrate.
Fig. 4 Illustration of the test procedure.

RESULTS AND DISCUSSION

Study of ESC generated from PE fibers blended by Cu textile can reveal specific information on the suitability of the proposed conducting material to be used in artificial turf. In order to understand the phenomenon of generation of ESC, it is necessary to determine the triboelectric series of the tested materials, Fig. 5, where the materials are ranked according to their sign of charge and intensity of ESC. The present study aims to decrease ESC on PE fibers by blending by suitable conductor such as Cu textile. Conductors transport and distribute electrons until the repulsive forces acting on excess electrons is minimized. When the charged conductor is contacted other object, it may transfer its charge. When the insulator is negatively charged, and touches a conductor, the excess electrons will move to the conductor. Besides, the electrons on the conductors will move from the conductors to the insulator. When PE fibers are charged by friction with rubber, Cu textile and Al film, the electrons from the rubbing surfaces are transferred. The number of the transformed electrons is proportional to the contact area of the rubbing surfaces. Based on that, it can be concluded that charged insulator or conductor is capable to transfer the charge to the other objects. The result of the charge transfer in insulators will be the same as the result of charging by conduction. Considering the mobility of electrons is much lower in insulators. Figure 5 shows that, when rubber rubbed PE, it gained positive ESC, while PE gained negative ESC. In the presence of Cu textile, rubber gained negative ESC. Al film coated rubber gained positive ESC when it rubbed Cu textile and PE fibers.

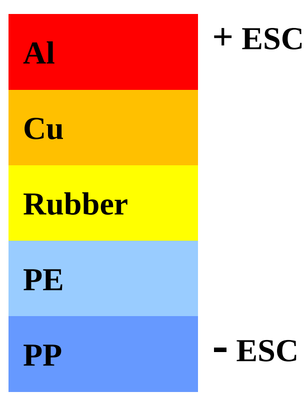


Fig. 5 Triboelectric series of the tested materials.

The effect of Cu textile on ESC generated on rubber and PE turf from contact and separation as well as sliding of dry rubber on PE turf of different substrates is shown in Figs. 6 – 9. PE fibers blended by Cu textile showed drastic decrease in ESC generated on rubber, Fig. 6. In addition to that, Cu substrate recorded the lowest ESC values at contact and separation with the turf of different substrates, while the highest ESC was experienced by PP substrate. The grounded metallic substrates displayed further ESC decrease. The lowest ESC values were observed by PE blended by Cu textile adhered to grounded Cu substrate. This behavior can be attributed to the performance of Cu textile that conducted negative ESC to the rubber surface leading to decrease its gained positive ESC, Figs. 7, 8. Added to that, copper textile conducted the excess electrons and redistributed on the surface of PE fibers.

Sliding of rubber on the tested fibers of different substrates showed remarkable ESC increase compared to that measured at contact and separation, Fig. 9. Cu textile drastically decreased ESC generated on the rubber surface. The lowest ESC was recorded for the blended PE fibers adhered to the grounded Cu substrate. ESC of 8000 volts gained by rubber for PP substrate dropped to 800 volts for the blended fibers.

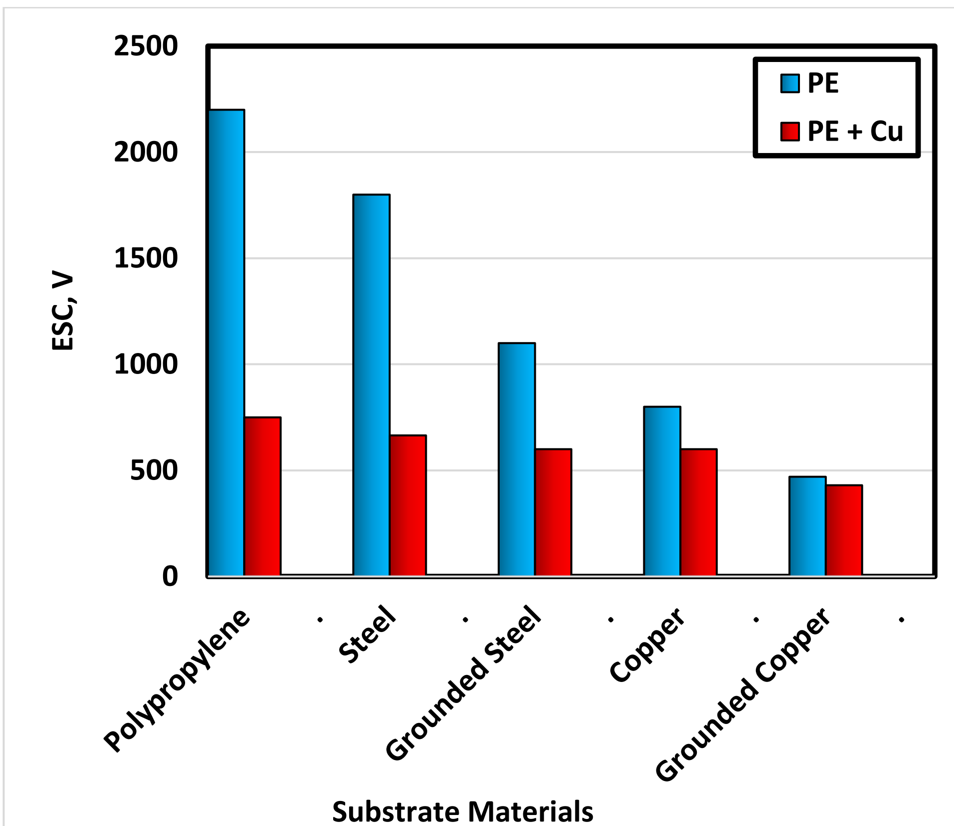
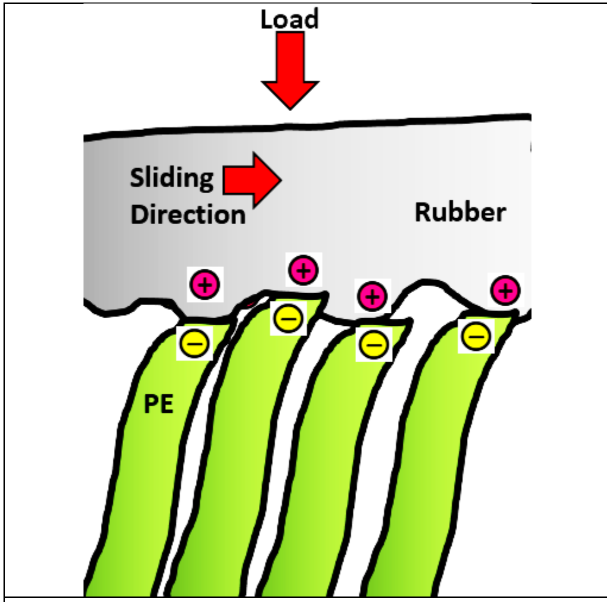


Fig. 6 Effect of Cu textile on ESC generated on rubber from contact and separation of dry rubber and turf of different substrates.



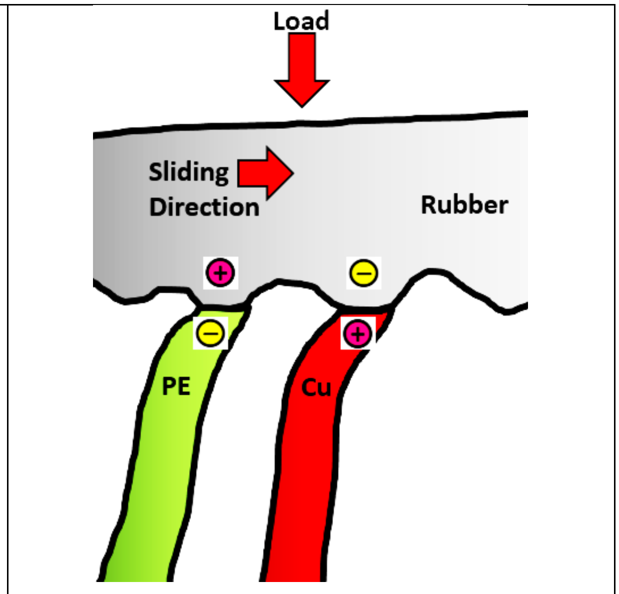


Fig. 7 Sliding of rubber on PE fibers.	Fig. 8 Sliding of rubber on PE fibers blended by Cu textile.

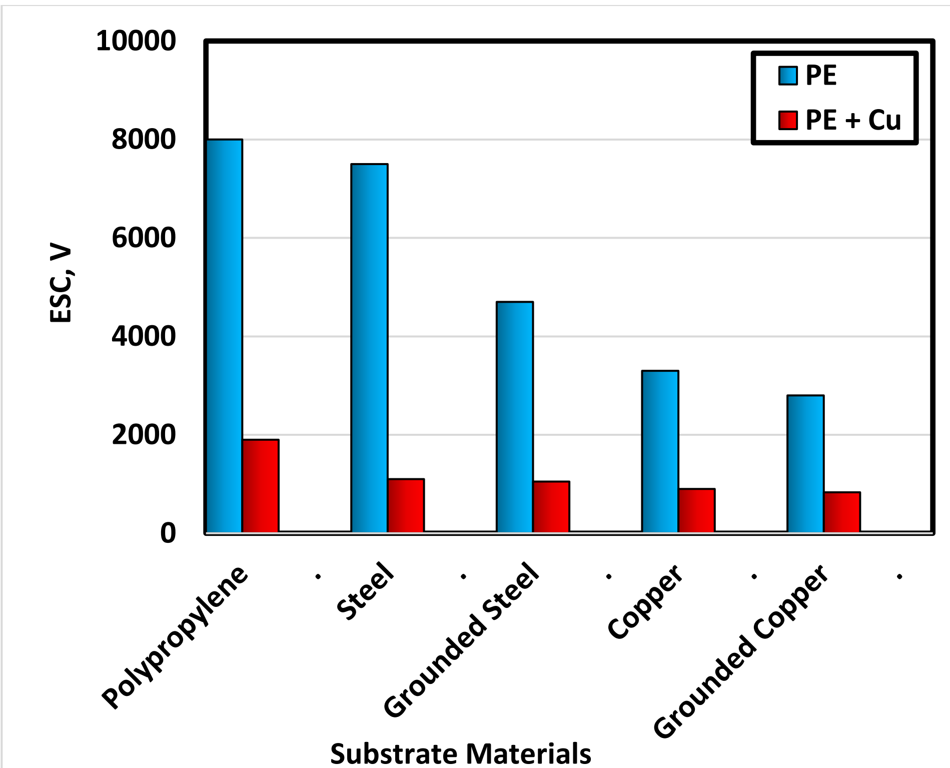


Fig. 9 Effect of Cu textile on ESC generated on rubber from sliding of dry rubber and turf of different substrates.

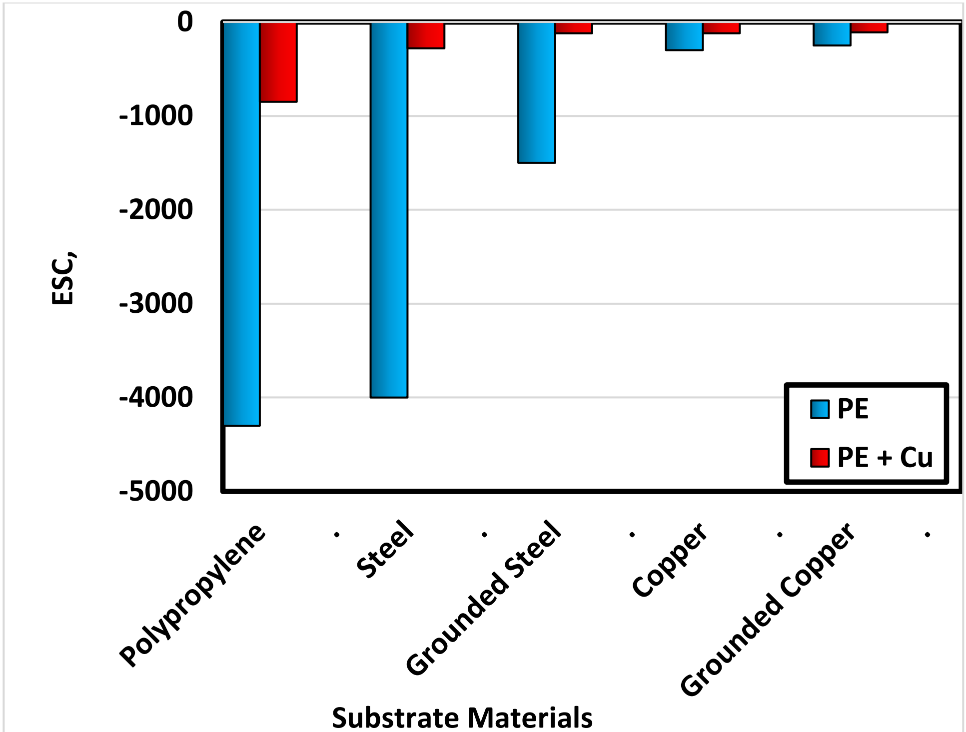


Fig. 10 Effect of Cu textile on ESC generated on turf fibers from contact and separation of dry rubber and turf of different substrates.

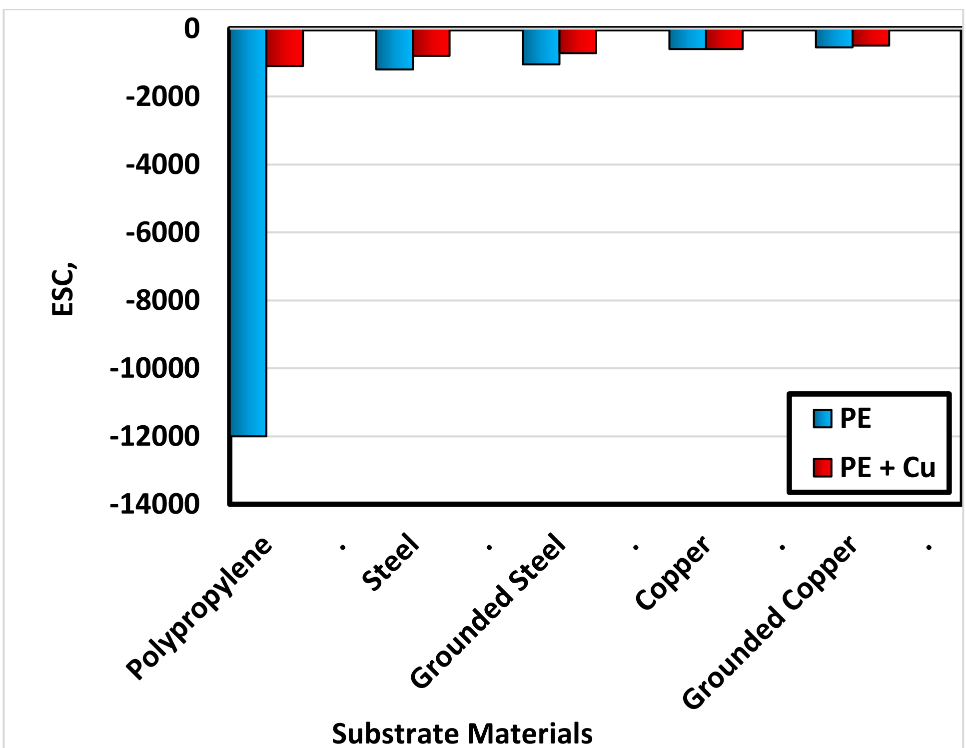


Fig. 11 Effect of Cu textile on ESC generated on turf from sliding of dry rubber and turf of different substrates.

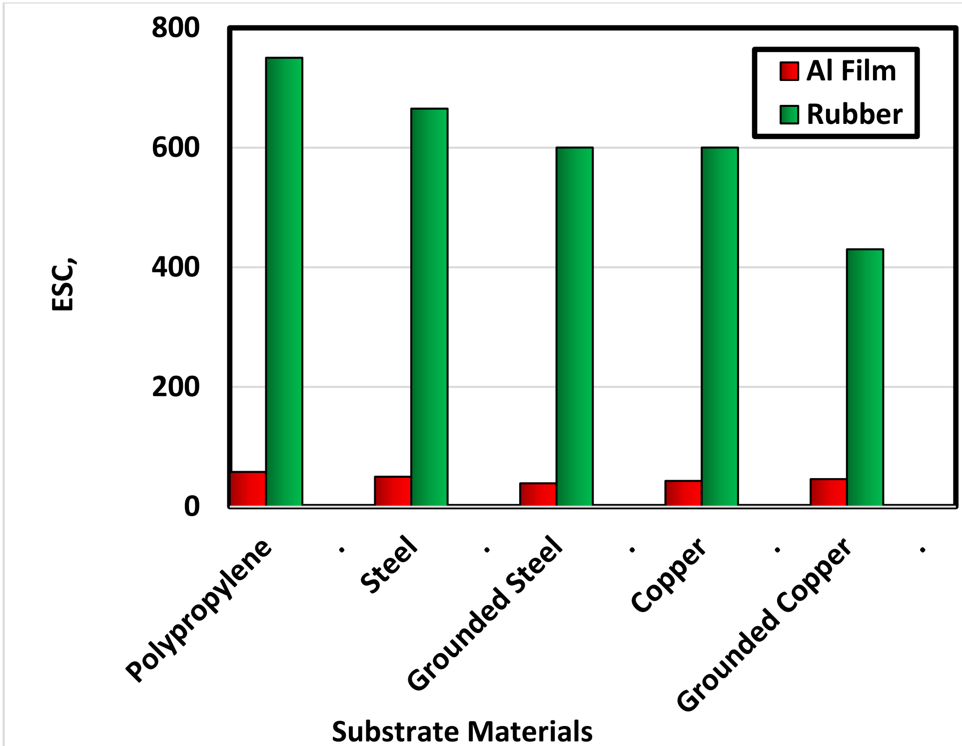


Fig. 12 Effect of Cu textile on ESC generated on Al film from contact and separation of Al film and turf of different substrates.

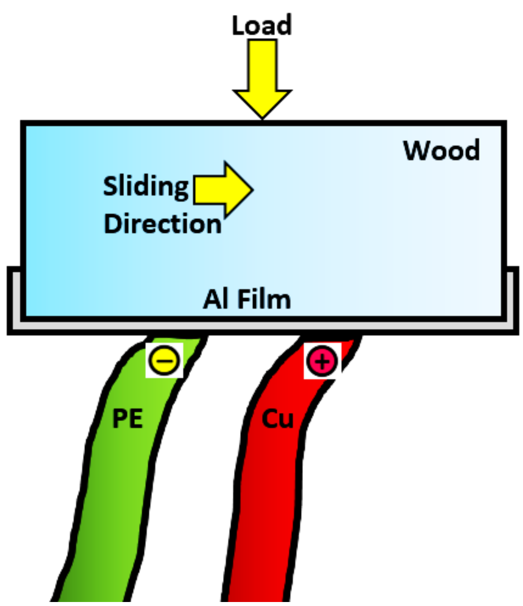


Fig. 13 illustration of the contact between Al film and the tested turf.

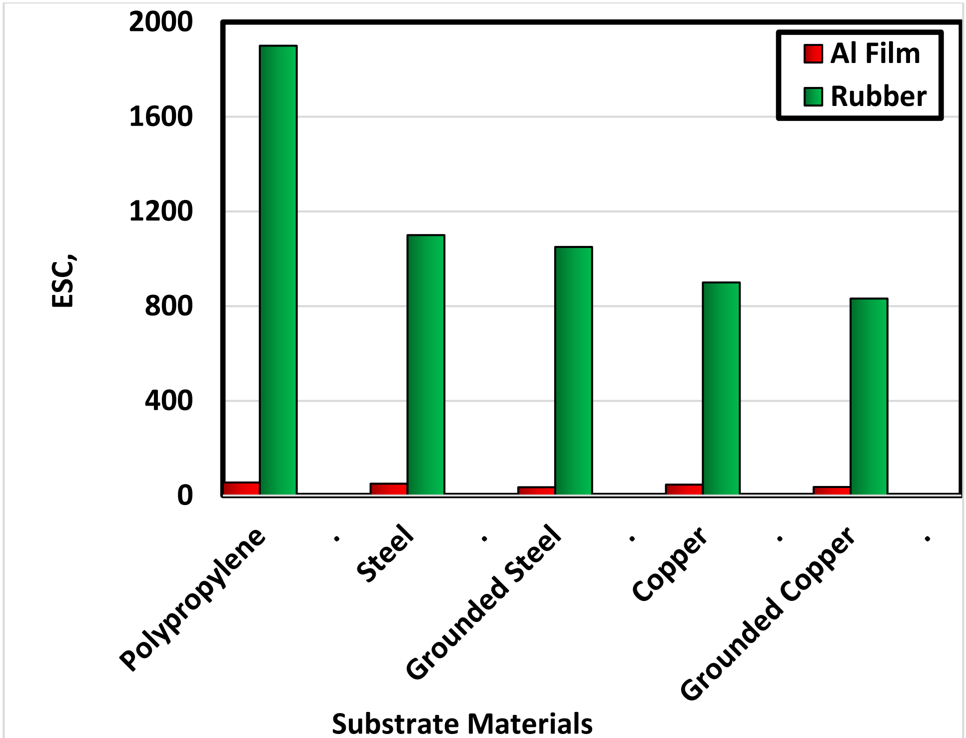


Fig. 14 Effect of Cu textile on ESC generated on Al film from sliding of Al film on turf of different substrates.

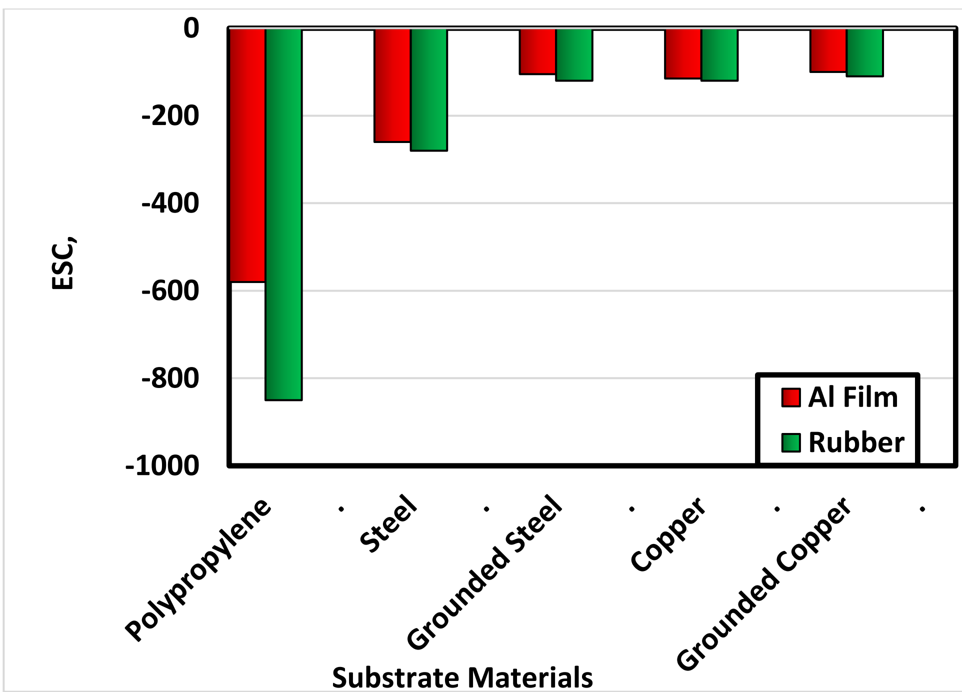


Fig. 15 Effect of Cu textile on ESC generated on turf fibers from contact and separation of Al film and turf of different substrates.

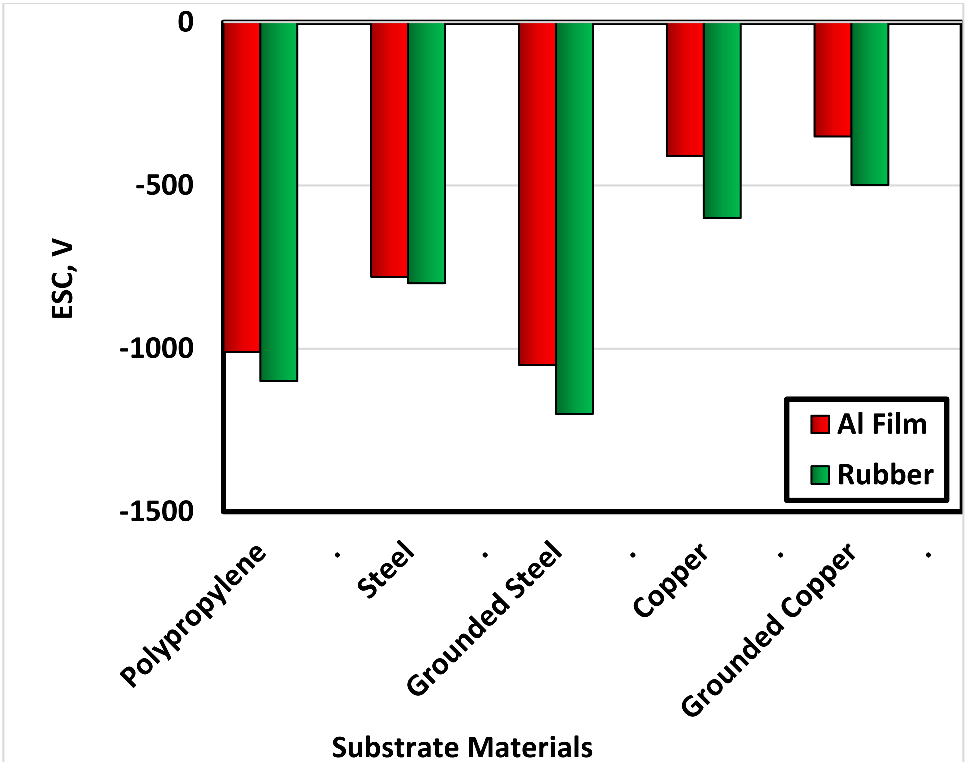


Fig. 16 Effect of Cu textile on ESC generated on turf fibers from sliding of Al film and turf of different substrates.

ESC generated on the surface of the PE fibers was much influenced by the Cu textile, Figs. 10, 11. The double enhancing effect of Cu textile and grounded Cu substrate dropped the value of ESC from -4300 to -110 volts for PP and grounded substrate respectivly, Fig. 10. Cu textile decreased ESC for all tested substrate materials. The same trend was observed for sliding, Fig. 11. The reduction in ESC was much clear, where PP and Cu substrates displayed -12000 and -500 volts.

ESC generated from contact and separation as well as sliding of Al film and PE turf blended by Cu textile is shown in Figs. 12 - 16. Effect of Al film on ESC generated from contact and separation with turf is illustrated in Fig. 12, where the value of ESC did not exceed 58 volts for PP substrate. ESC recorded 750 and 430 volts respectively on rubber surface. This behavior confirms the suitability of manufacturing the counterface from conducting materials. The charged conductor is capable to transfer ESC from PE fibers to Cu textile, Fig. 13, where the mobility of electrons is much higher in conductors. Further enhancement was observed for sliding of Al film on turf of different substrates, Fig. 14, where the values of ESC gained by Al film was 55 and 36 volts for PP and grounded substrates respectively.

ESC generated on turf fibers from contact and separation of Al film and turf of different substrates represented relatively lower values than that observed for the condition of rubber, Fig. 15. Turf gained -580 volts when contacted Al film, then increased to -850 volts when contacted rubber. The same trend was observed at sliding, Fig. 16, with better enhancement.

CONCLUSIONS

1. PE fibers blended by Cu textile showed drastic decrease in ESC generated on the contact surfaces. Cu substrate recorded the lowest ESC values at contact and separation. The highest ESC was experienced by PP substrate. The grounded metallic substrates displayed further ESC decrease. The lowest ESC values were observed by PE blended by Cu textile adhered to grounded Cu substrate. The same trend was observed at sliding with greater enhancement.

2. Replacing rubber by Al film drastically dropped ESC generated from contact and separation as well as sliding of Al film and PE fibers blended by Cu textile. The value of ESC did not exceed 58 volts for PP substrate.

3. It is recommended to coat the rubber by conducting material to transfer ESC from PE fibers to Cu textile and decrease its accumulation on the rubber surface. This behavior can decrease ESC transmitted to the human body.

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