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# EFFECT OF BLENDING POLYETHYLENE TURF BY POLYMETHYL METHACRYLATE AND POLYAMIDE ON GENERATION OF ELECTROSTATIC CHARGE

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## ABSTRACT
**One of the major drawbacks of polyethylene (PE) artificial turf is the generation of high values of electrostatic charge (ESC) during the contact and separation as well as sliding of rubber against the turf. Polymethyl methacrylate (PMMA) and polyamide (PA) gain positive ESC when they rub rubber, while PE is negatively charged. The aim of the present study is to reduce the negative ESC generated from rubbing PE fibers on rubber by blending by yarns or textile of PMMA and PA that gain positive ESC. PP and metallic substrates like steel and copper sheets were tested.**

**It was found that copper substrate represented the lowest ESC values, while PP substrate displayed the highest values. Besides, grounding the metallic substrate caused significant ESC reduction. PE fibers blended by PMMA yarns drastically decreased ESC regardless the material of the substrate. In addition to that, it was observed that increasing the ratio of PA yarns blending PE turf decreased ESC, while PA textiles in form of ribbons experienced more reduction in ESC because the flexibility of the turf enables for extra deformation of turf leading to an increase in the contact area. Finally, the value of ESC can be minimized by the control of the content of PA textile.**

## KEYWORDS
**Polyethylene turf, polymethyl methacrylate, polyamide yarns, triboelectrification.**

## 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.**

**Artificial grass is made of PE fibers to replace natural grass, [3], in the different applications. Artificial turf should be infilled by sand and granulated rubber, [2 - 4], where rubber has harmful effect on the environment. Besides, abrasion of skin by PE turf is more severe than natural grass. Limitation of rainfall increases the demand to PE turf. Intensive care should be considered to increase the safety of sport players to avoid the abrasion of the turf, [5 - 14]. Dimension of the fiber and the infill materials influenced the mechanical and tribological properties of PE turf, [15 – 17].**

**The friction coefficient of polyethylene fibers of different length and thickness was tested as artificial turf when footwear slid against it, [18, 19]. It was revealed that football shoes represented the lowest friction values.**

**It was experienced that ESC generated from rubbing of human skin and artificial turf especially in dry sliding, [20, 21], is the major disadvantage. Besides, turf of smooth surface generated relatively higher ESC values, [22]. It was observed that when football shoes slid against it.**

**The present work investigates the possibility of reducing ESC generated from sliding of rubber on polyethylene turf by blending by polymethyl methacrylate and polyamide yarns.**

## EXPERIMENTAL

**Experiments were carried out at contact and separation as well as sliding. The test specimens were prepared by fixing PE fibers on 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 PE fiber width and thickness were 2.0, 0.22 mm respectively. PE fibers were blended by PMMA yarns of 2.0 mm diameter, Figs. 1, 2. Besides, PA yarns of 0.3 mm diameter and textile in form of ribbons of 10 mm wide were used to blend PE, Figs. 3 – 6. The test specimen indicated by (PE + PA) indicated that the number of both PE fiber and PA yarns are equal, while (PE + 2PA) showed that the number of PA yarns are double the PE fibers. The turf was tested using grounded and ungrounded metallic substrates. Rubber of 60 Shore A hardness of 5 mm thickness adhered to a 40 × 0 × 40 $mm^3$ wooden cube was used as counterface. Rubber surface was loaded at the turf surface at 17.5 N weights and pulled horizontally at dry contact condition. Surface DC Voltmeter SVM2 was used to measure ESC generated on the surface of the tested turf and rubber. The test procedure is illustrated in Fig. 7.**

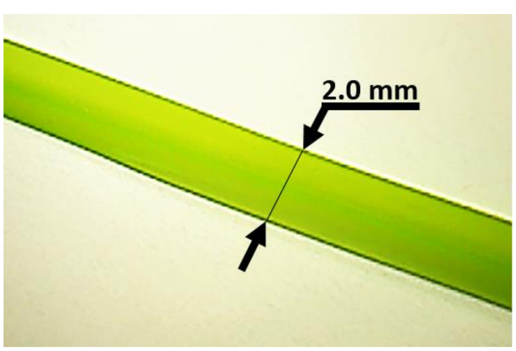



**Fig. 1 PE Fiber.**

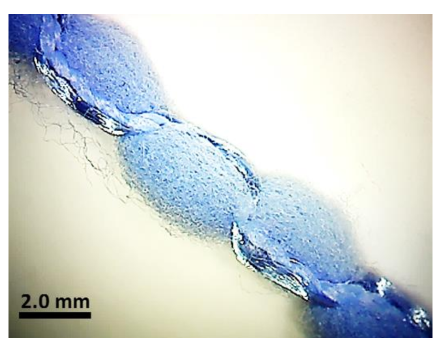


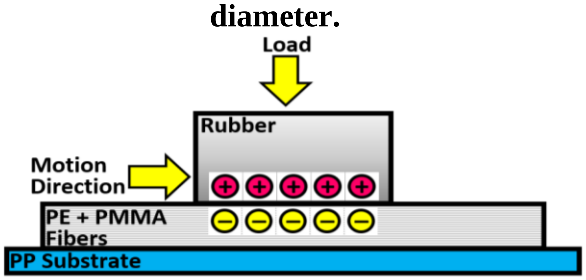

**Fig. 2 PMMA Fiber.**

Fig. 3 PE turf.

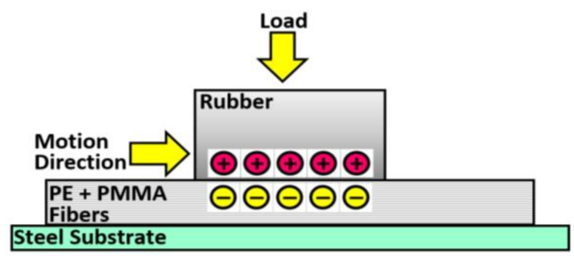
Fig. 4 PE blended by PMMA yarns.

Fig. 5 PE blended by PA yarns of 0.3 mm diameter.

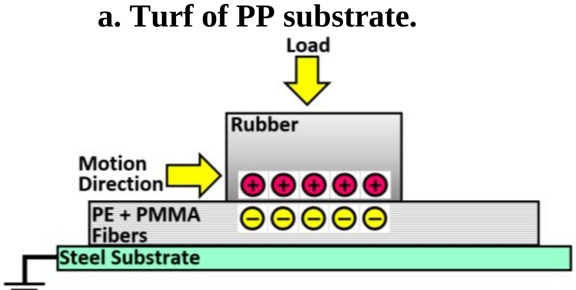
Fig. 6 PE blended by PA textile.



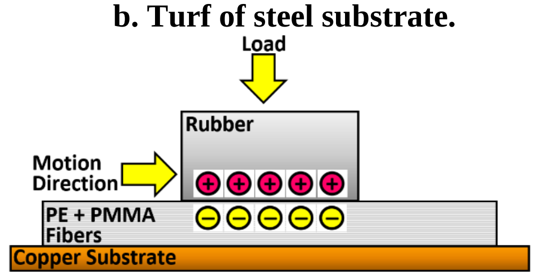

a. Turf of PP substrate.



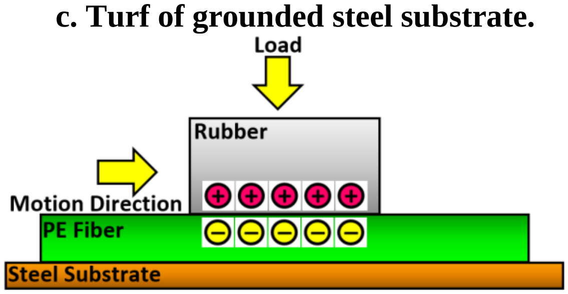

b. Turf of steel substrate.



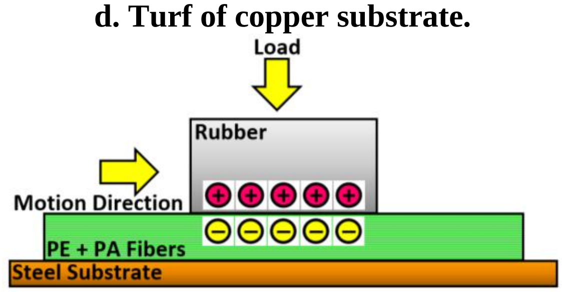

c. Turf of grounded steel substrate.




d. Turf of copper substrate.




e. PE turf of steel substrate.




f. PE turf blended by steel substrate.

Fig. 7 Illustration of the test procedure.

## RESULTS AND DISCUSSION

**Triboelectrification of PE fibers used in artificial turf represents major problem. The key of understanding the phenomenon of generation of ESC is the triboelectric series, where the materials are arranged according to their relative polarity. The materials that gain positive charge are in the upper section of the series, while that gain negative charge are in the lower half, [23]. In addition to that, the materials are ranked according to the intensity of the generated ESC. The triboelectric series indicates that when two materials rub each other, ESC increased as the ranking distance between the two surfaces increased. The triboelectric series of the tested materials are shown in Fig. 8. Based on the ranking of the tested materials, PMMA and PA gain positive ESC when they rub rubber, while PE gains negative ESC. The aim of the present study is to reduce the negative ESC that generated from rubbing PE fibers by rubber. This may be done by blending PE by yarns or textile of PMMA and PA that gain positive ESC during contact and separation as well as sliding on rubber.**

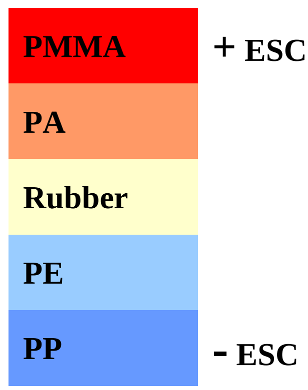



**Fig. 8 Triboelectric series of the tested materials.**

**The effect of the material of the substrate on the value of ESC is illustrated in Figs. 9 – 12. In those experiments PE fibers were blended by PMMA yarns. ESC generated on rubber from contact and separation with the dry tested turf of different substrates is shown in Fig. 9. It is clearly noticed that copper substrate represented the lowest ESC values. The highest ESC was displayed by PP substrate. Grounding the metallic substrates caused drastic decrease in the value of ESC. The best result was that PMMA yarns gained relatively lower ESC value. It seems that the negative charge gained by PE fibers was reduced by the positive charge gained by PMMA when they contacted rubber surface.**

**ESC generated on rubber from sliding of dry rubber and turf of different substrates showed relatively higher ESC values than that measured at contact and separation, Fig. 10. PMMA yarns changed the polarity of ESC generated on the rubber surface into negative with very low values. The lowest ESC values were observed for the grounded copper substrate. The value of ESC was 8000 volts gained by rubber for PP substrate and dropped to 280 volts for grounded copper substrate.**

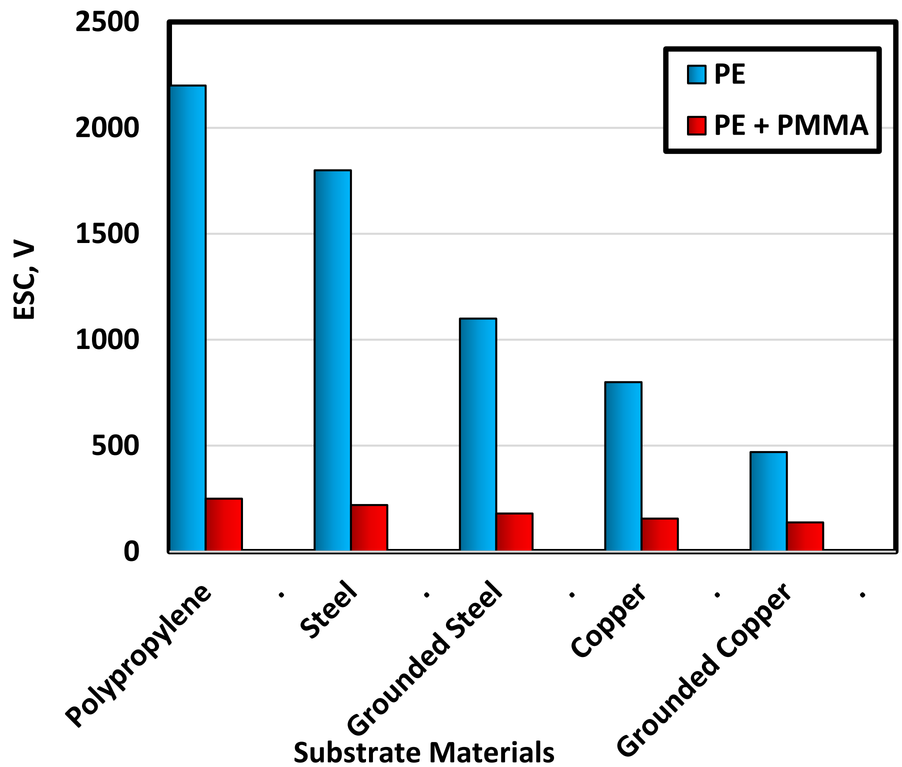



**Fig. 9 Effect of PMMA fibers on ESC generated on rubber from contact and separation of dry rubber and turf of different substrates.**

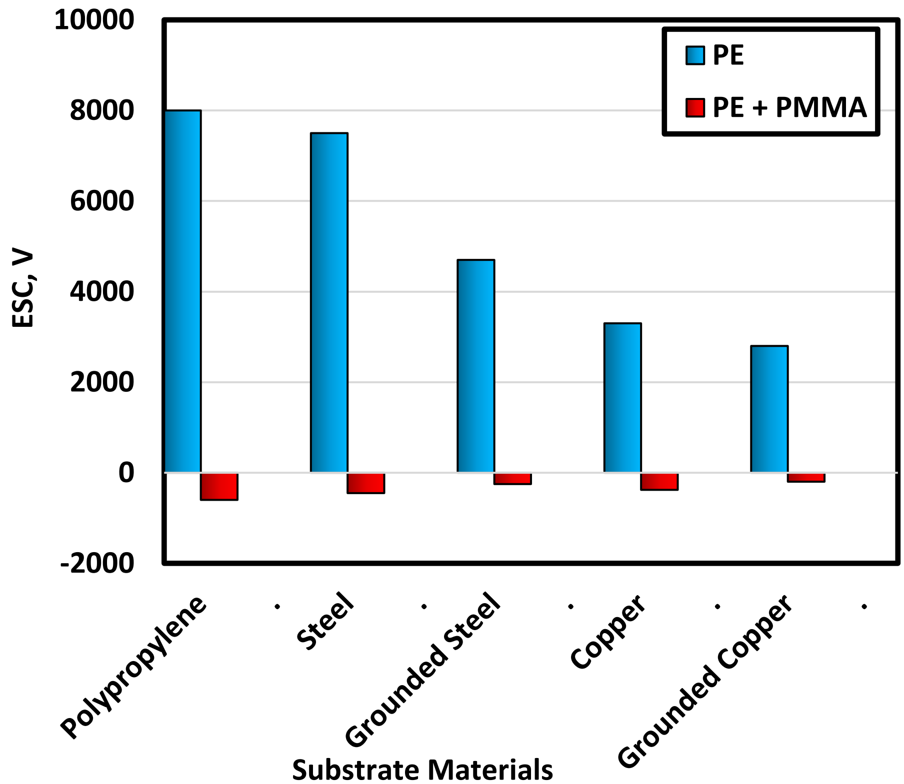



**Fig. 10 Effect of PMMA fibers on ESC generated on rubber from sliding of dry rubber and turf of different substrates.**

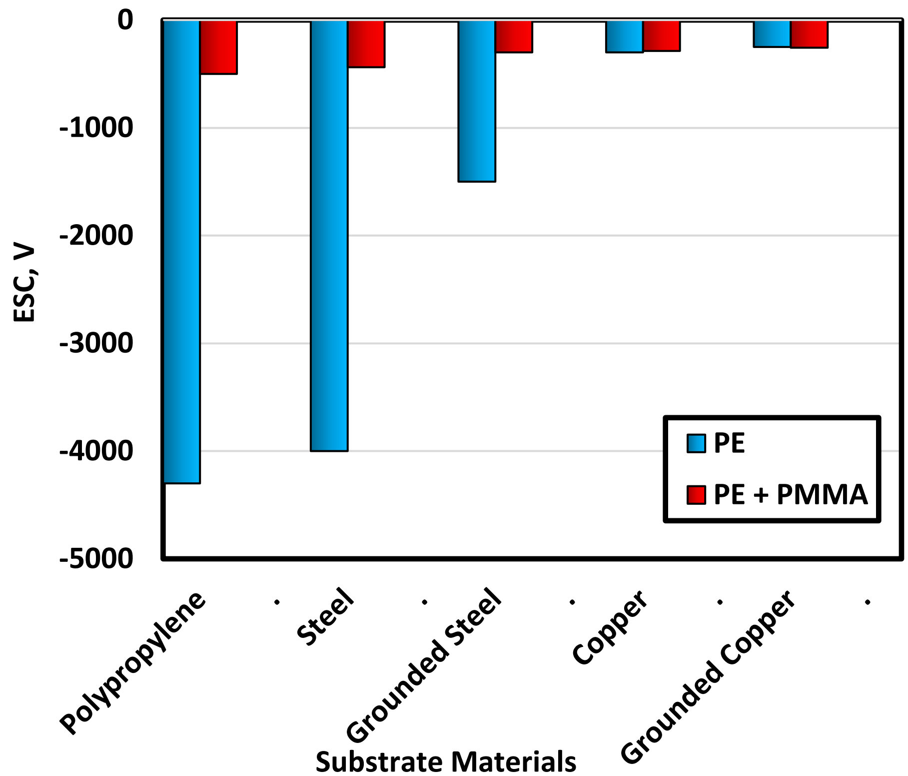



**Fig. 11 Effect of PMMA fibers on ESC generated on turf fibers from contact and separation of dry rubber and turf of different substrates.**

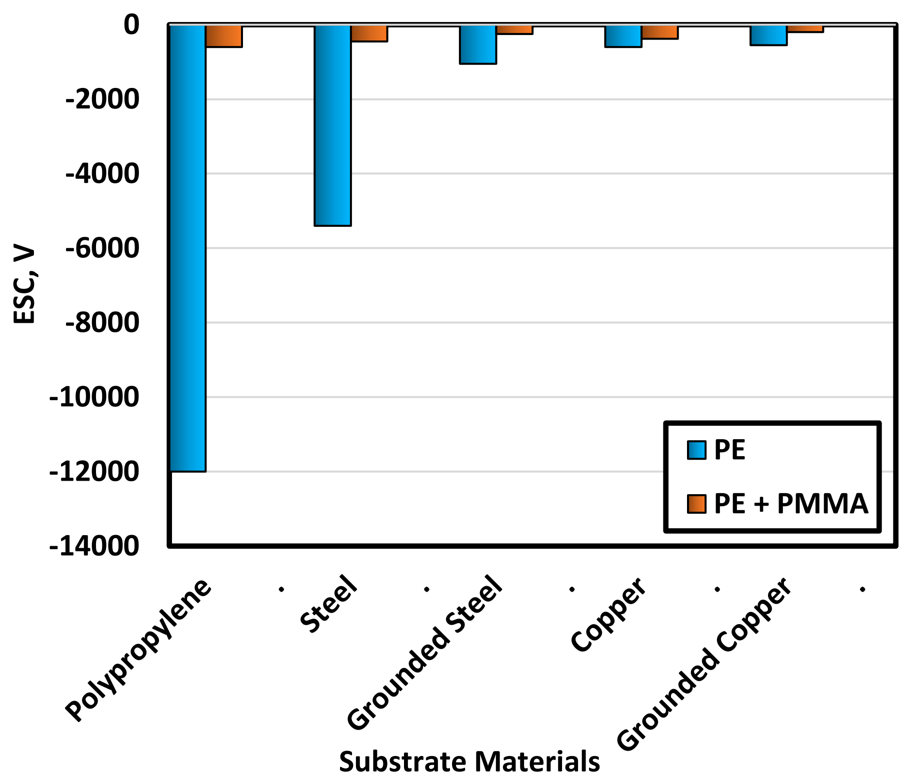



**Fig. 12 Effect of PMMA fibers on ESC generated on turf fibers from sliding of dry rubber and turf of different substrates.**

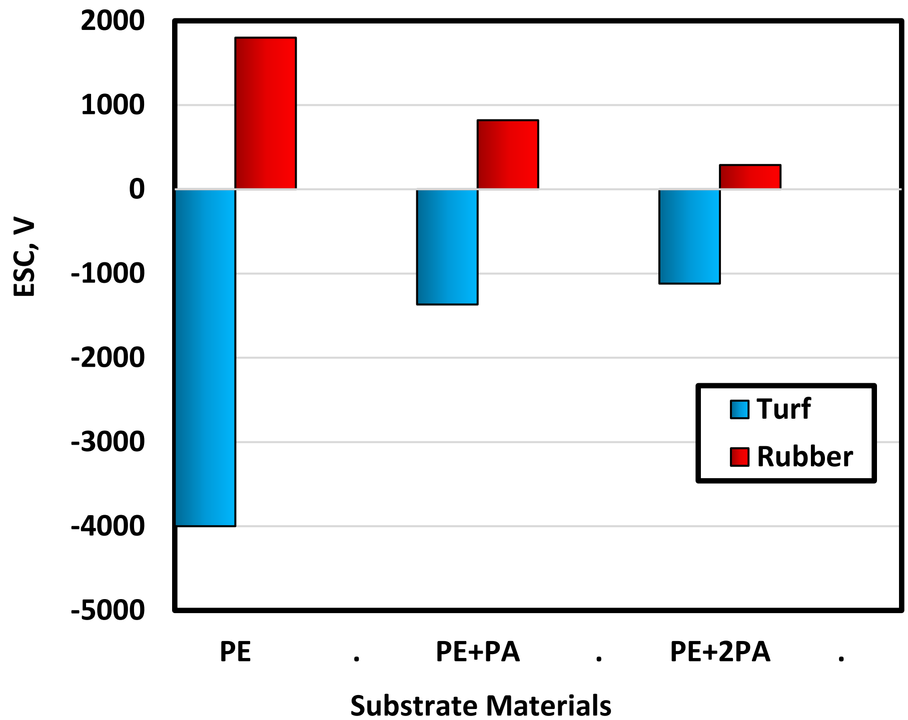



**Fig. 13 Effect of PA yarns on ESC generated from contact and separation of dry rubber and turf.**

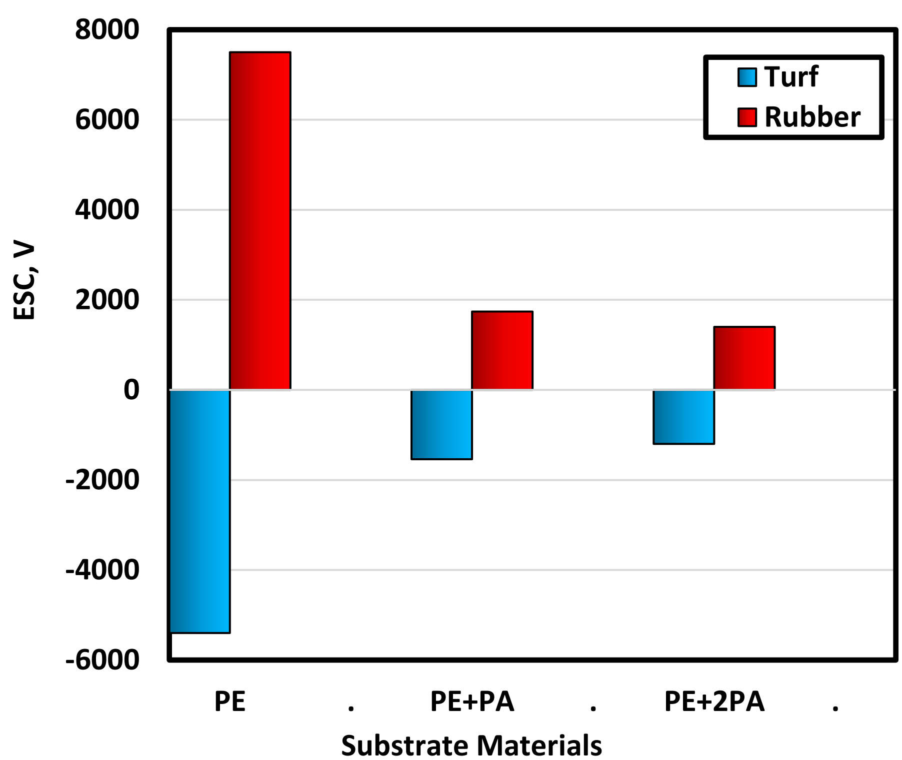



**Fig. 14 Effect of PA yarns on ESC generated from sliding of dry rubber and turf.**

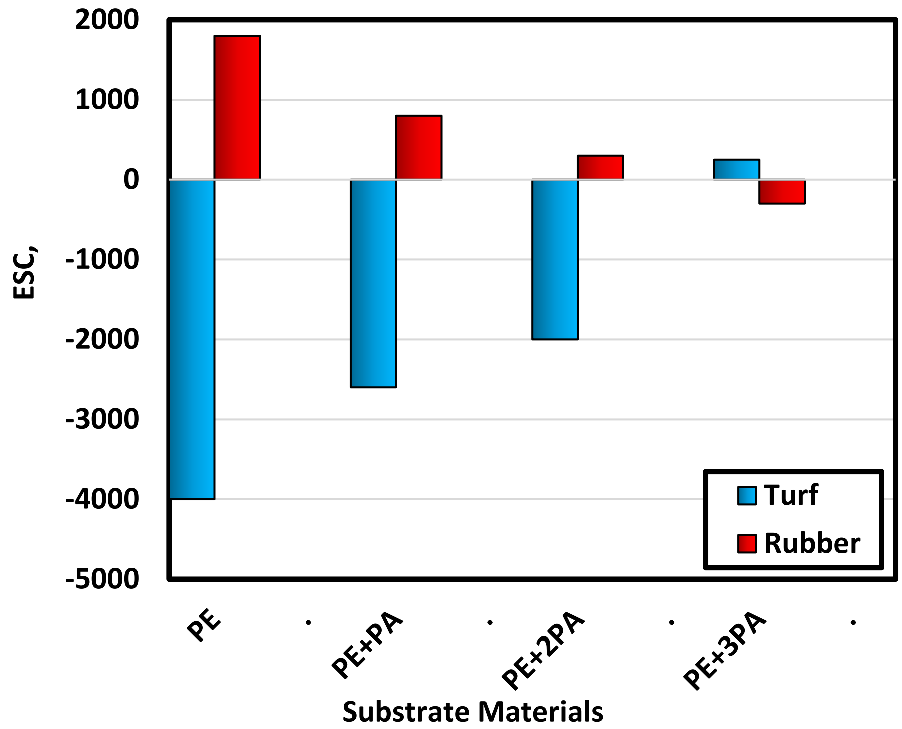



**Fig. 15 Effect of PA textile on ESC generated from contact and separation of dry rubber and turf.**

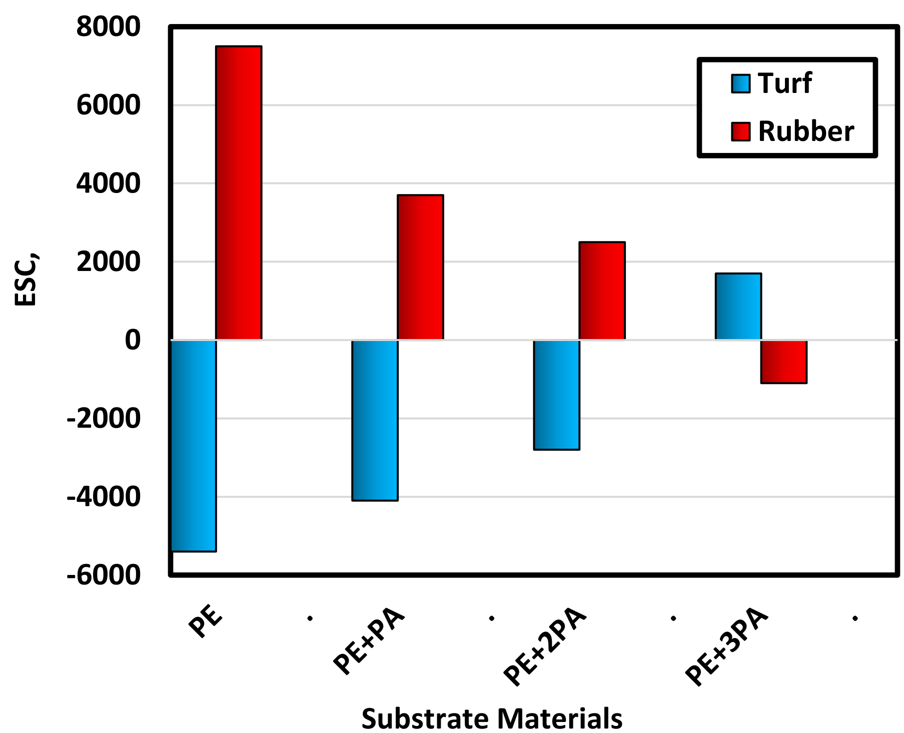



**Fig. 16 Effect of PA textile on ESC generated from sliding of dry rubber and turf.**

**The same trend was observed for ESC generated on the surface of the turf, Figs. 11, 12 for contact and separation as well as sliding respectively. Grounded copper substrate experienced drastic decrease in ESC, where copper leaked ESC generated on PE fibers. Besides the PMMA yarns decreased ESC regardless the material of the substrate. Based on the that observation, it can be recommended to use substrates made from conductive materials like copper sheet.**

**The results of experiments carried out to measure ESC generated from PE turf blended by PA yarns of 0.3 mm diameter are shown in Figs. 13, 14. Effect of PA yarns on ESC generated from contact and separation of dry rubber and turf decreased with increasing the ratio of PA yarns, Fig. 13. PE gained -4000 volts, while the blended specimen by PA showed -1200 volts. Rubber gained +1800 volts when contacted PE, then decreased to +250 volts for the blended turf. At sliding, Fig. 14, the same behavior was observed but ESC values were much higher.**

**Replacing PA yarns by PA textiles in form of ribbon of 10 mm wide with the same length of PE turf (60 mm) gave the blended turf more flexibility than the yarns. In that condition, the deformation of the blended turf was higher than that of yarns blended turf. As result of that, the ratio of PA could be increased. The positive ESC could be increased to overcome the negative one generated on PE turf, Figs. 15, 16. ESC values was -4000 and 1800 volts, Fig. 15, for PE and rubber respectively for contact and separation, while blended turf generated 250 and -350 volts for blended fibers and rubber respectively. At sliding, ESC slightly increased with the same trend, Fig. 16. Based on the experimental findings it can be confirmed that PA textile is more flexible and promising to blend PE turf. Besides, control of the PA content blending PE can minimize the value of ESC.**

## CONCLUSIONS

**1. Among the tested substrates, copper substrate represented the lowest ESC values, while the highest ESC was displayed by PP substrate. Grounding the metallic substrate caused extra reduction in ESC.**
**2. PE fibers blended by PMMA yarns drastically decreased ESC.**
**3. PMMA yarns decreased ESC regardless the material of the substrate.**
**4. Increasing the ratio of PA yarns blending PE turf decreased ESC.**
**5. PA textiles in form of ribbons experienced more reduction in ESC. The textile ribbons increased deformation of the turf and increased the contact area with rubber.**
**6. Control of the content of PA textile blending PE can minimize the value of ESC.**

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