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EFFECT OF BLENDING POLYETHYLENE TURF BY CONDUCTING MATERIALS ON ELECTROSTATIC CHARGE GENERATED FROM FRICTION

Ali A. S.[1], Ali W. Y.[2] and Ibrahem R. A.[3]

[1]Mechanical Engineering Dept., Faculty of Engineering, Suez Canal University, EGYPT.
[2]Department of Production engineering and Mechanical Design, Faculty of Engineering, Minia University, El-Minia, EGYPT.
[3]Mechanical Engineering Dept., Faculty of Engineering, Beni-Suef University, Beni-Suef, EGYPT.

ABSTRACT
The present work aims to investigate the effect of blending polyethylene (PE) fibers by polyurethane fibers (PU), polyamide textile (PA) and polymethyl methacrylate (PMMA) yarns to compensate the negative charge of PE by positive one of blending polymers. Besides, conducting materials such as thin copper wires, carbon fibers and aluminium film ribbons were tested as fillers to conduct the charges between fibers. Three groups of the proposed fibers were tested; PE, PU and copper wires, PE, PA and carbon fibers (CF) and PE, PMMA and Al film.

The experiments revealed that Cu wires associated with PE and PU caused drastic decrease in ESC. It seems that Cu wires conducted the positive and negative charges generated on the surfaces of PU and PE respectively and consequently the resultant value decreased. Further drop in ESC generated on the tested fibers containing PE, CF and PA textile as well as PE, Al film and PMMA showed minimum values indicating the efficiency of CF and Al film ribbons to transfer and exchange the charges from PE to PU and PMMA. This observation is promising in the application of the proposed fibers as artificial turf in kid gardens and sport yards.

KEYWORDS
Polyethylene fibers, polymethyl methacrylate yarns, polyurethane fibers, polyamide textile, aluminium film ribbons, copper wire, carbon fibers.

INTRODUCTION
The limitation of rainfall and water has increased the application of artificial turf for indoors and sport yards to replace natural fibers, [1, 2], that suffer from high maintenance cost the effect of weather. Artificial turf fibers were tested to guarantee the safety of players against their abrasion, [3, 4]. Several researches were performed to develop skin-friendly turf. Polypropylene and polysulfobetaine methacrylate yarns were investigated

as turf sliding against silicone skin, [5], where the friction was reduced. Besides, polymeric yarn turfs mixed with rubber and/or sand infill were widely applied, [6, 7]. It was proved that polymeric turf causes higher level of injuries than natural fibers, [8 - 10]. The effect of environment on the behavior of artificial turf was tested, [11]. Skin injuries depend on the degree of abrasion of the turf, [12 - 14]. It was found that artificial turf reduced the risk of knee injury compared to natural turf. The effect of applied load on friction coefficient displayed by footwear sliding against turf made of polyethylene fibers was investigated, [15, 16]. It was shown that flat sole caused drastic decrease in friction coefficient compared to bare foot.

The increased application of artificial polyethylene (PE) turf as floor materials in sport yards should be balanced by finding solutions to reduce electrostatic charge (ESC) generated from friction with the rubber surface. One of those solutions was to blend PE fibers by polyurethane (PU) to decrease ESC, [17]. The other proposal was to replace PE substrate by polypropylene (PP), [18]. Besides, it was found that, using substrates from steel and copper sheet influenced ESC, while grounding the substrate decreased ESC. PE fibers were blended by yarns and textiles of PMMA and PA respectively, where the experiments revealed that PA textiles showed significant reduction in ESC more than the PMMA yarns, [19]. While, PMMA yarns presented drastic decrease in ESC.

The effect of the length and thickness of PE fibers on their friction behavior was tested when rubber footwear slid against it. It was shown that football shoes represented the lowest friction values, while ESC generated from rubbing of human skin and artificial turf especially in dry sliding recorded high values of ESC, [20 - 22]. Besides, PE fibers of smooth surface generated higher ESC. It was found that replacing rubber by Al film, Cu textile and CF, ESC showed drastic decrease, [23]. Besides, the intensity of ESC gained by the conductors was lower than that measured for the fibers. It was revealed that Cu textile blending PE fibers decreased ESC, [24]. Besides, when Cu substrate replaced PE substrate ESC recorded the lowest values.

The present work aims to investigate the effect of blending PE fibers by PU fibers, PA textile and PMMA yarns on ESC generated from sliding of rubber and conducting materials on the tested blend. Besides, thin copper wires, carbon fibers and aluminium film ribbons were tested as fillers inside the fibers.

EXPERIMENTAL

The present work aims to reduce ESC generated from the friction of rubber sole and PE turf. It is proposed to blend PE turf by PU, PA and PMMA to compensate the negative charge of PE by positive one generated from the blending polymers. Besides, conducting materials such as aluminium film, copper wires as well as carbon fibers were tested as counterface as well as rubber. Three groups of the proposed fibers were tested. The first group contained PE, PU and copper wires, (I), Fig. 1. The second one contained PE, PA and carbon fibers, (II, Fig. 2. While the third contained PE, PMMA and aluminium film, (III), Fig. 3. The Experiments were carried out to measure ESC at contact and separation as well as sliding of PE turf fibers against rubber, Al film, Cu textile and CF, Fig. 4. PE fibers were adhered on PP substrate. The tested conducting materials were adhered to one

surface of wooden block of 200 × 200 × 50 mm^3. The arrangement of the test rig is shown in Fig. 5. The conducting materials were aluminium sheet (Al) of 0.25 mm thickness, copper (Cu) wire of 0.14 mm diameter and carbon fibers (CF), where the width and thickness of PE fibers were 2.0, 0.22 mm respectively. PE fibers were blended by PMMA yarns of 2.0 mm diameter, PA textile of 5.0 mm width and strips of PU in form of ribbons of 5.0 mm wide. The wooden block was loaded against the tested turf surface at 15 N weights and slid horizontally at dry surface condition for 100 mm. ESC generated on the surfaces of the tested turf and wooden block covered by the conducting materials was measured by Surface DC Voltmeter SVM2.

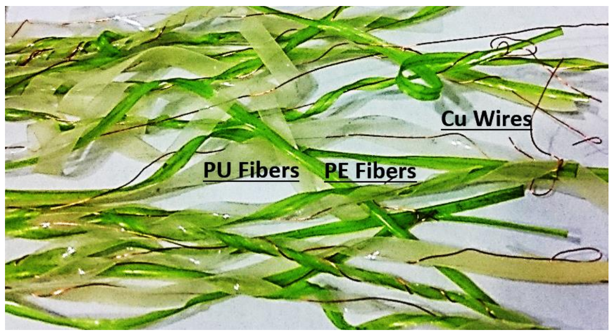

Fig. 1 PE Fibers, PU Fibers and copper wires, (I).

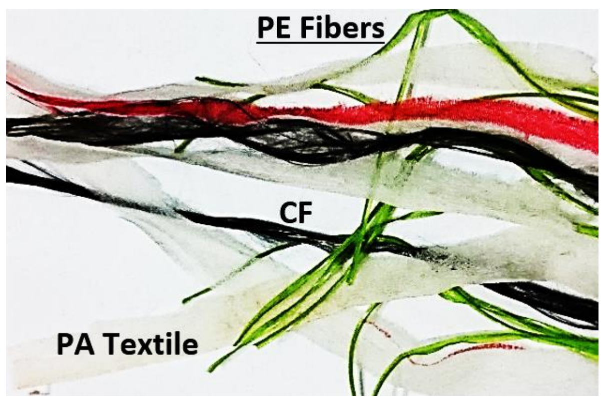

Fig. 2 PE Fibers, PA Textile and CF, (II).

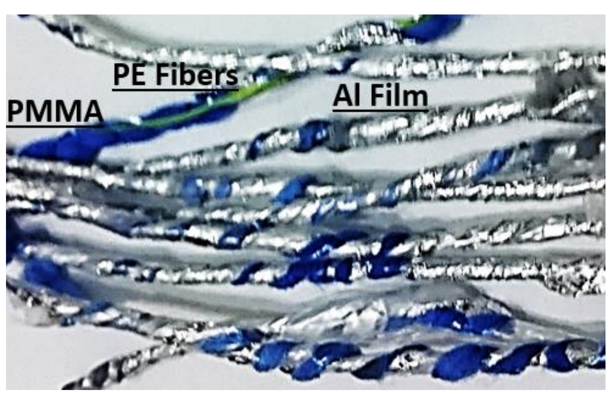

Fig. 3 PE Fibers, PMMA Yarns and Al film, (III).

		
Rubber.	**Cu textile.**	**Al Film.**

Fig. 4 The tested counterface.

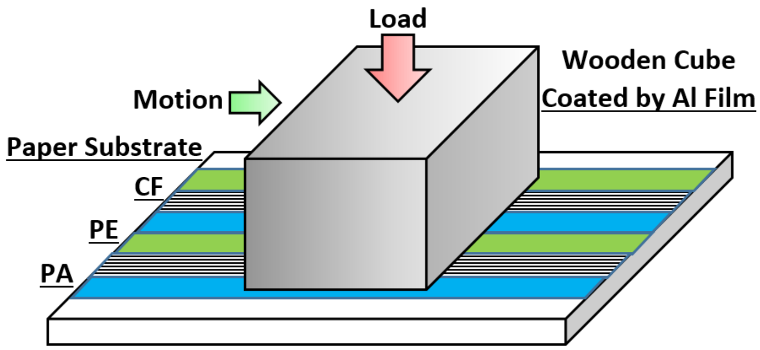

Fig. 5 Arrangement of the test rig.

RESULTS AND DISCUSSION

The results of the experiments carried out to measure ESC generated on rubber and conducting materials from contact and separation of the tested turf blended by copper wires are illustrated in Fig. 6. Rubber gave the highest ESC values followed by Al film, Cu textile and CF. Cu wire caused further decrease in ESC compared to PE and PU. It seems that Cu wire conducted the positive and negative charges generated of the surfaces of PU and PE respectively and consequently the resultant value decreased. In the figure, the sign of ESC for counterface slid on PU was negative. ESC generated on the tested turf blended by copper wires, Fig. 7, clearly showed the effect of Cu wire on decreasing ESC, where PE recorded -6200 volts and -210 volts in the presence of Cu wire and PU fibers. This behavior can be explained by the ability of exchanging ESC inside the proposed turf by the good conductivity of Cu wires.

In condition of sliding on the tested turf blended by copper wires, ESC generated on rubber and conducting materials recorded higher values than that observed for contact and separation, Fig. 8. Rubber slid against PE and PU fibers gained +4200, -7100 volts, while the measured value was only 420 volts in the presence of Cu wire. ESC generated on the tested turf blended by copper wires was -270 volts, Fig. 9. The measured values for PE and PU were -6700 and +634 respectively. These values confirm the enhancing influence of the Cu wire inside PE and PU fibers. Figures 10 and 11 explains the role of Cu wires in reducing ESC by conducting the charges from PE to PU. The surface of Cu conducts the negative charge from PE to PU and consequently neutralize the positive charge gained by PU.

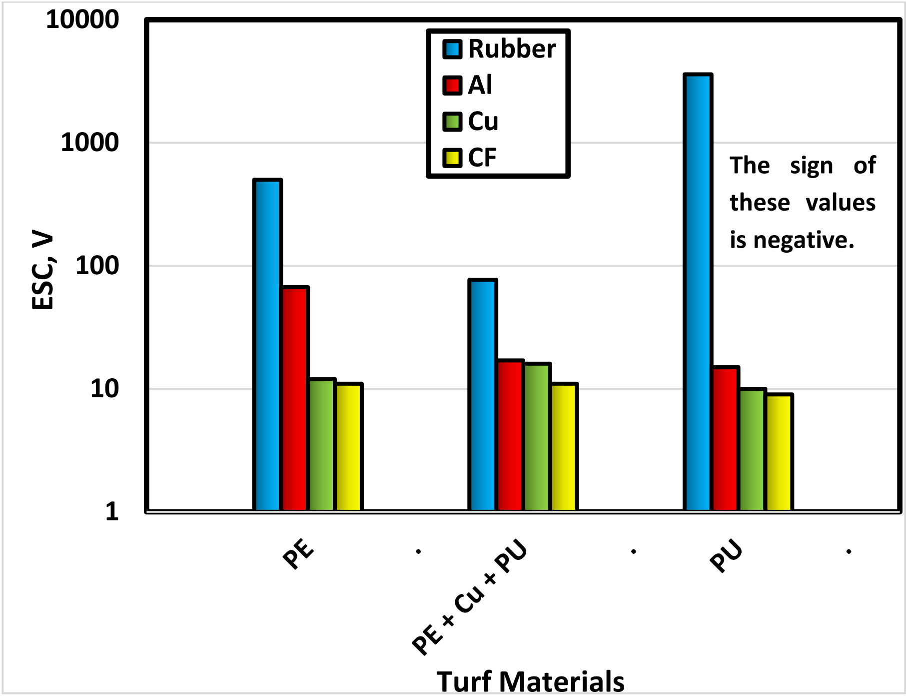

Fig. 6 ESC generated on rubber and conducting materials from contact and separation of the tested turf blended by copper wires.

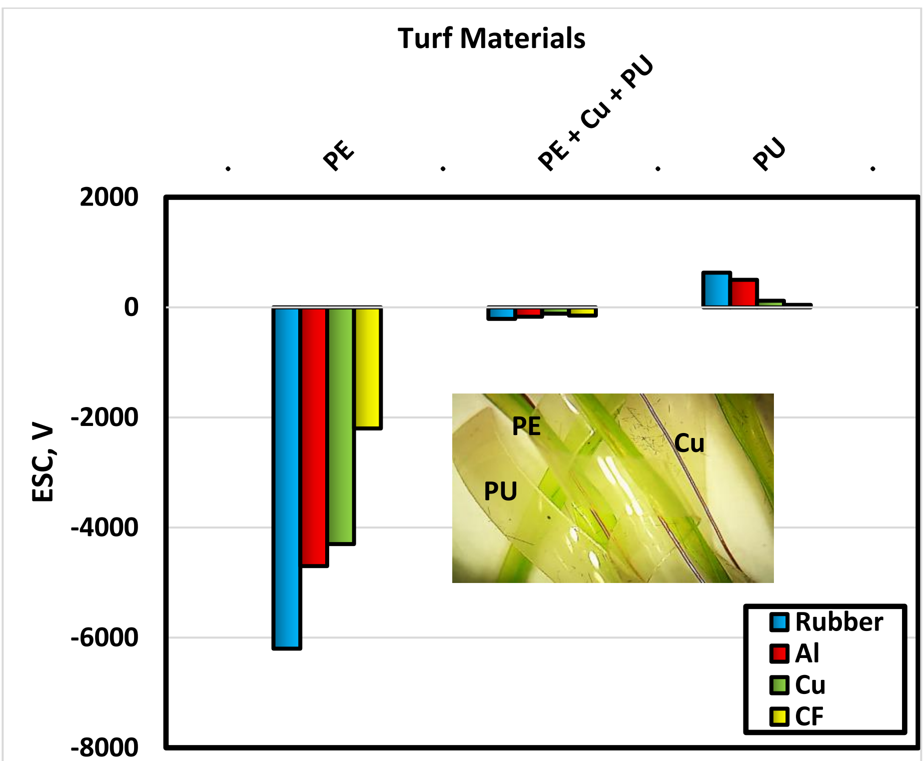

Fig. 7 ESC generated on the tested turf blended by copper wires from contact and separation.

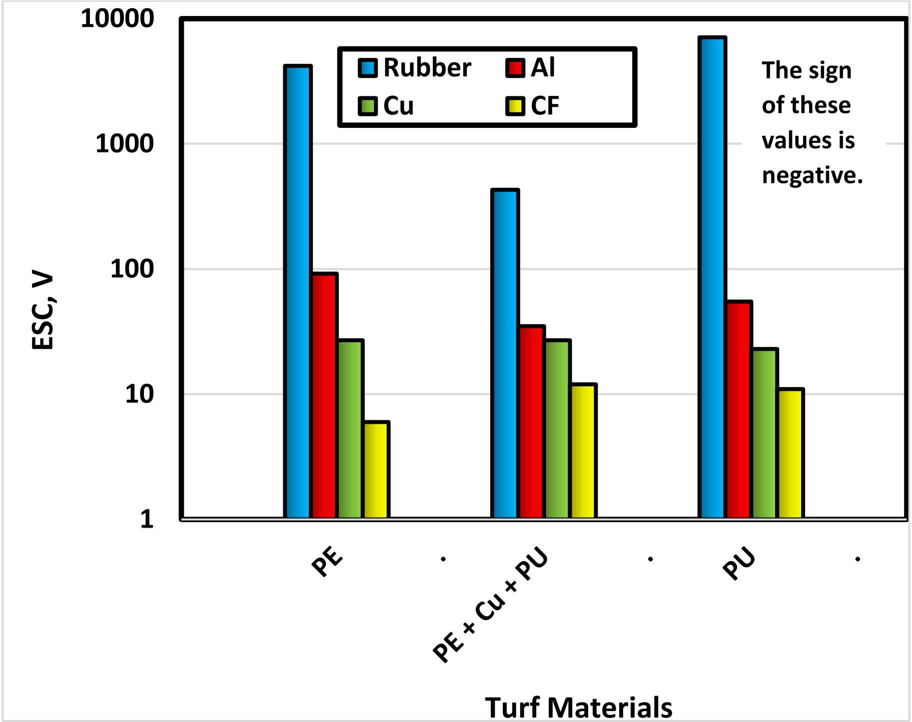

Fig. 8 ESC generated on rubber and conducting materials from sliding on the tested turf blended by copper wires.

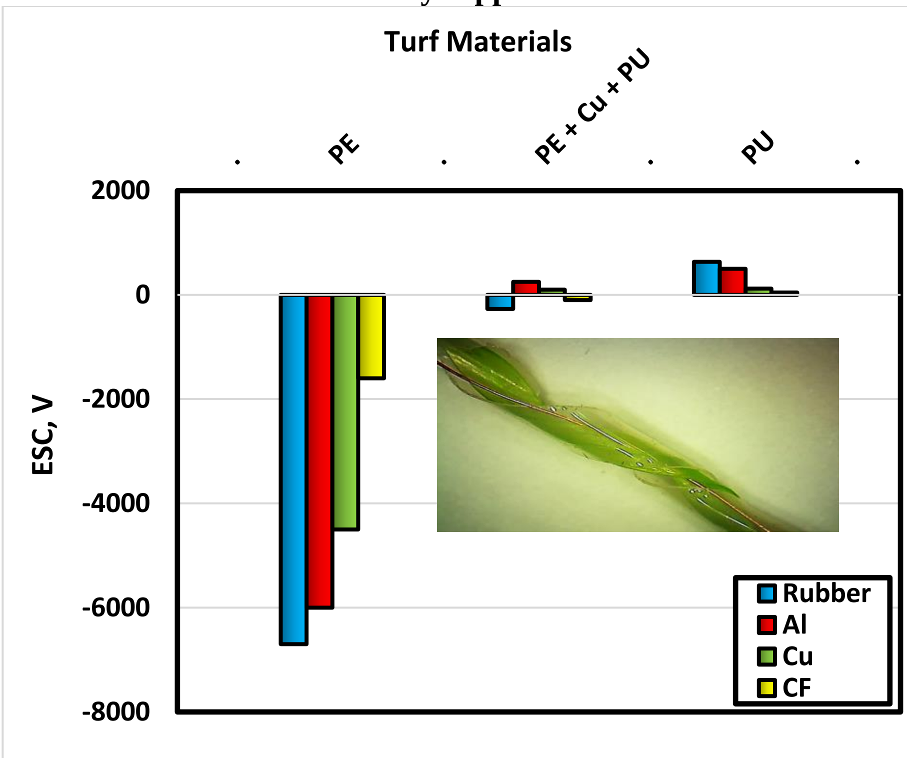

Fig. 9 ESC generated on the tested turf blended by copper wires from sliding.

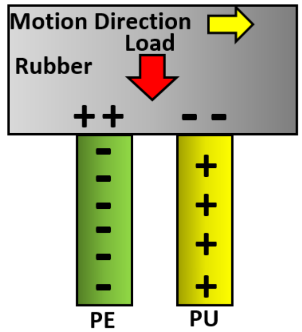

Fig. 10 Distribution of ESC on rubber and fibers.

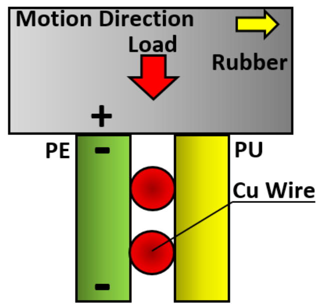

Fig. 11 Distribution of ESC on rubber and Fibers in the presence of Cu wires.

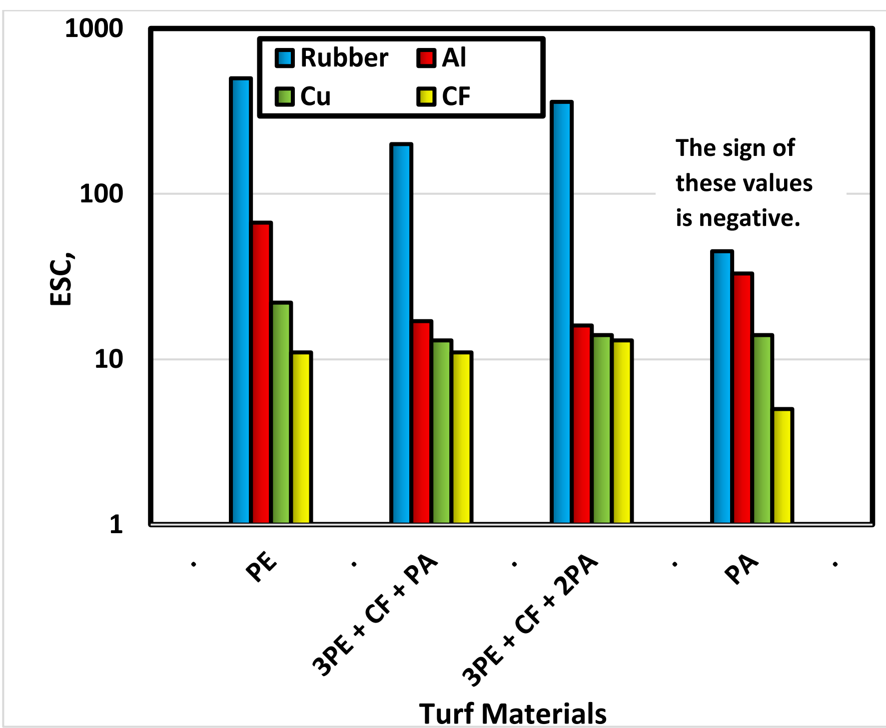

Fig. 12 ESC generated on rubber and conducting materials from contact and separation of the tested turf blended by carbon fibers.

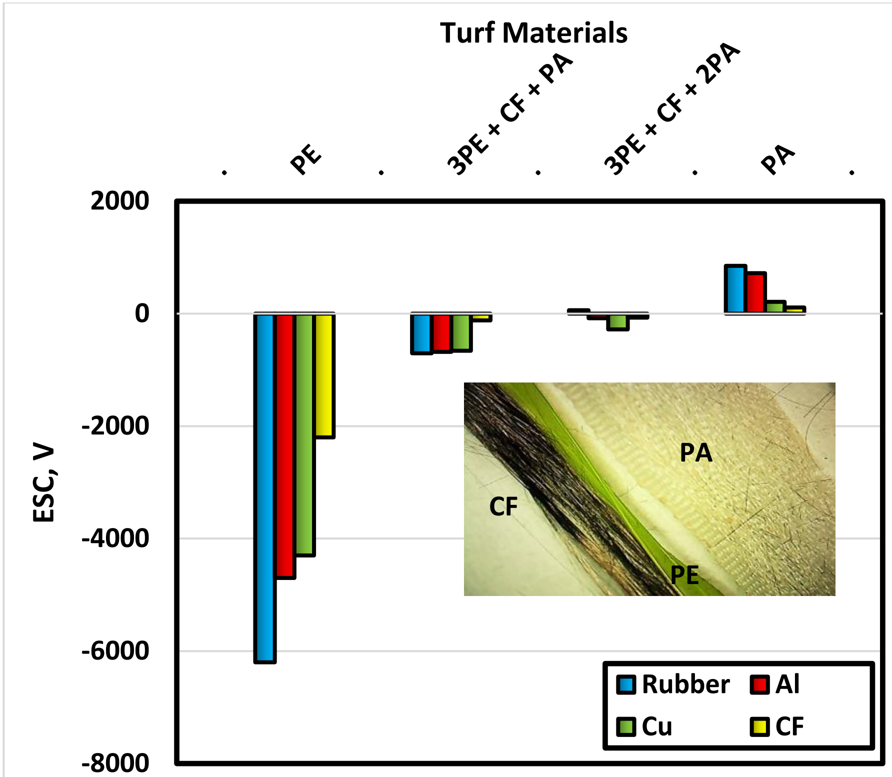

Fig. 13 ESC generated on the tested turf blended by carbon fibers from contact and separation.

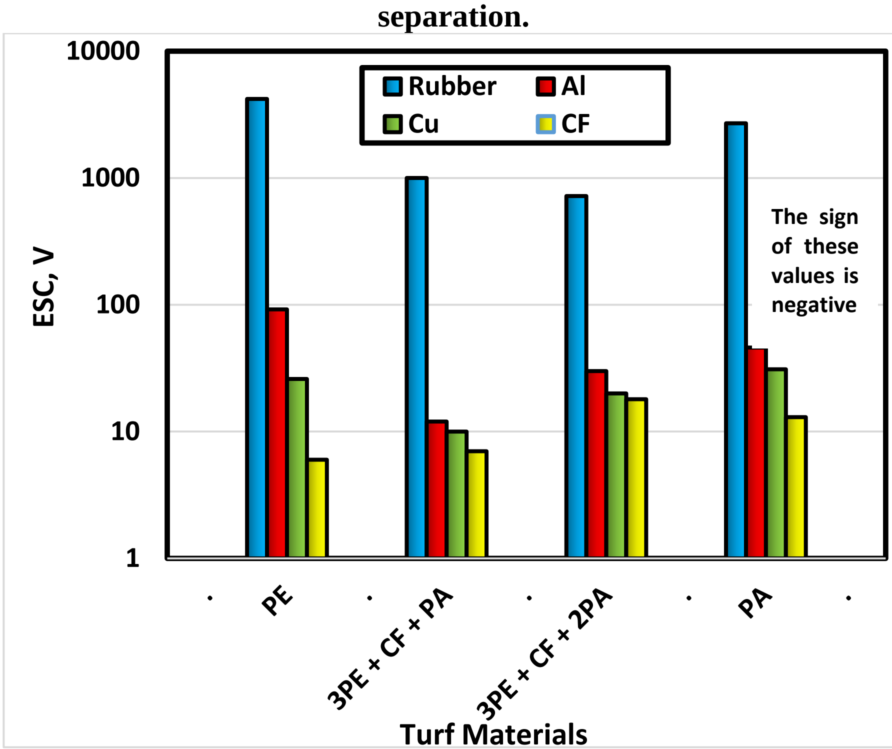

Fig. 14 ESC generated on rubber and conducting materials from sliding on the tested turf blended by carbon fibers.

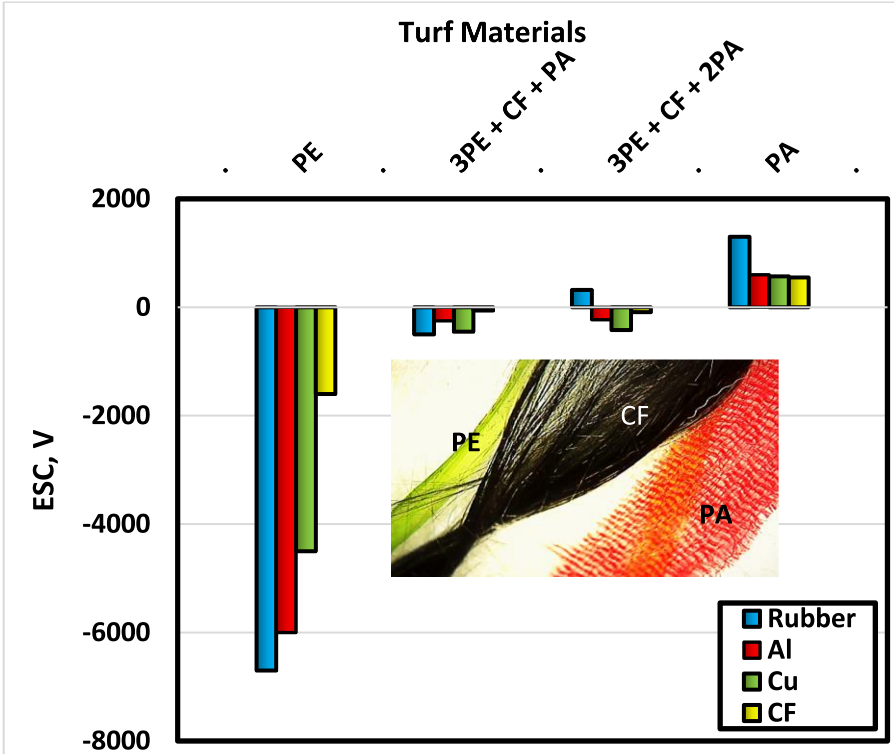

Fig. 15 ESC generated on the tested turf blended by carbon fibers from sliding.

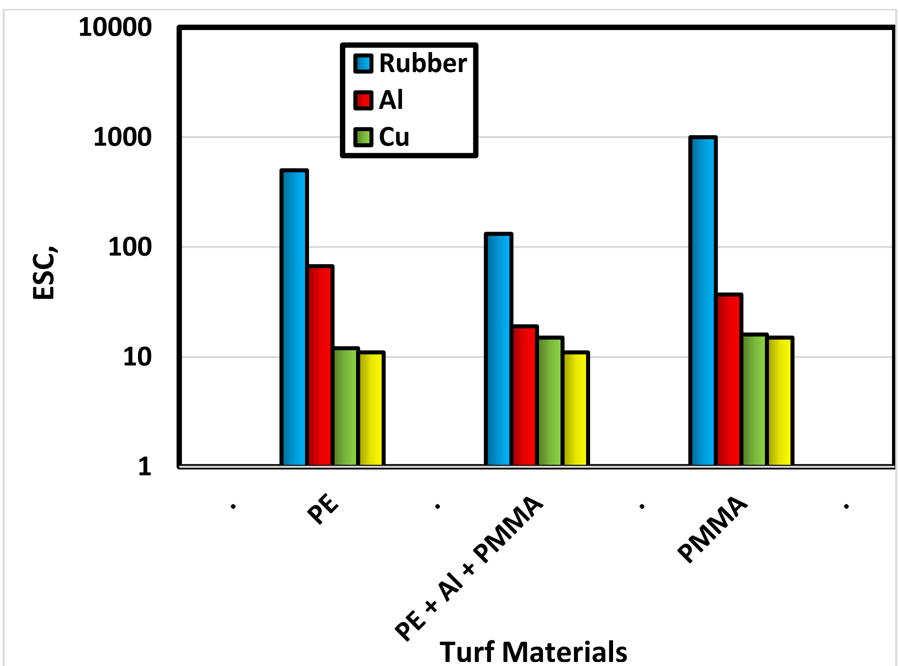

Fig. 16 ESC generated on rubber and conducting materials from contact and separation of the tested turf blended by Al film.

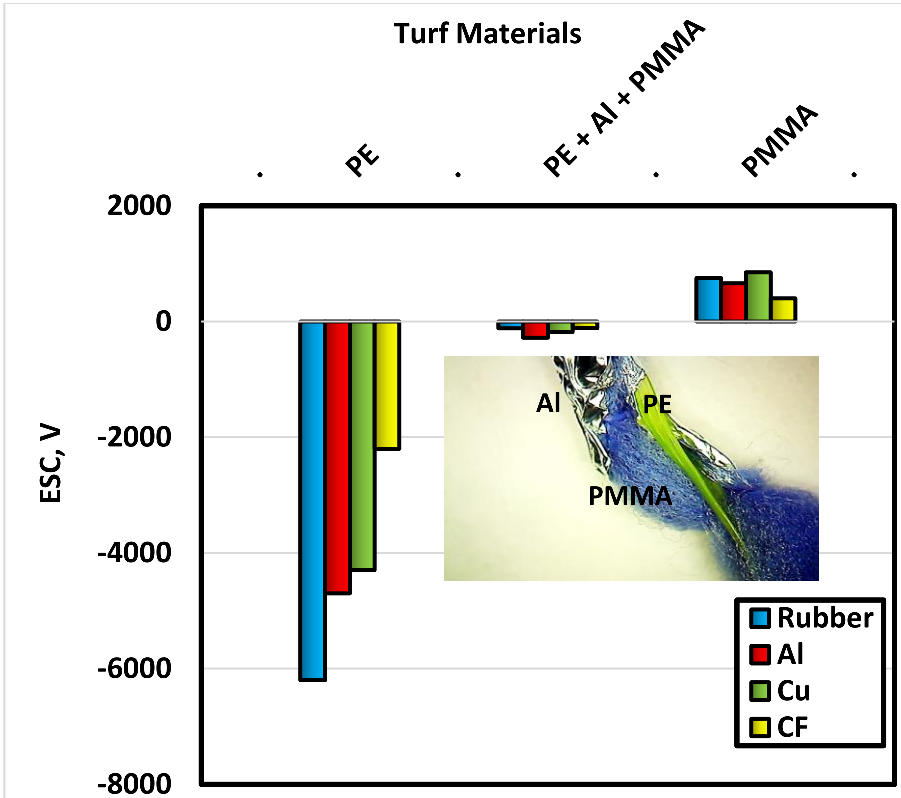

Fig. 17 ESC generated on the tested turf blended by Al film from contact and separation.

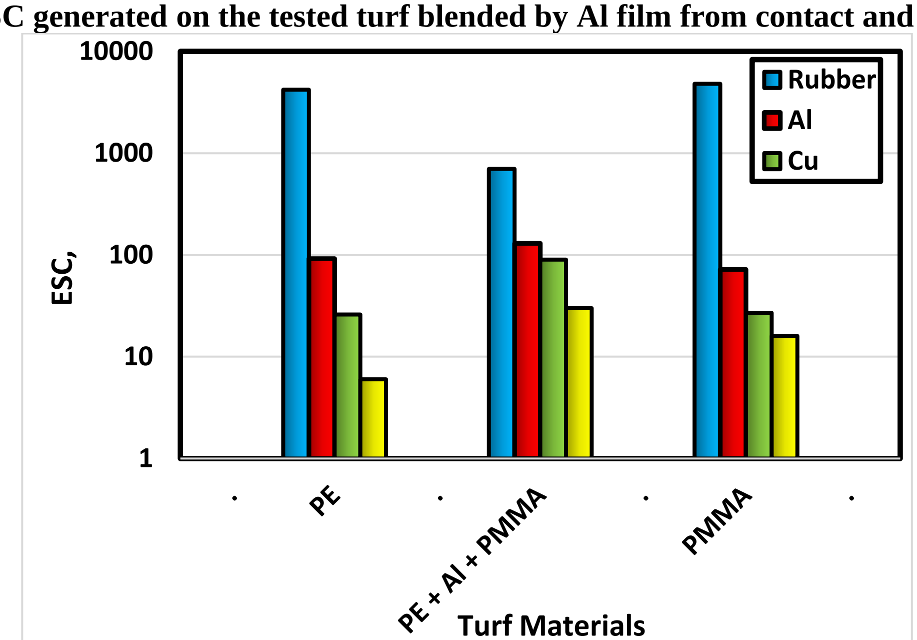

Fig. 18 ESC generated on rubber and conducting materials from sliding on the tested turf blended by Al film.

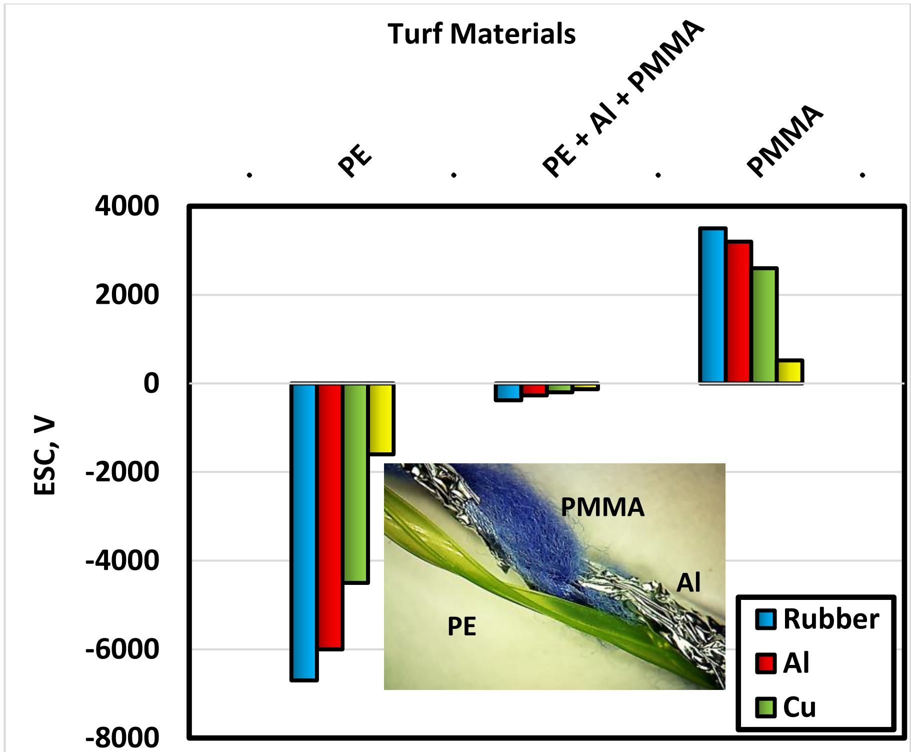

Fig. 19 ESC generated on the tested turf blended by Al film from sliding.

The results of the second group that contained PE, PA and carbon fibers are shown in Figs. 12 – 15. ESC generated on rubber and conducting materials from contact and separation showed slight reduction in ESC in the presence of CF, Fig. 12. While ESC generated on the tested turf showed drastic reduction, where the minimum values were recorded for PE and PA ratio of 3/2 in the presence of CF, Fig. 13. This observation is promising in the application of the proposed turf in kid gardens and sport yards. The values of ESC decreased from -6200 to +61 volts for PE and (3PE + CF + 2PA) respectively.

Sliding of rubber and conducting materials on the tested turf blended by carbon fibers generated higher ESC, Fig. 14. Rubber represented the highest values followed by Al film, Cu textile and CF. Siding on PE, rubber gained 500 volts, while Al film, Cu textile and CF gained 87, 22 and 11 volts respectively. The lowest values were recorded for PU in negative sign, Fig. 15. ESC generated on the tested turf drastically decreased for the proposed fibers of (3PE + CF + PA) and (3PE + CF + 2PA) indicating the efficiency of CF to transfer and exchange the charges from PE and PU so that the resultant showed relatively lower values.

When Al film was used as conducting element inside the PE fibers and PMMA yarns, ESC recorded for rubber slid on the proposed fibers decreased from 500 to 132 volts indicating the possibility of applying Al film as ribbons with PE fibers and PMMA yarns to form theturf of relatively low ESC, Fig. 16. At the surface of the fibers, the enhancing effect was

higher, where ESC decreased from -6200 to -132 volts, Fig. 17. Based on that observation, the proposed turf (PE + Al + PMMA) can be recommended to repalce PE fibers.

At sliding, Figs. 18 and 19, the reduction showed promising trend, where Al film slid on PE fibers and (PE + Al + PMMA) gained 4200 and 700 volts respectively. ESC gained by fibers showed value of -6700 volts and dropped to -380 volts for the proposed fibers.

CONCLUSIONS

1. Rubber conterface gave the highest ESC values followed by Al film, Cu textile and CF.
2. Cu wires caused further decrease in ESC compared to that gained by PE and PU in the absence of the wires.
3. The lowest values of ESC were recorded for PE and PA ratio of 3/2 in the presence of CF. Experiments confirmed the efficiency of CF to transfer and exchange the charges from PE and PU so that the resultant showed relatively lower values.
4. Using Al film in form of ribbons as conducting element inside the PE fibers and PMMA yarns proved its applicability to form the turf of relatively low ESC. The proposed fibers consisting of PE, Al film ribbon and PMMA yarns can be recommended to repalce PE fibers.

REFERENCES

1. Zanetti E. M., Bignardi C., Franceschini G., Audenino A. L., "Amateur football pitches: mechanical properties of the natural ground and of different artificial turf infills and their biomechanical implications", J. Sports Sci 2013, 31 (7), pp. 767 - 778. (2013).
2. Robert A. Francis, "Artificial lawns: Environmental and societal considerations of an ecological simulacrum", Urban Forestry & Urban Greening 30, pp. 152 - 156, (2018).
3. Morales H. M., Peppelman M., Zeng X., Van Erp P. E. J., Van Der Heide E., "Tribological behavior of skin equivalents and ex-vivo human skin against the material components of artificial turf in sliding contact", Tribology International, 102, pp. 103 – 113, (2016).
4. FIFA, "FIFA Quality programme for football turf", Handbook of test methods. Zurich; (2015).
5. Elisabetta M. Zanetti, "Amateur football game on artificial turf: Players’ perceptions", Applied Ergonomics, 40, pp. 485 – 490, (2009).
6. Fleming P., "Artificial turf systems for sport surfaces: current knowledge and research needs", Proc. Inst. Mech. Eng. Part P J. Sport. Eng. Technol., 225, pp. 43 – 62, (2011).
7. Junge A., Dvorak J., "Soccer injuries: a review on incidence and prevention", Sports Med., 34, pp. 929 - 938, (2004).
8. Fuller C. W., Clarke L., Molloy M. G., "Risk of injury associated with rugby union played on artificial turf", J. Sports Sci. 28, pp. 563 – 570, (2010).
9. Burillo P., Gallardo L., Felipe J. L., Gallardo A. M., "Artificial turf surfaces: perception of safety, sporting feature, satisfaction and preference of football users", Eur. J. Sport Sci. 14, S437 - S447, (2014).
10. Van der Heide E., Lossie C. M., Van Bommel K. J. C., Reinders S. A. F., Lenting H. B. M., "Experimental investigation of a polymer coating in sliding contact with skinequivalent silicone rubber in an aqueous environment, Tribol. Trans., 53, pp. 842-847, (2010).

11. Eijnde W. V. D., Peppelman M., Weghuis M. O., Erp P. E., "Psychosensorial assessment of skin damage caused by a sliding on artificial turf: The development and validation of a skin damage area and severity index", Journal of Science and Medicine in Sport, 17, pp. 18 - 22, (2014).

12. American Society for Testing and Materials, "Standard test method relative abrasiveness of synthetic turf playing surfaces", F1015-02, Annual Book of ASTM Standards. Vol. 15.07, End Use Products West Conshohocken, PA, ASTM, (2002).

13. FIFA. Determination of skin/surface friction and skin abrasion (FIFA test method 08), In: A Quality Concept for Football Turf—Handbook of Test Methods., pp. 33 – 36, (2008).

14. Strutzenberger G., Cao H. M., Koussev J., Potthast W., Irwin G., "Effect of turf on the cutting movement of female football players", Journal of Sport and Health Science, 3, pp. 314 – 319, (2014).

15. El-Sherbiny Y. M., "Friction coefficient displayed by sliding against artificial grass", EGTRIB, Vol. 12, No. 1, January 2015, pp. 13 – 25, (2015).

16. Daoud M. A., Abu-Almagd G. M., El-Rahman M. A. and Ali W. Y., "Behavior Of Football Shoe Sole Sliding Against Artificial Grass", Journal of Multidisciplinary Engineering Science and Technology (JMEST), Vol. 3 Issue 5, pp. 4708 – 4713, (2016).

17. Ali A. S. and Ali W. Y. and Samy A. M., "Electrostatic Charge Generated from Sliding on Polyethylene Turf", Journal of the Egyptian Society of Tribology, Vol. 17, No. 1, January 2020, pp. 1 - 13, (2020).

18. Ali A. S., Al-Kabbany A. M., Ali W. Y. and Samy A. M., "Reducing the Electrostatic Charge Generated from sliding of Rubber on Polyethylene Artificial Turf", Journal of the Egyptian Society of Tribology, Vol. 17, No. 2, April 2020, pp. 40 - 49, (2020).

19. Ali A. S., Ali W. Y. and Ibrahem R. A., "Effect of Blending Polyethylene Turf by Polymethyl Methacrylate and Polyamide on Generation of Electrostatic Charge", Journal of the Egyptian Society of Tribology, Vol. 17, No. 2, April 2020, pp. 50 - 60, (2020).

20. Charalambous L., Wilkau H., Potthast W., Irwin G., "The effects of artificial surface temperature on mechanical properties and player kinematics during landing and acceleration", J. Sport Health Sci., 5, (3), pp. 355 - 360, (2016).

21. James I. T., McLeod A. J., "The effect of maintenance on the performance of sand-filled synthetic turf surfaces", Sports Technol., 3, (1), pp. 43 – 51, (2010).

22. Samy A. M. and Ali W. Y., "Effect of the Thickness and Width of Artificial Turf Fiber on the Friction and Electrostatic Charge Generated During Sliding", Journal of the Egyptian Society of Tribology, Vol. 16, No. 2, April 2019, pp. 48 - 56, (2019).

23. Ali A. S., Ali W. Y., Ibrahem R. A. and Ameer A. K., "Effect of Conducting Materials on Electrostatic Charge Generated from Sliding on Polyethylene Turf" Journal of the Egyptian Society of Tribology, Vol. 17, No., July 2020, pp. 48 - 58, (2020).

24. Ali A. S., Ali W. Y. and Ibrahem R. A., "Influence of Blending Polyethylene Turf by Copper Textile on Generation of Electrostatic Charge", Journal of the Egyptian Society of Tribology, Vol. 17, No. 3, July 2020, pp. 14 - 25, (2020).