EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 17, No. 1, January 2020, pp. 1 - 13 **ISSN 2090 - 5882**
(Received October 12. 2019, Accepted in final form December 02. 2019) **www.egtribjournal.com**

ELECTROSTATIC CHARGE GENERATED FROM SLIDING ON POLYETHYLENE TURF

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ABSTRACT
The extensive use of PE fibers in artificial turf necessitates to study their electrification when they rub rubber surface. Electrostatic charge (ESC) generated from the contact and separation as well as sliding of rubber against PE turf was discussed in the present work. Experiments were carried out to measure the generated ESC under varying load at dry and water wet surfaces.

It was found that using metallic substrates like copper and steel sheets rubber surface gained higher values of ESC than that measured for PE fibers. The high value of ESC measured for rubber and PE fibers increases the adhesion between skin and turf and consequently increases severity of injury. The very low values of ESC generated from contact and separation as well as sliding recommends using water on the contact surfaces. Besides, the material of the substrate of PE fibers strongly influences ESC. It is recommeded to perform more experiments to properly introduce new material of relatively low ESC in that application.

KEYWORDS
Artificial turf, electrostatic charge, rubber, contact and separation, sliding.

INTRODUCTION
Artificial turf is manufactured from polymeric fibers to replace natural grass, [1], in sport yards, roof gardens, swimming pool surrounds and kid schools. One of the drawbacks of artificial turf is the infill that contains sand and granulated rubber that has bad effect on the environment, [2 - 4]. Friction of artificial turf made of polyethylene yarn and skin of the player may cause abrasions and burns in sports. There is an increasing demand to apply artificial turf in condition of limited rainfall.

Fibers of artificial turf should be tested to guarantee the safety of sport players against the abrasion of the turf. Besides, the types and depth of infill materials of turf have significant

effect on the performance of players, [5], where they control the friction of artificial turf with the skin, [6, 7]. Several trials were tested to decrease abrasion of skin by turf, [8 - 10]. The surface properties of the artificial turf were studied to investigate their effect on the abrasion on skin, [11 - 13]. The influence of the environment on the wear of the artificial turf was tested, [14]. The mechanical behavior of the artificial turf was controlled by the type and dimension of the fiber materials as well as infill materials, [15 – 17]. Skin irritation caused from abrasion of the turf during sliding in football yard was investigated, [18], using silicone and foam to simulate skin, [19 - 21]. It was proved that compared to natural turf, artificial turf decreased the risk of knee injury.

Static friction coefficient resulted from sliding of footwear against artificial turf was tested, [22, 23]. Polyethylene fibers of different length and thickness was the material of the tested artificial turf. The test results revealed that football shoes showed the lowest friction values, while flat sole decreased friction coefficient drastically compared to bare foot when sliding against water wet turf.

Electrostatic charge (ESC) is generated from sliding against artificial turf that has a tendency to develop ESC when rubbed with human skin especially in dry sliding, [24, 25]. This behavior represents major disadvantage for the artificial turf. Three types of turf were tested, where the surface protrusions of the turf fiber influenced ESC generation, [26]. It was observed that turf of smooth surface generated the highest ESC values when football shoes slid against it. It was recommended to introduce new materials of relatively lower ESC to be used as artificial turf.

The present work discusses the generation of ESC from contact and separation as well as sliding of rubber against PE turf at dry and water wet conditions.

EXPERIMENTAL

The PE fibers of the artificial turf were tested at contact and separation as well as sliding. The tested artificial turf is shown in Fig. 1. The counterface was rubber of 60 Shore A hardness of 5 mm thickness adhered to a wooden cube of 40 × 40 × 40 mm^3. The rubber surface was loaded at the turf surface at weights of 2.5, 5.0, 7.5, 10.0, 12.5, 15.0 and 17.5 N. The rubber was pulled manually to move horizontally at dry and water wet sliding conditions. PE, PP, steel and copper sheets were used as substrate for the PE fibers. The thickness of the substrates was 0.25 mm. The PE fiber length, width and thickness were 60, 2.0, 0.22 mm respectively. ESC generated on the surface of PE fibers and rubber surface was measured using an AlphaLab inc. Surface DC Voltmeter SVM2, where the values of ESC were recorded. Readings were done with the sensor 25 mm apart from the surface being tested.

Fig. 1 The tested artificial turf.

RESULTS AND DISCUSSION

ESC generated from contact and separation of dry rubber and turf of conventional (PE) substrate is shown in Fig. 2, where the details of the test are illustrated in Fig. 3. Rubber surface gained positive ESC that gradually increased with increasing load, while PE fibers gained negative charge. This behaviour could be attributed to the fact that, according to the tribo-electric series, Fig. 4, friction between two surfaces causes the object in the upper position of the series to be charged positively (rubber) and that in the lower position to be charged negatively (PE). It is known that different polarity means attraction. Also, it could be attributed to that the long gap gives higher chance to exchange more charges (electrons) between the two different materials rubbing each other. Illustration of the generation of ESC on the sliding surfaces is shown in Fig. 3, where the equal ESC of different signs would increased the attractive force between the two surfaces and consequently influenced adhesion that increases friction.

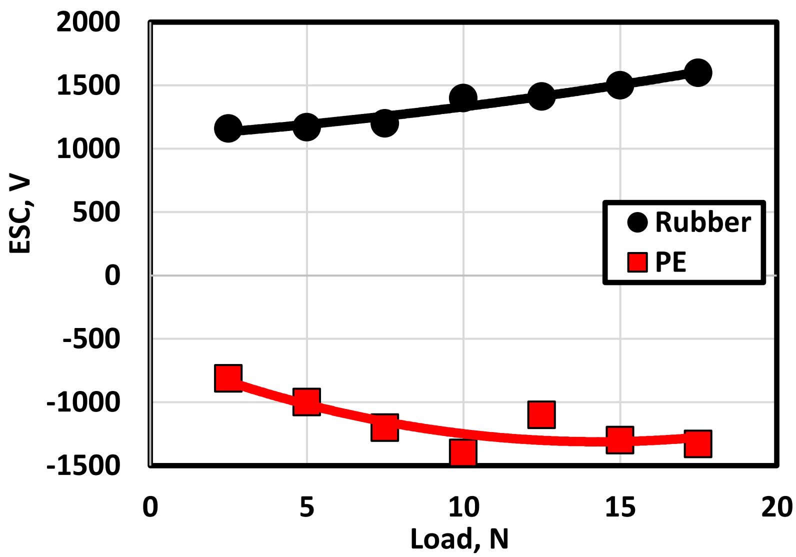

Fig. 2 ESC generated from contact and separation of dry rubber and turf of conventional (PE) substrate.

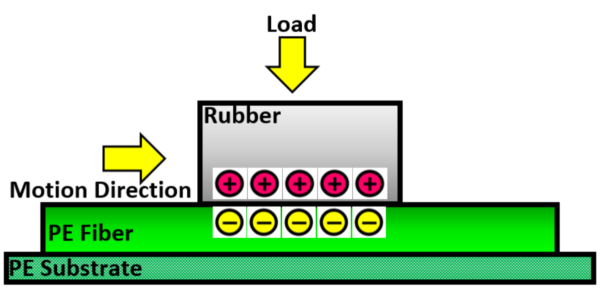

Fig. 3 Illustration of the test of turf of PE substrate.

Figure 4 shows ESC generated from sliding of dry rubber on turf of conventional (PE) substrate, where the value approached 6000 and -12000 volts for rubber and PE fibers respectively. It is well known that abrasion of skin is the major disadvantage of artificial

turf, where skin irritation depends on the degree of abrasion. The high value of ESC can influence player performance and increase severity of injury.

At water wet contact condition, ESC generated from contact and separation as well as sliding of rubber on turf of conventional (PE) substrate showed very low values, Figs. 5 and 6 respectively. The contact materials as insulators contain a distribution of charges that are conserved. Presence of water film decreased ESC due to its electrical conductivity that leaked the charge out of the contact surfaces. The results of the wet contact recommend using water to reduce the excessive ESC generated on PE and rubber surfaces.

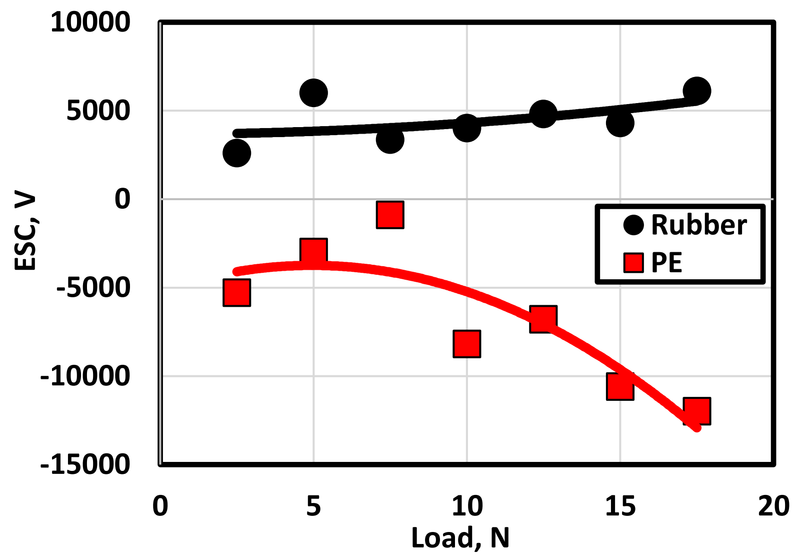

Fig. 4 ESC generated from sliding of dry rubber on turf of conventional (PE) substrate.

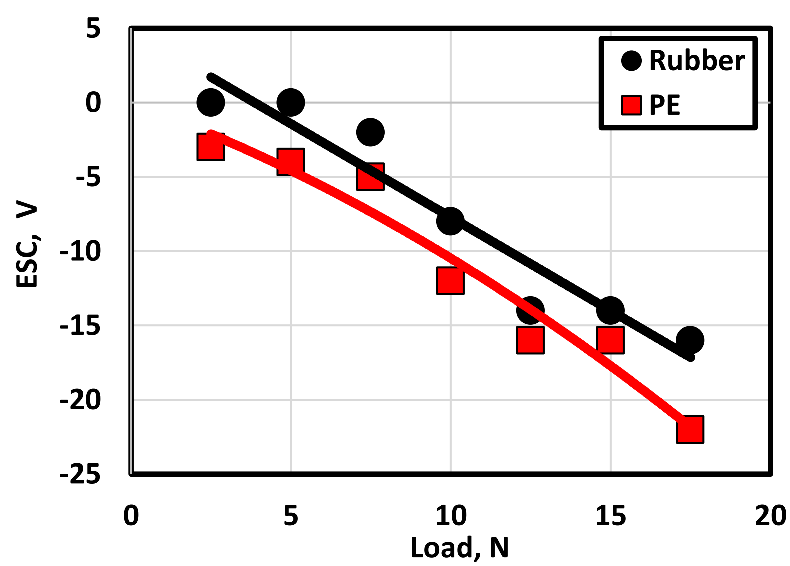

Fig. 5 ESC generated from contact and separation of water wet rubber and turf of conventional (PE) substrate.

Replacing PE substrate with PP one caused significant increase in ESC at dry contact and separation as well as sliding, Figs. 7, 9 respectively. The details of the contact arrangement is shown in Fig. 8. The highest ESC values was -4000 and 1800 volts for PE and rubber respectively for contact and separation, while sliding generated -19000 and 7500 volts for PE fibers and rubber respectively. To reduce ESC, steel sheet was tested as substrate to leak the charge generated on the PE fibers surface. Figures 10 and 12 show the dependency of ESC on the applied load for contact and separation as well as sliding respectively. It was observed that drastic ESC decrease was detected for both rubber and PE fibers. This observation can lead to proper solution of decreasing ESC. The position of PP substrate is shown in Fig. 11. Grounding the steel sheet caused insignificant influence in the value of the generated ESC, Figs. 13 – 15. It seems that the surface area of the steel substrate can influence the intensity of ESC rather than grounding.

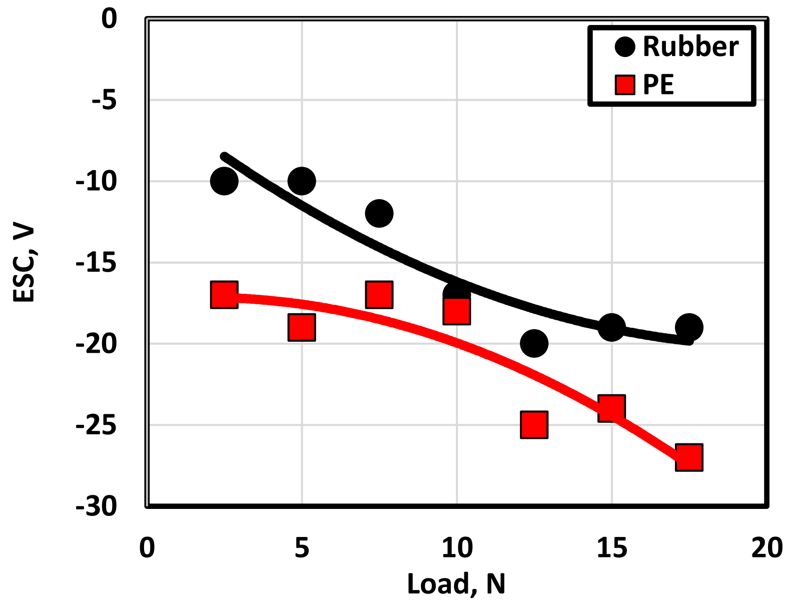

Fig. 6 ESC generated from sliding of water wet rubber on turf of conventional (PE) substrate.

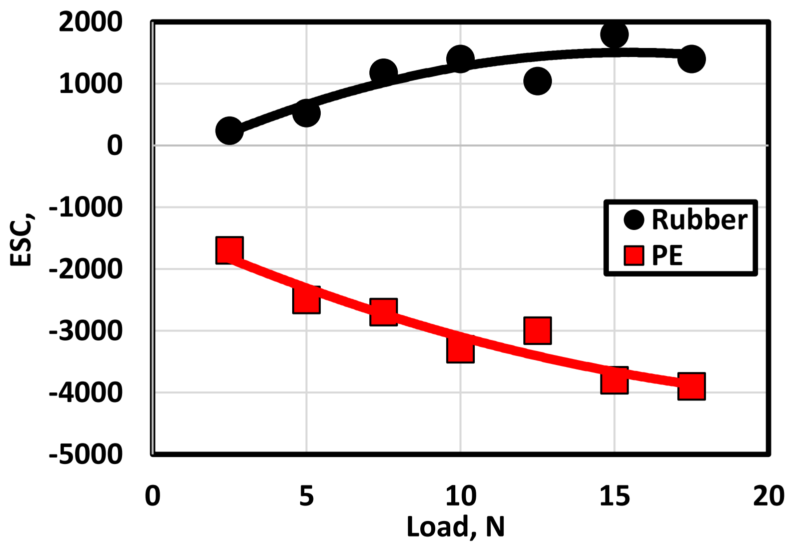

Fig. 7 ESC generated from contact and separation of dry rubber

and turf of PP substrate.

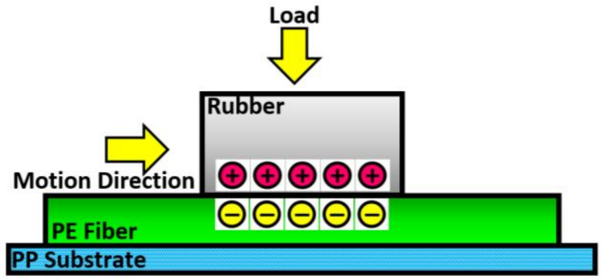

Fig. 8 Illustration of the test of turf of PP substrate.

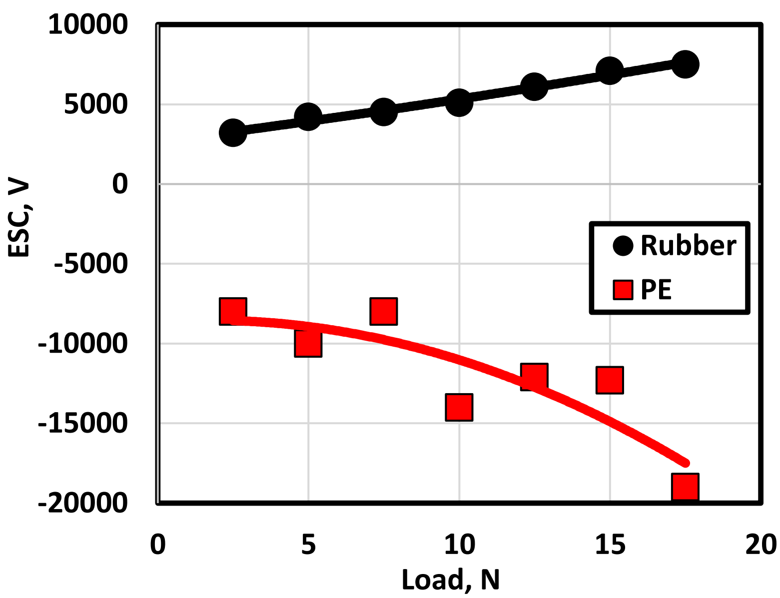

Fig. 9 ESC generated from sliding of dry rubber on turf of PP substrate.

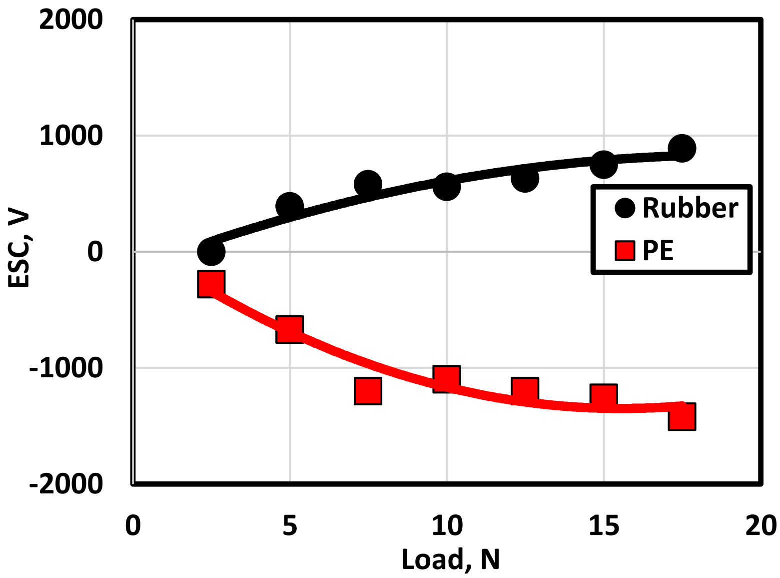

Fig. 10 ESC generated from contact and separation of dry rubber and turf of steel sheet substrate.

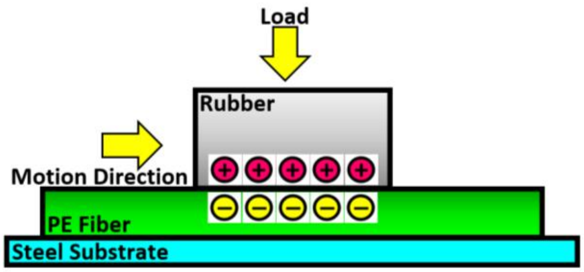

Fig. 11 Illustration of the test of turf of steel substrate.

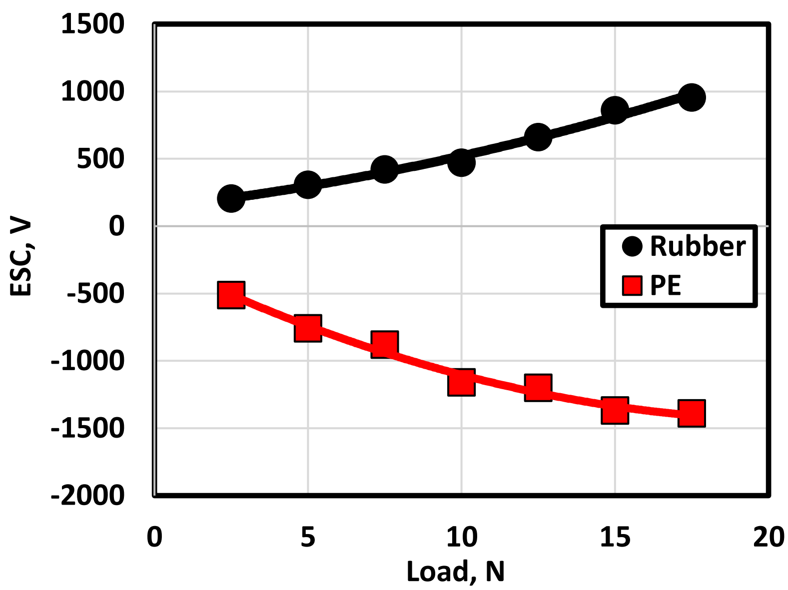

Fig. 12 ESC generated from sliding of dry rubber on turf of PP and steel sheet substrates.

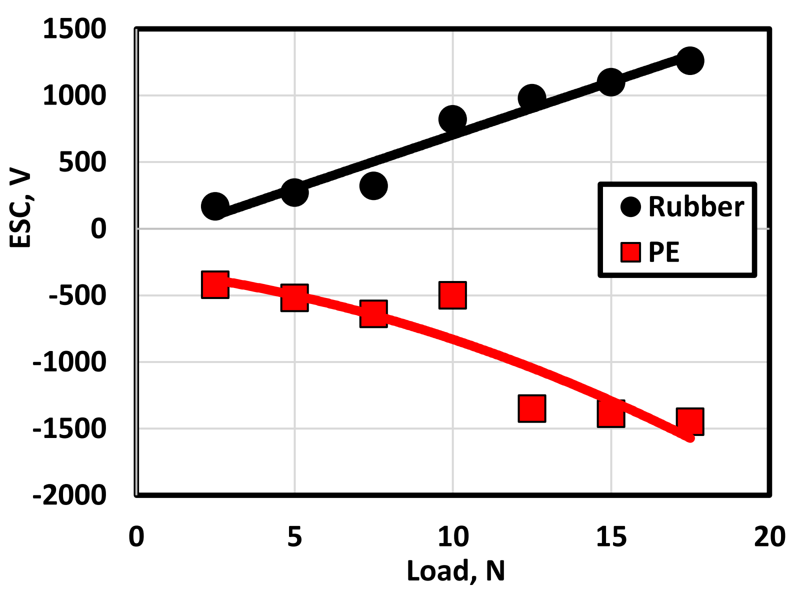

Fig. 13 ESC generated from contact and separation of dry rubber and turf of grounded steel sheet substrate.

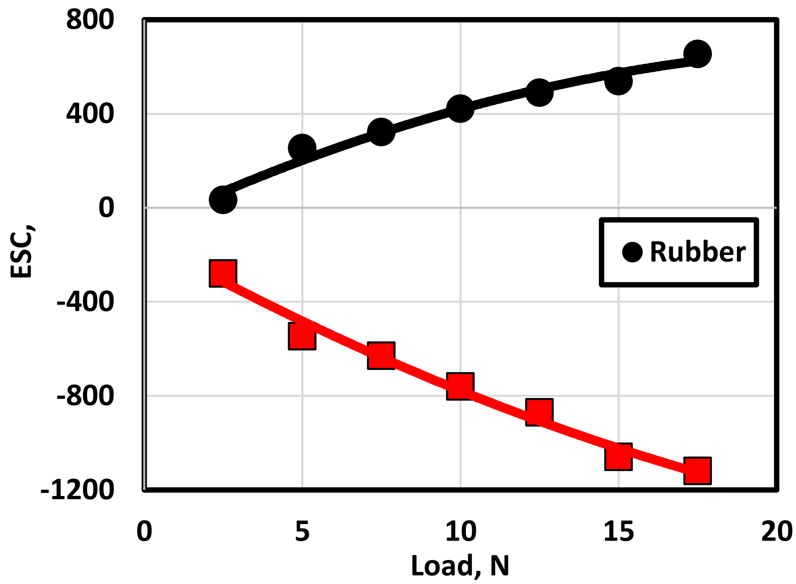

Fig. 14 ESC generated from sliding of dry rubber on turf of grounded steel sheet substrate.

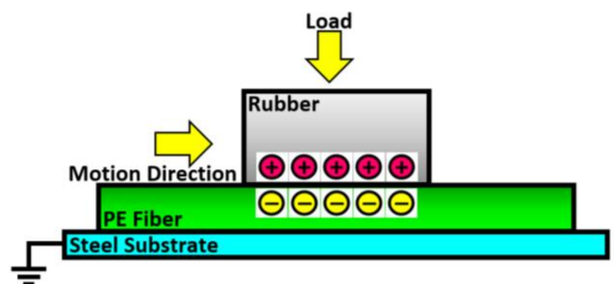

Fig. 15 Illustration of the test of turf of grounded steel substrate.

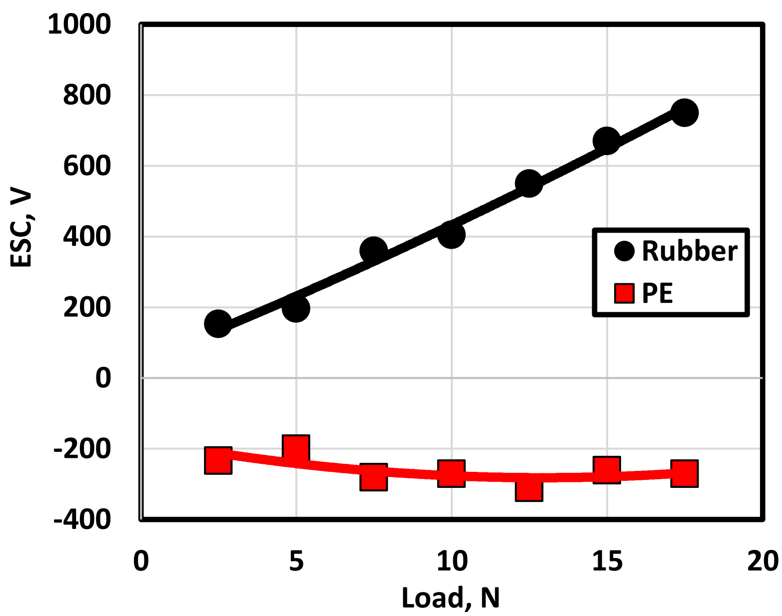

Fig. 16 ESC generated from contact and separation of dry rubber and turf of copper substrate.

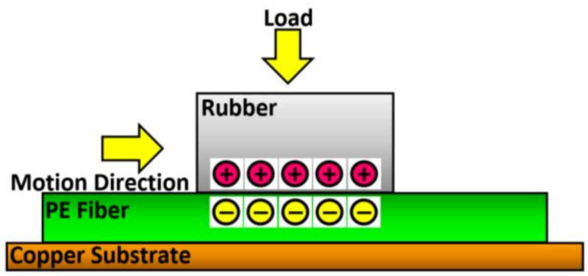

Fig. 17 Illustration of the test of turf of copper substrate.

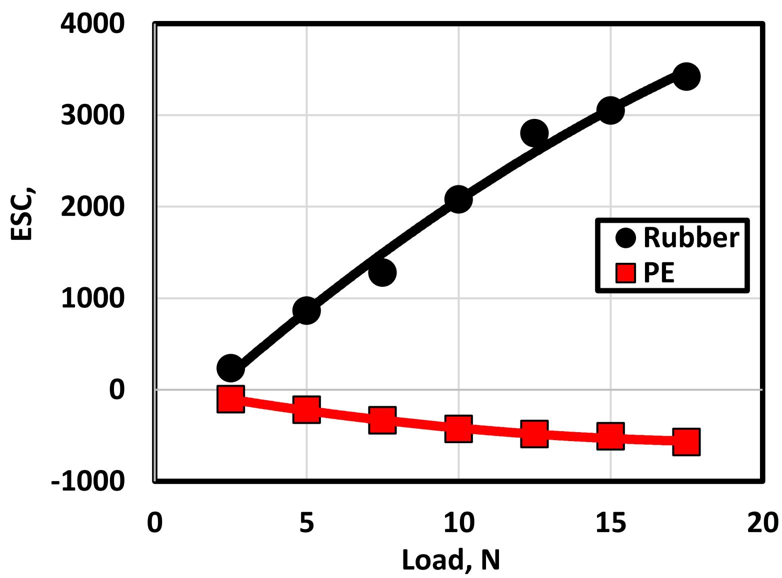

Fig. 18 ESC generated from sliding of dry rubber on turf of copper substrate.

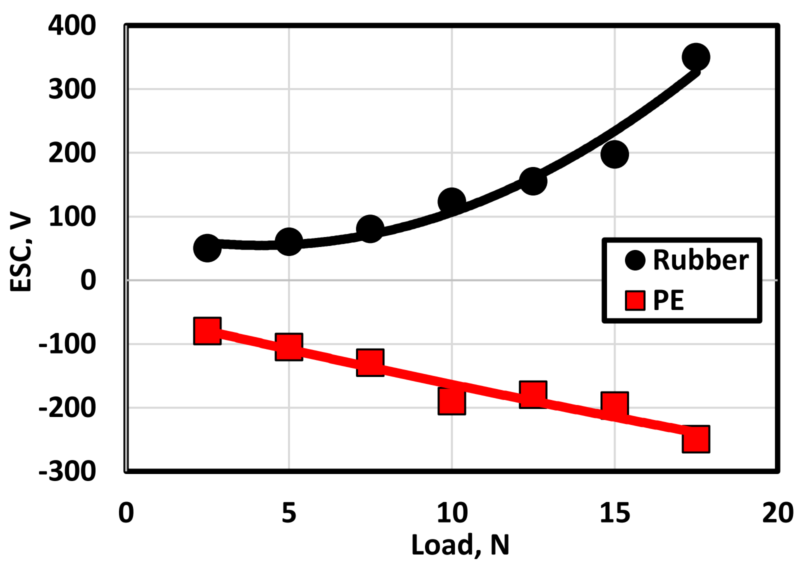

Fig. 19 ESC generated from contact and separation of dry rubber and turf of PP and copper substrates.

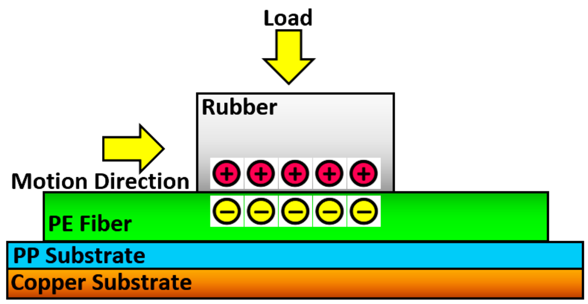

Fig. 20 Illustration of the test of turf of PP and copper substrates.

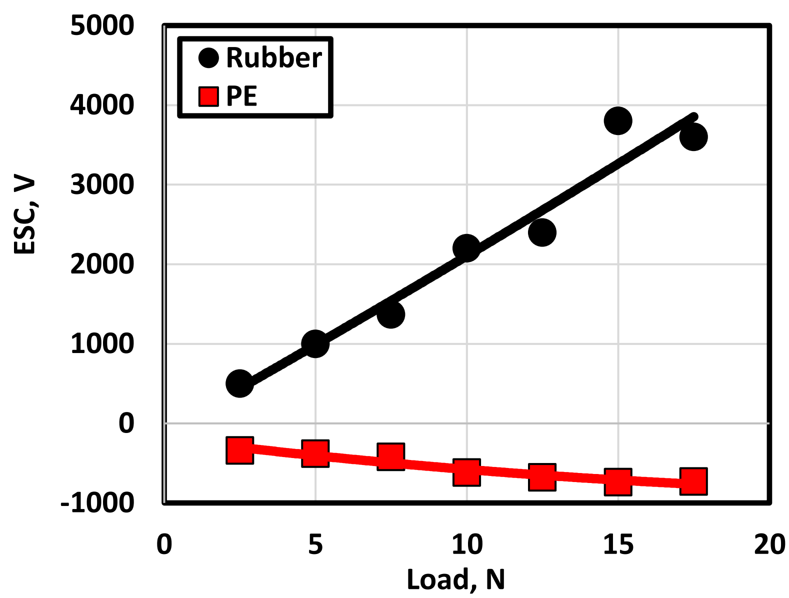

Fig. 21 ESC generated from sliding of dry rubber on turf of PP and copper substrate.

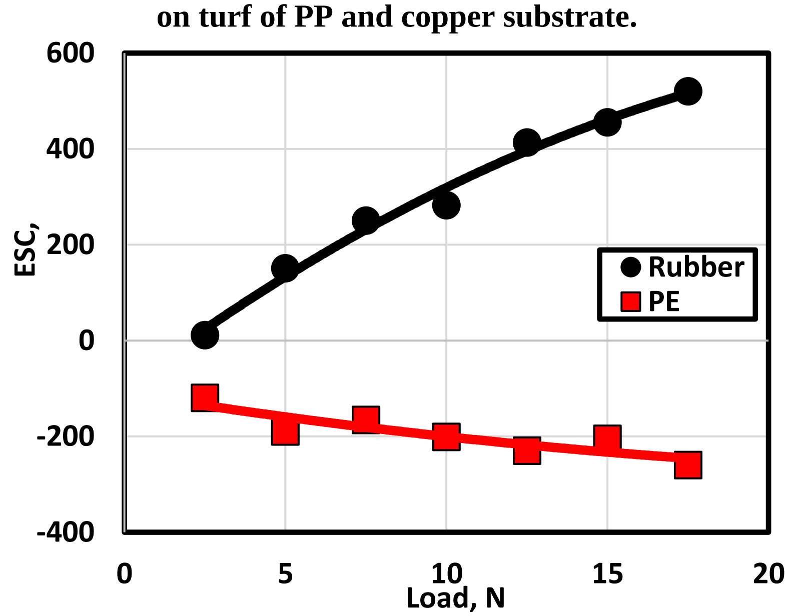

Fig. 22 ESC generated from contact and separation of dry rubber and turf of grounded copper substrate.

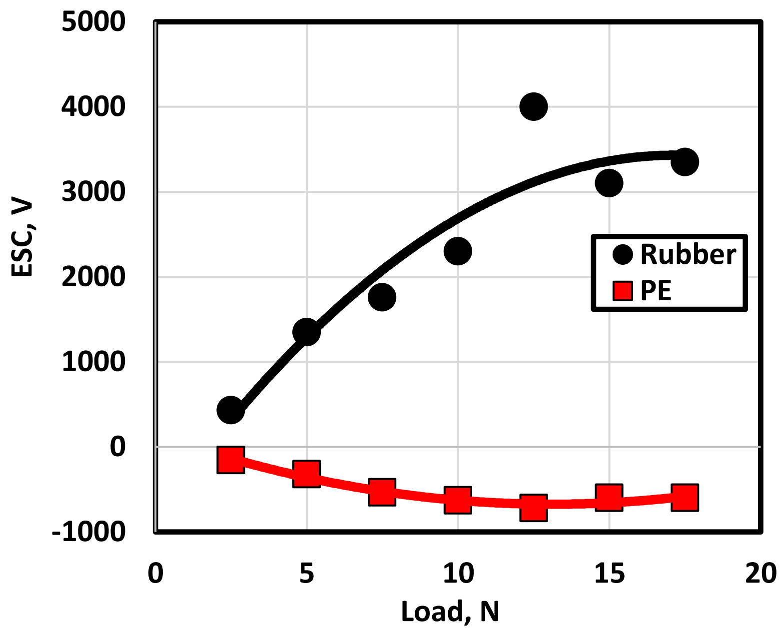

Fig. 23 ESC generated from sliding of dry rubber on turf of grounded copper substrate.

Copper substrate was used to leak ESC generated on PE fibers, Figs. 16 - 18. It was observed that rubber surface gained higher values of ESC than that tested by steel substrate after sliding, while PE fibers gained lower ESC due to the good electrical conductivity of copper.

Isolating PE fibers from copper by PP substrate, Figs. 19 – 21, or grounding copper substrate, Figs. 22 and 23, caused insignificant change in ESC. Besides, the ESC generated from sliding was much higher than that oberved after contact and separation. Based on the experimental findings, the material of the substrate strongly influenced the intensity of ESC. It is necessary to carry out more experiments to select substrate material that reduce ESC when being rubbed by PE fibers and rubber surfaces.

CONCLUSIONS

1. ESC generated from contact and separation of dry rubber and PE fibers of conventional PE substrate gradually increased with increasing load. ESC generated from sliding represented higher values that that observed from contact and separation. Rubber surface gained positive ESC, while PE fibers gained negative charge so that ESC of different signs would increase the attractive force between the two surfaces and consequently influenced adhesion that increases friction. The high value of ESC can influence player performance and increase severity of injury.
2. At water wet contact condition, ESC generated from contact and separation as well as sliding of rubber on turf of conventional (PE) substrate showed very low values. The results of the wet contact recommend using water to reduce the excessive ESC generated on PE and rubber surfaces.
3. Replacing PE with PP substrate caused remarkable ESC increase. Grounding the steel sheet caused insignificant influence in the value of the generated ESC.

4. Using copper substrate showed that rubber surface gained higher values of ESC than that measured for steel substrate after sliding, while PE fibers gained lower ESC. Isolating PE fibers from copper by PP substrate or grounding copper substrate generated insignificant change in ESC. Based on the experimental findings, the material of the substrate strongly influenced the intensity of ESC. It is necessary to carry out more experiments to select substrate material that reduce ESC when being rubbed by PE fibers and rubber surfaces.

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