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REDUCING ELECTROSTATIC CHARGE GENERATED FROM SLIDING OF RUBBER ON PROPOSED ARTIFICIAL TURF

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ABSTRACT
Artificial turf (AT) made of polyethylene (PE) fibers needs no water. It can replace natural turf. The major disadvantage of the AT is the electrostatic charge (ESC) generated from friction with other materials. ESC has bad healthy effects on human beings. The present study investigates the possibility to reduce ESC generated from friction of rubber soles by blending AT by polyamide (PA).

The experiments reveal that ESC generated on the surfaces of rubber and AT decreased with the increase of PA content. Water wet contact-separation of AT and rubber, displayed lower ESC values than that shown for dry contact. It seems that the presence of water as good conductor facilitated ESC transfer. When the applied load increased ESC decreased. That can be due to the area of contact of the PA strings and AT increased with the increase of the load, where positive and negative ESC neutralized each other. AT fibers blended by PA strings displayed lower ESC values at water wet sliding. ESC drastically decreased with increasing the applied load because the area of contact of the PA strings with AT increased. Finally, it can be proposed to blend AT by PA strings to decrease the generated ESC after contact-separation and sliding. PA content of 50 wt. % relative to the AT showed the favorite results.

KEYWORDS
Polyamide, polyethylene composites, artificial turf, electrostatic charge, contact-separation, sliding.

INTRODUCTION
Artificial turf made from PE fibers can replace natural grass, [1]. Its applications are in sport yards, kid schools, roof gardens and swimming pool surrounds. The major drawback of AT is the generation of ESC after contact-separation and sliding on rubber soles, [2 – 4]. Because PE turf has a high tendency to gain ESC when rubbed human skin. It was found that smooth surface of PE turf generated the highest ESC

values when rubber shoes slid on it. Besides, PE turf abrades human skin causing abrasions and burns in sports. The shortage of water and rainfall demands the application of PE turf.

Several researches discussed the effect of AT on the safety and performance of players. It was observed that the infill materials of turf influence the behavior of players, [5], due the friction control of AT with the skin, [6, 7]. While abrasion of skin by turf, [8 - 10], was analyzed by inspecting the surface properties of AT to investigate their influence on the skin abrasion, [11 - 17]. Silicone and foam simulated human skin to study abrasion of the AT in football yard, [18 - 20].

The material of the substrate of PE fibers significantly influences ESC, [21]. Blending AT by Cu textile drastically reduced ESC, [22]. In addition to that, Al film coating the soles showed lower ESC values. It was recommended to use conducting material to coat outer soles surface to leak ESC to Cu textile.

In addition to that, blending AT by fibers of opposite ESC was inspected, [23], where the blend generated lower ESC compared to unblended AT. It was found that coating 80 vol. % of AT by polyurethane (PU) drastically reduced ESC. Yarns and textile of PA that gain positive ESC blended AT, [24], to reduce ESC. Cu textile, aluminum (Al) film and carbon fibers (CF) slid on AT blended by PU fibers and PA yarns were tested, [25]. ESC generated from contact-separation and sliding of shoes on AT was reduced by filling PE composites soles by Al, Cu and iron (Fe), [26]. Recently, the reduction of ESC generated from friction of the AT with rubber has been discussed, [27]. It was found that the addition of PA into AT drastically reduced ESC at contact-separation and sliding of rubber on AT.

The present paper discusses the effect of filling PE composites by PA strings on the reduction of ESC generated during contact-separation and sliding on rubber soles at both dry and water wet conditions.

EXPERIMENTAL

The AT test specimen of 300 × 300 mm^2 was adhered into wooden base, while the counterface made of rubber of 60 Shore A hardness and 8 mm thickness was adhered to one surface of wooden cube of 50 × 50 × 50 mm^3. The load was applied by weights of 1, 2, 3, 4, 5 and 6 N at dry and water wet sliding conditions. PA strings of 2 mm diameter and 50 mm length blended AT by 10, 20, 30, 40 and 50 wt. % content. An Alpha Lab Inc. Surface DC Voltmeter SVM2 was used to measure ESC generated on AT and rubber surface, where readings were detected by the sensor 25 mm apart from tested surface. The details of AT specimens and test procedure are shown in Figs. 1 - 3. Sliding of rubber on AT was carried out by moving the rubber 250 mm by 0.05 m/s sliding speed.

Fig. 1 AT test specimen.

Fig. 2 AT test specimen blended by 50 wt. % PA fibers.

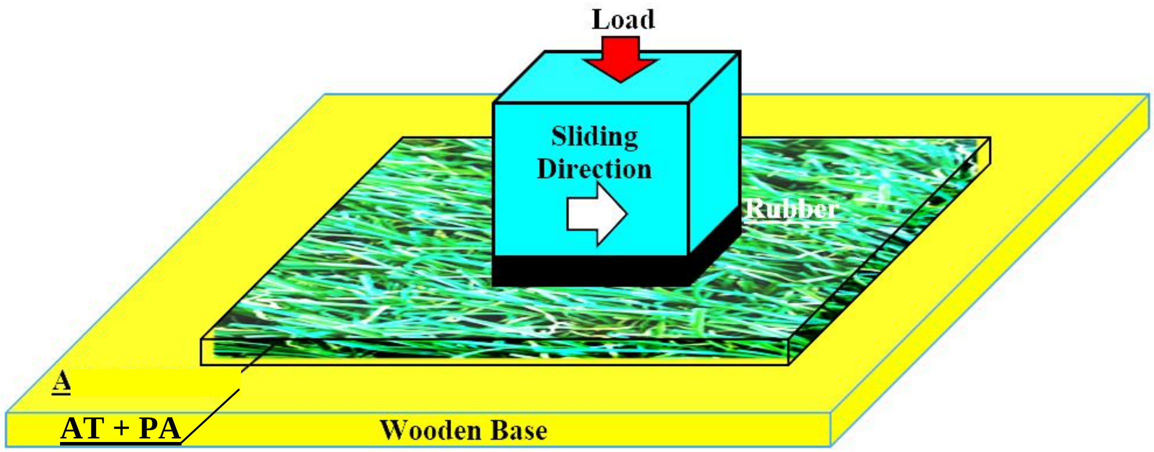


Fig. 3 The arrangement of the test procedure.

RESULTS AND DISCUSSION

Contact-separation of rubber and AT generated ESC as function with increasing PA content in AT, Fig. 4. As PA content increased, ESC generated on the surfaces of rubber and AT decreased. The lowest ESC recorded for AT was -13 volts at 50 wt. % of PA, while AT free of PA was -230 volts. The same trend was observed for rubber with relatively lower values. For contact-separation of AT and rubber at water wet condition, Fig. 5, ESC drastically decreased. This behavior can be attributed to the presence of water that worked as good conductor that facilitated ESC transfer.

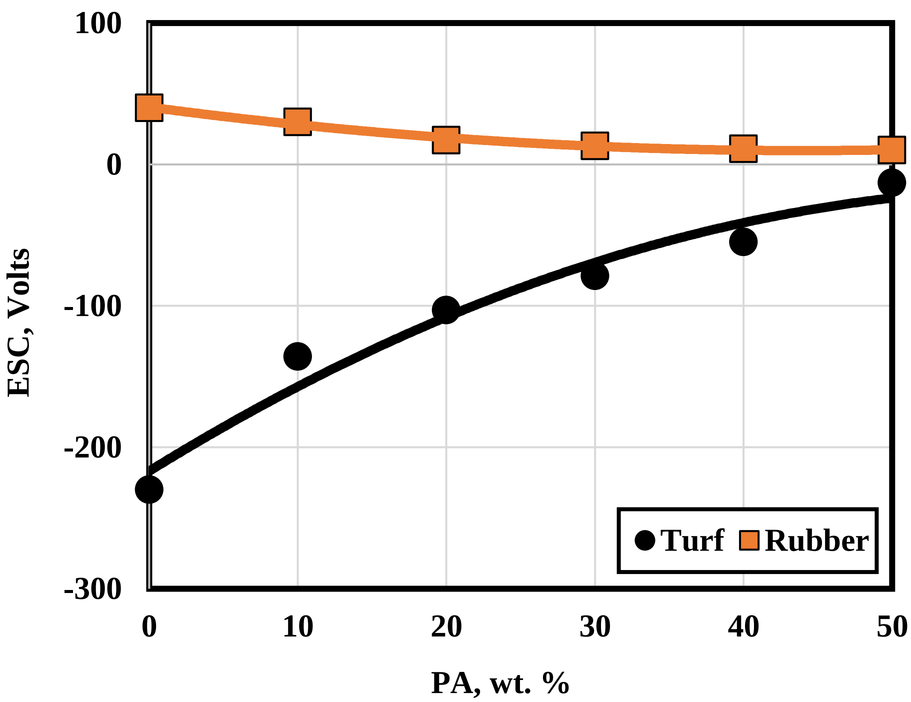


Fig. 4 ESC generated from dry contact-separation of AT and rubber.

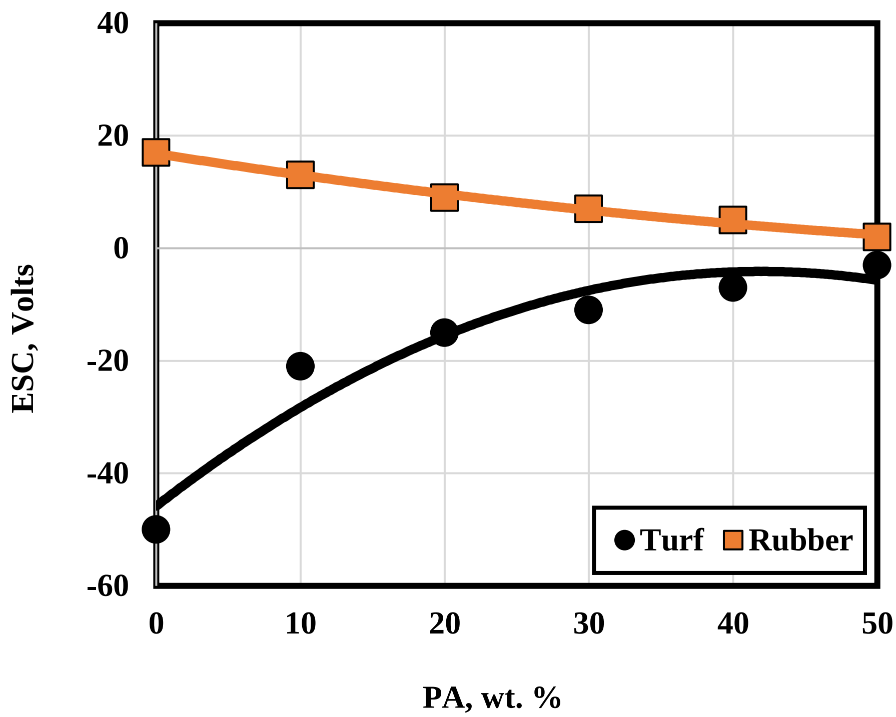
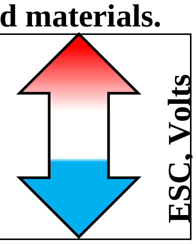


Fig. 5 ESC generated from water wet contact-separation of AT and rubber.

Figure 6 shows the influence of the applied load on the generation of ESC after dry contact-separation of AT and rubber. ESC decreased with the increase of the load, where AT gained -50 and -13 volts at 1.0 N and 6.0 N load respectively. While rubber gained The 46 and 10 volts at 1.0 N and 6.0 N load respectively. It seems that the contact of the fibers of PA and AT increased with the increase of the load. Generation of ESC on the surfaces of rubber, PA and AT is illustrated in Fig. 7. It is known that the material of AT is PE that gains negative ESC after contact with rubber, while PA gains positive ESC. The positive and negative ESC transfer with each other, where that transfer increased with the increase of the load. This explanation is confirmed by the rank of the materials in the triboelectric series, Table 1. It is known that the materials are classified in the triboelectric series according to their polarity, where materials that gain positive ESC are set in the upper part of the series, while materials of negative ESC are classified in the lower one. In addition to that, the materials are ranked according to their ESC intensity. Drastic ESC reduction was observed for water wet contact-separation of AT and rubber due the effect of the humidity on the generation of ESC, Fig. 8.

Table 1 Triboelectric series of the tested materials.

Positive charge
Polyamide (PA)
Rubber
Polyethylene (PE)
Negative charge



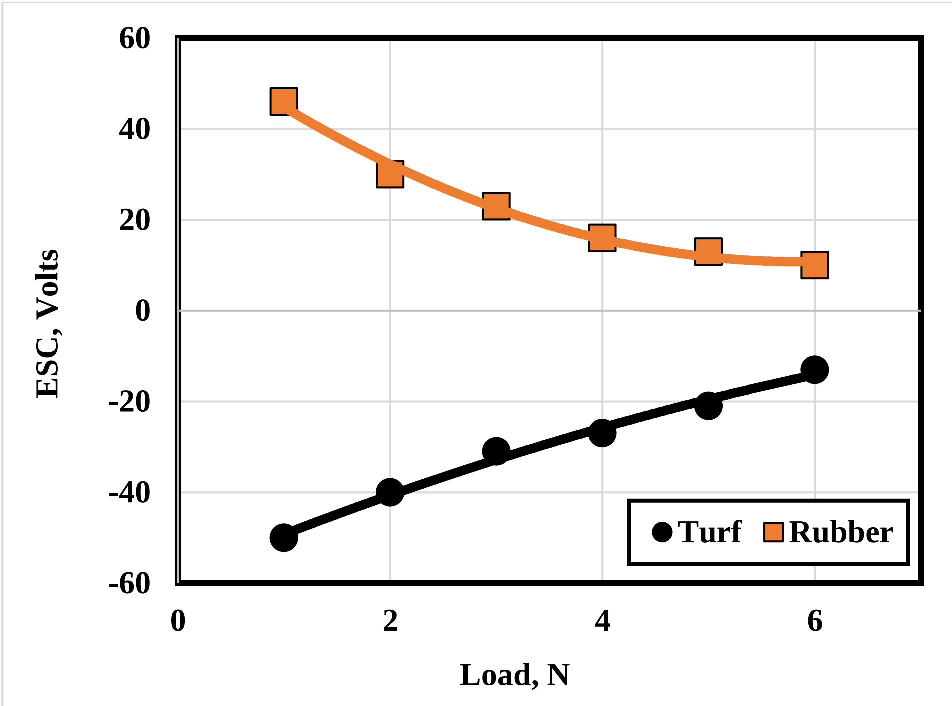


Fig. 6 Effect of applied load on ESC generated from dry contact-separation of AT and rubber.

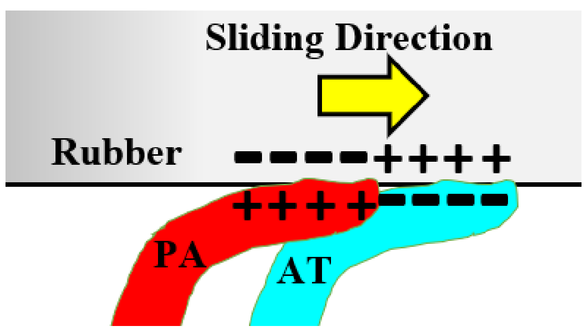


Fig. 7 Generation of ESC on the surfaces of rubber, PA and AT.

Experiments carried out to measure ESC after dry sliding of rubber on AT is shown in Figs. 9 – 12, where ESC represented much higher values than that observed in contact-separation. Besides, increasing the content of PA up to 50 wt. % decreased ESC generated on the surfaces of AT and rubber. The values for AT decreased from -150 to -21 volts at 0 and 50 wt. % PA content respectively, while Rubber showed ESC decrease from 60 to 11 volts.

The effect of humidity on the value of ESC after sliding is shown in Fig. 10, where AT fibers blended by PA strings showed very low ESC values. The positive ESC gained by PA could be increased to neutralize the negative one generated on AT.

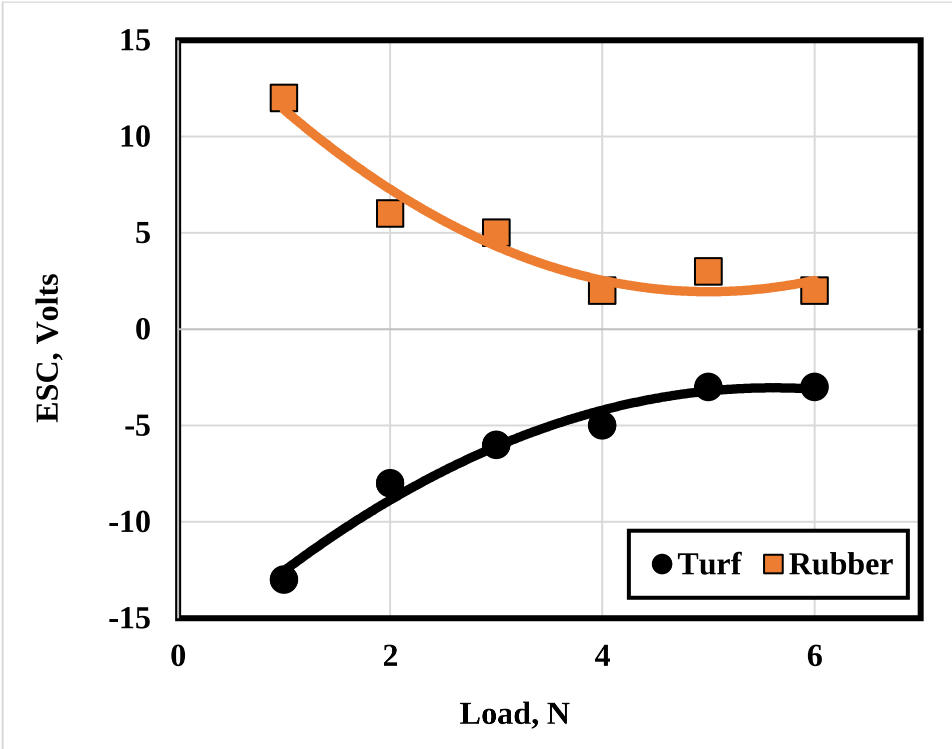


Fig. 8 Effect of applied load on ESC generated from water wet contact-separation of AT and rubber.

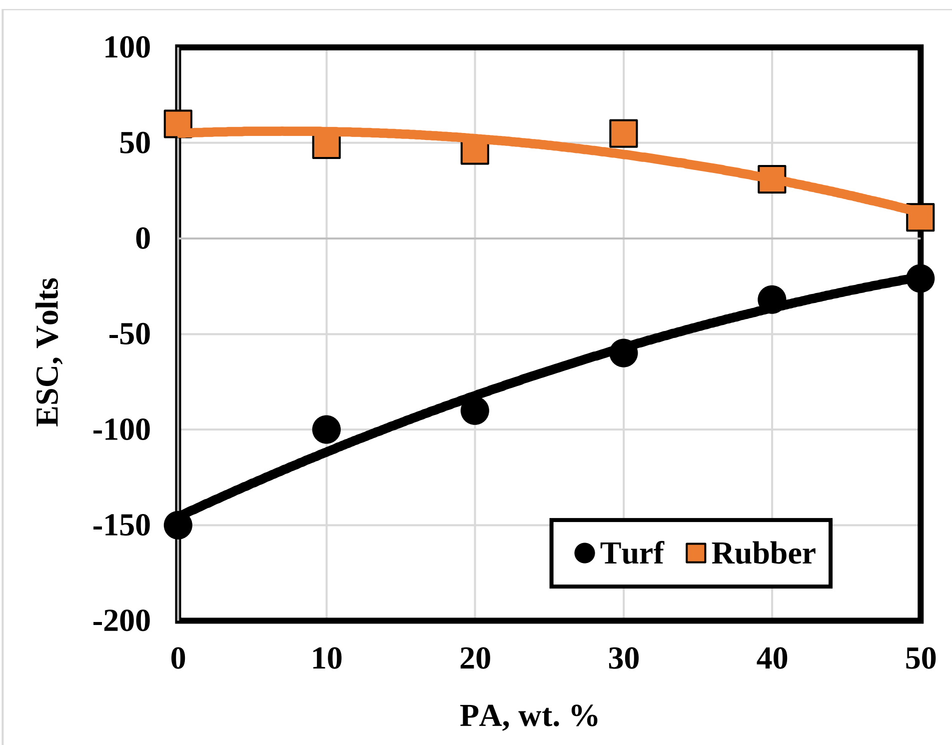


Fig. 9 ESC generated from dry sliding of rubber on AT.

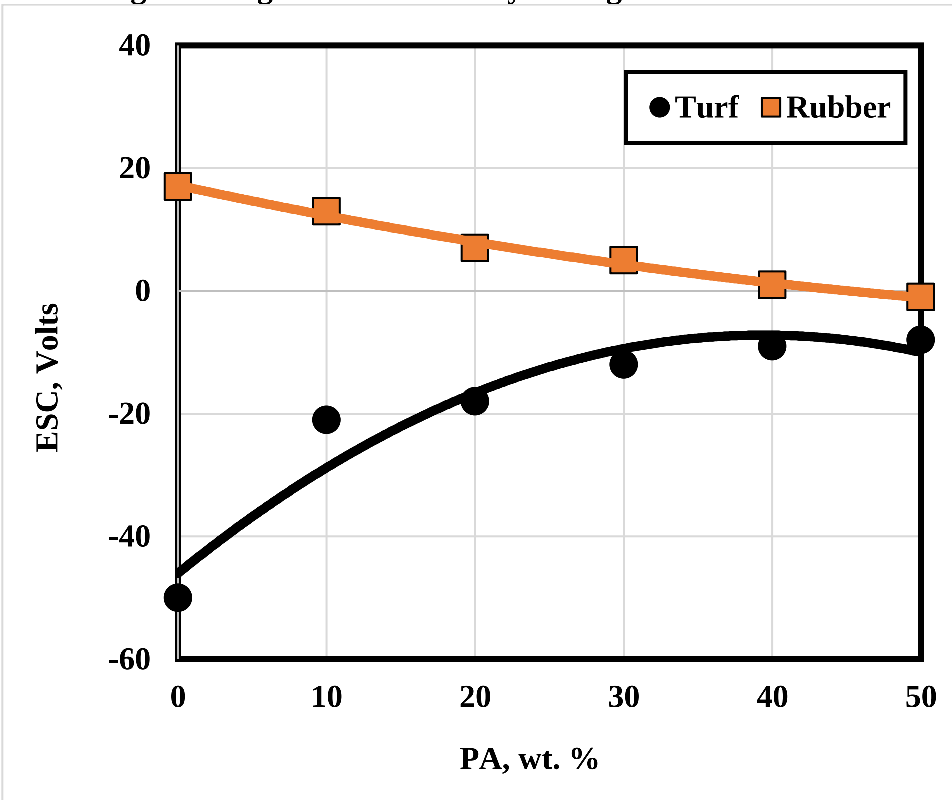


Fig. 10 ESC generated from water wet sliding of rubber on AT.

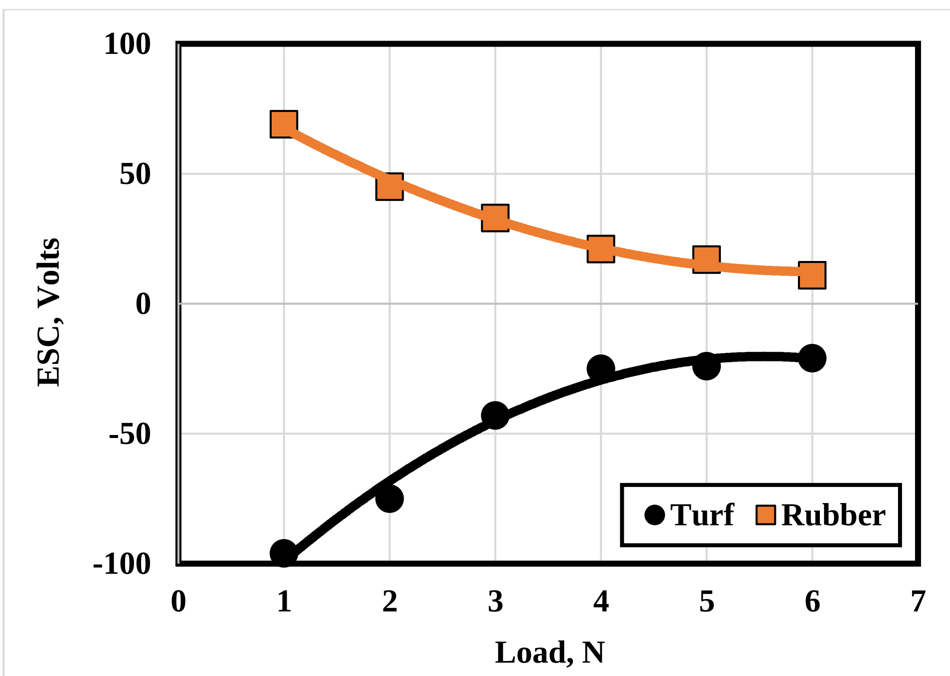


Fig. 11 Effect of applied load on ESC generated from dry sliding of rubber on AT.

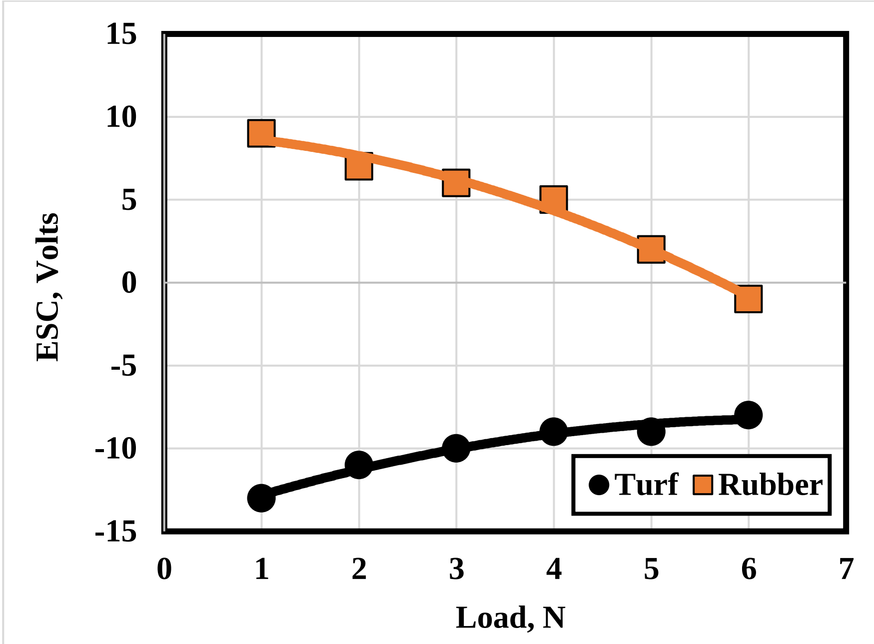


Fig. 12 Effect of applied load on ESC generated from water wet sliding of rubber on AT.

ESC generated on rubber and AT after sliding decreased with the increase of the load, Fig. 11. It seems that the interaction of PA strings of positive ESC with AT fibers of negative ESC and the charge transfer between them were responsible for the ESC decrease. The contact of the fibers with AT was enhanced by the load increase. In the condition of water wet sliding, the effect of load on ESC is displayed in Fig. 12, where the values showed lower ESC values. Based on the experimental results, it can be confirmed that PA strings blending AT can be promising solution to reduce ESC generated after both contact-separation and sliding. Added to that, the best PA content was 50 wt. % relative to the AT.

CONCLUSIONS

1. The increase of PA content decreased ESC generated on the surfaces of rubber and AT.
2. For water wet contact-separation of AT and rubber, ESC represented lower values than displayed by dry contact.
3. As the applied load increased, ESC decreased.
4. In sliding, ESC represented relatively higher values than that observed in contact-separation.
5. AT fibers blended by PA strings showed relatively lower ESC values at water wet sliding.
6. ESC drastically decreased with increasing the applied load because the area of contact of the PA strings with AT increased. That behavior facilitated the ESC transfer to the contacting surfaces.

7. It can be recommended to blend AT by PA strings to reduce the generated ESC after contact-separation and sliding. It was observed that, the 50 wt. % PA content displayed the best results.

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