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

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ABSTRACT
The application of artificial turf (AT) made of polyethylene (PE) fibers is extensively applied in different fields. Because it needs no water and is relatively cheap and carefree, it replaces natural turf. The major drawback of the AT is the high magnitude of generated electrostatic charge (ESC) that has negative effects on the safety of the people. The present work aims to reduce ESC generated from contact-separation and sliding of rubber soles by the addition of polymethyl methacrylate (PMMA) into AT.

The present experimental work reveals that ESC decreased as PMMA content increased up to 50 wt. % of AT. When AT was rinsed by water, ESC drastically decreased at contact-separation and sliding of rubber on AT because water was responsible to transfer the negative and positive ESC to the surfaces of rubber and AT. Besides, ESC decreased with the increase of the load. AT gains negative ESC, while PMMA gains positive one after contact-separation and sliding on rubber. The transfer of the ESC with each other increased with increasing the load. Finally, It can be recommended to blend AT by PMMA strings up to 50 wt. % of the AT.

KEYWORDS
Polyethylene composites, artificial turf, polymethyl methacrylate, electrostatic charge, contact-separation, sliding.

INTRODUCTION
AT manufactured from PE fibers replaces natural grass, [1]. It is applied in kid schools, roof gardens, sport yards and swimming pool surrounds. One of the drawbacks of AT is the generation of ESC due to contact-separation and sliding of rubber soles, [2 – 4]. PE turf has a high tendency to acquire ESC when rubbed human skin, where the surface protrusions of the AT influenced ESC generation. Smooth surface of PE turf generated the highest ESC values when rubber shoes slid on it. In addition, contact of PE turf and human skin causes abrasions and burns in sports. The limited rainfall increases the demand to apply PE turf.

Tests were carried out on the fibers of PE turf to guarantee the safety of sport players against the abrasion of the turf. Several researches were carried out to investigate the effect of AT on the safety and performance of players. It was founded that the types of infill materials of turf influence the behavior of players, [5], by controlling the friction of AT with the skin, [6, 7]. Abrasion of skin by turf, [8 - 10], was studied through inspecting the surface properties of AT to know their influence on the skin abrasion, [11 - 13]. It was noticed that the dimension of AT and infill materials control their mechanical behavior, [14 – 17]. Human skin was simulated by using silicone and foam to study abrasion of the AT during sliding in football yard, [18 - 20].

It was observed that, the material of the substrate of PE fibers remarkably affects ESC, [21]. AT blended by Cu textile drastically decreased ESC, [22]. Besides, Al film coating the soles displayed lower ESC values. It was recommended to coat soles surface by conducting material to transmit ESC to Cu textile.

Blending AT by fibers of opposite ESC was discussed, [23], the blend generated lower ESC compared to AT. Polypropylene (PP) fibers and polyurethane (PU) composites reduced ESC. In addition, coating 80 vol. % of AT by PU drastically decreased ESC. AT was blended by yarns and textile of polymethyl methacrylate (PMMA) and polyamide (PA) that gain positive ESC, [24]. Fibers of PA textiles reduced ESC. Besides, sliding of Cu textile, aluminum (Al) film and carbon fibers (CF) as conducting materials on AT blended by PMMA yarns and polyurethane (PU) fibers was tested, [25]. ESC generated from contact-separation and sliding of shoes on AT was reduced by introducing PE composites soles filled by metallic particles such as aluminum (Al), copper (Cu) and Iron (Fe), [26].

The present paper proposes PE composites filled by PMMA strings to be used as AT to reduce ESC generated during their contact-separation and sliding on rubber soles at dry and water wet contact conditions.

EXPERIMENTAL

The proposed AT was tested at contact-separation and sliding at dry and water wet conditions. The test specimen of 200 × 200 mm^2 was adhered into wooden base. The counter face was rubber of 60 Shore A hardness of 5 mm thickness adhered to one surface of wooden cube of 40 × 40 × 40 mm^3. The rubber surface was loaded to the AT surface by weights of 1, 2, 3, 4, 5 and 6 N and moved horizontally at dry and water wet sliding conditions. PMMA strings of 2 mm diameter and 50 mm length were added to the AT by 10, 20, 30, 40 and 50 wt. % content. ESC generated on the surface of the tested AT and rubber surface was measured using an Alpha Lab Inc. Surface DC Voltmeter SVM2. Readings were done with the sensor 25 mm apart from the surface being tested. The details of the tested AT specimens and the test procedure are shown in Figs. 1 - 3. Sliding of rubber on AT was carried out by moving the rubber 150 mm by 0.02 m/s sliding speed.

Fig. 1 AT test specimen.

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

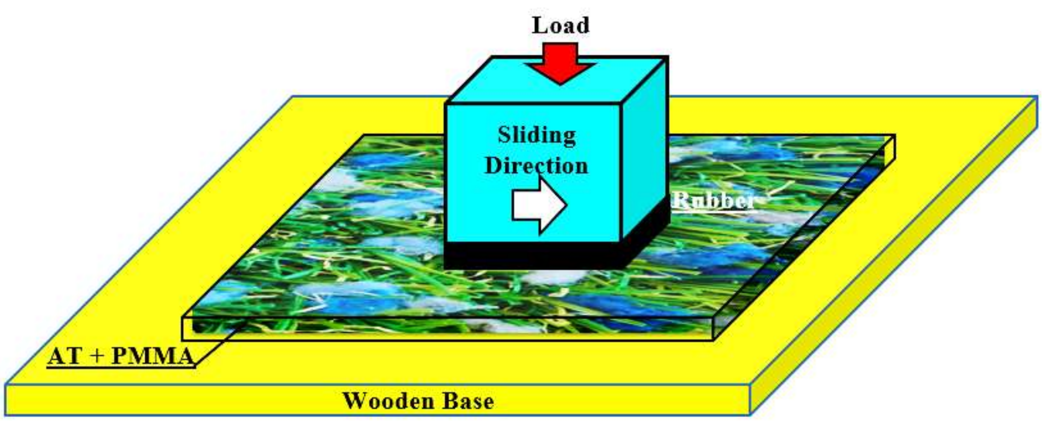


Fig. 3 The arrangement of the test procedure.

RESULTS AND DISCUSSION

The effect of PMMA content on ESC generated after contact-separation of rubber and AT are shown in Fig. 4. It is clearly shown that as the PMMA content increased, ESC generated on both the surfaces of rubber and AT decreased. The lowest ESC recorded for AT was -80 volts at 50 wt. % of PMMA, while AT free of PMMA was -900 volts. The same reduction was observed for rubber. The intensity of ESC generated on AT was higher than that measured on the rubber surface. At water wet contact-separation of AT and rubber, Fig. 5, a drastic decrease in ESC was observed when AT was rinsed by water. It seems that presence of water as good conductor was the reason for that behavior.

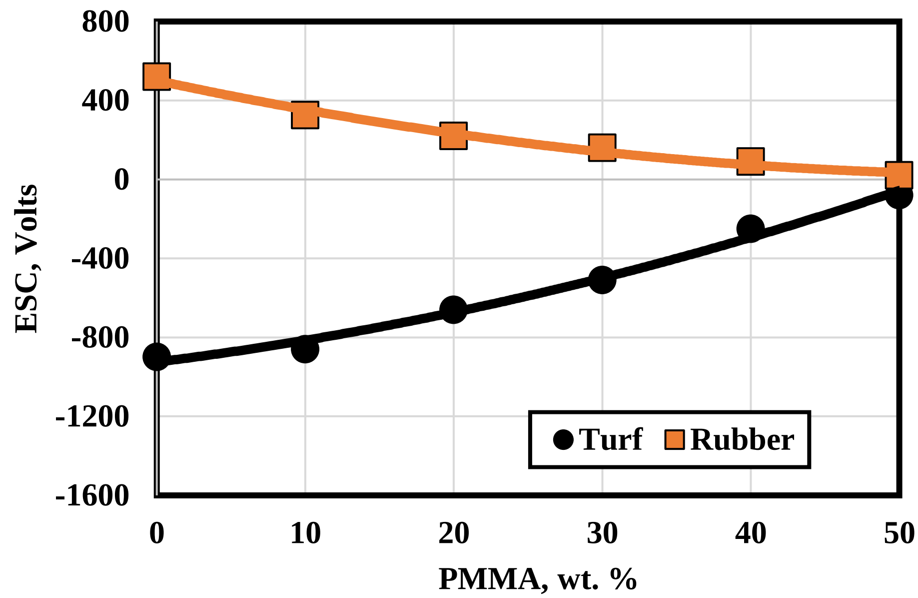


Fig. 4 ESC generated from dry contact-separation of AT and rubber.

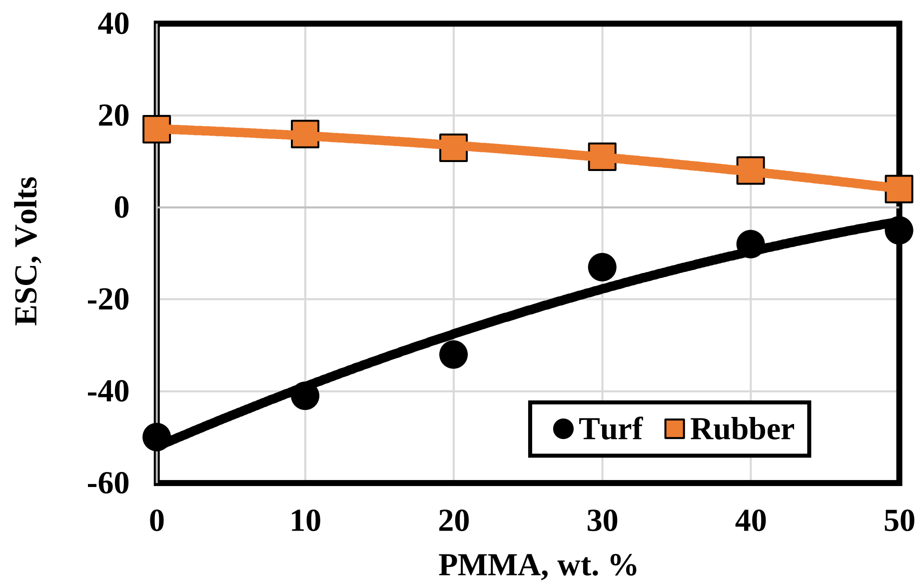
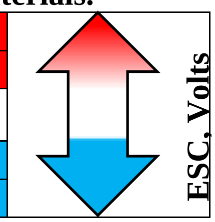


Fig. 5 ESC generated from water wet contact-separation of AT and rubber.

The influence of the applied load on ESC generated from dry contact-separation of AT and rubber is shown in Fig. 6. ESC decreased drastically with increasing the load, where AT gained -190 and -80 volts at 1.0 N and 6.0 N load respectively. The same trend was shown for rubber. This behavior can be explained on the bases that the contact of the fibers of PMMA strings increased with the increase of the load. Because the materials of AT is PE, it gains negative ESC, while PMMA gains positive ESC after contact-separation with rubber. The transfer of the positive and negative ESC with each other increased with increasing the load. This explanation depends on the rank of the materials in the triboelectric series, Table 1. The materials are arranged in the triboelectric series according to their relative polarity, where the materials that gain positive ESC are in the upper section of the series, while that gain negative ESC are in the lower one. Besides, the materials are ranked based on the intensity of the generated ESC. By means of triboelectric series it can be indicated that as the gap between two materials rub each other increased, ESC increased. The influence of applied load on ESC generated from water wet contact-separation of AT and rubber showed drastic reduction in ESC due the effect of the humidity on the generation of ESC, Fig. 7.

1 Triboelectric series of the tested materials.

Positive charge
Polymethyl methacrylate (PMMA)
Rubber
Polyethylene (PE)
Negative charge



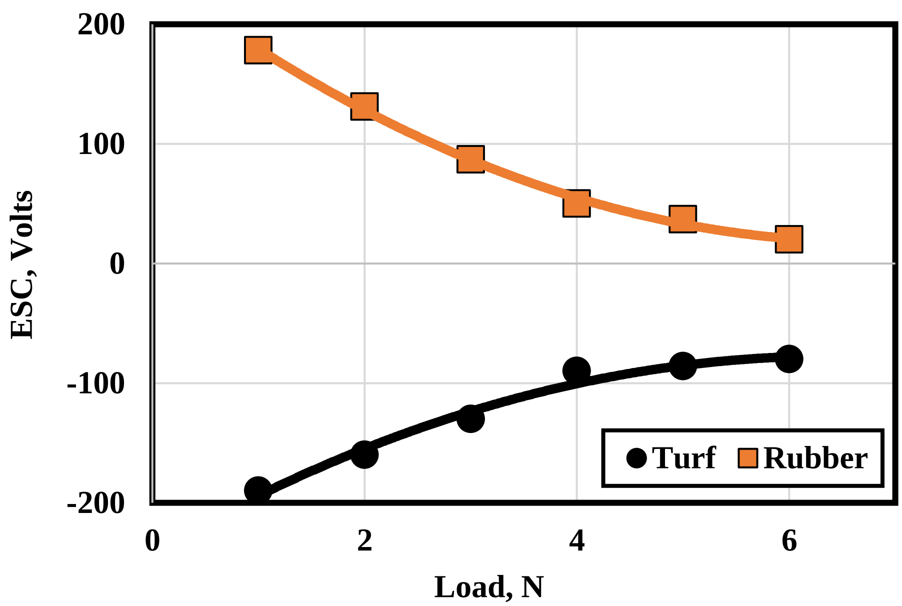


Fig. 6 Effect of applied load on ESC generated from dry contact-separation of AT and rubber.

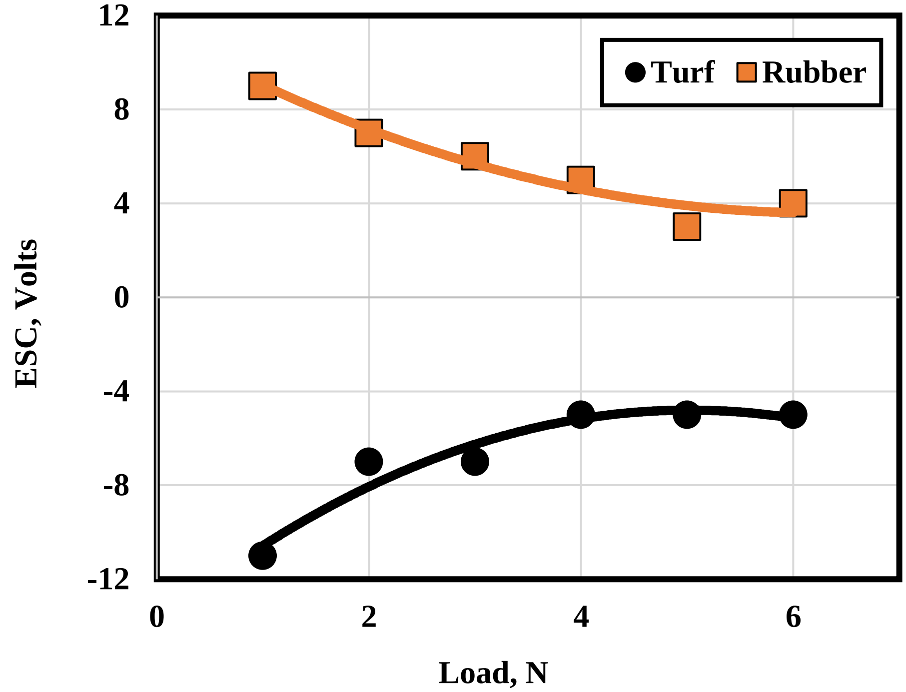


Fig. 7 Effect of applied load on ESC generated from water wet contact-separation of AT and rubber.

ESC generated from dry sliding of rubber on AT is shown in Fig. 8. The values of ESC were much higher than that observed in contact-separation. Increasing the content of PMMA up to 50 wt. % in the AT specimens decreased ESC generated on the surfaces of AT and rubber, where the values for AT decreased from -330 to -20 volts at 0 and 50 wt. % of PMMA content respectively. Rubber recorded decrease in ESC from 277 to 18 volts. The effect of humidity on the value of ESC is illustrated in Fig. 9. AT fibers blended by PMMA strings showed the behavior with very low values. The positive ESC gained by PMMA could be increased to overcome neutralized the negative one generated on AT.

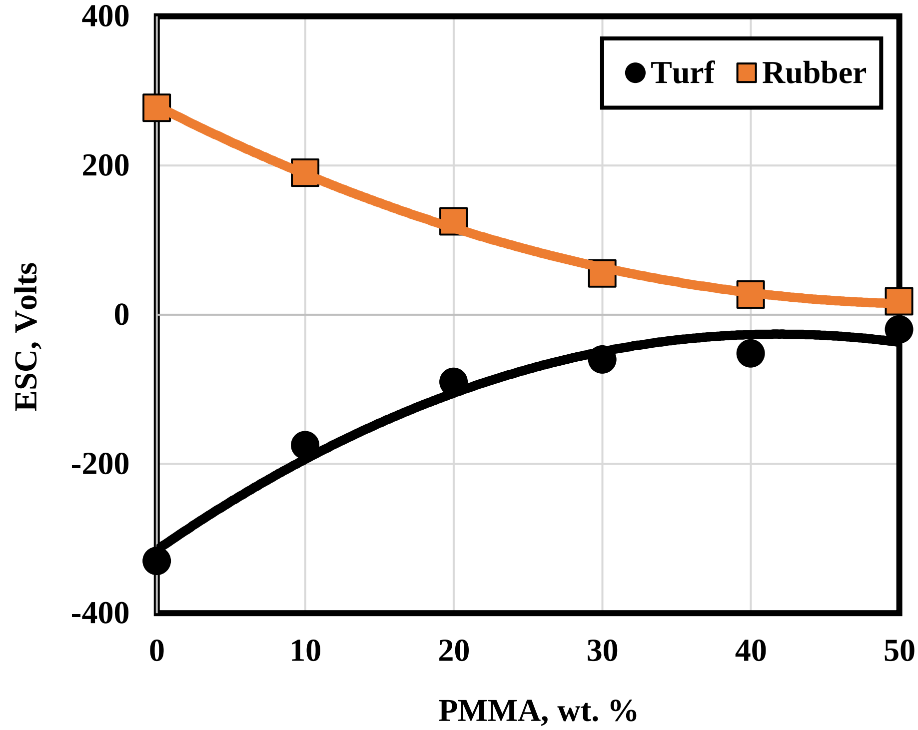


Fig. 8 ESC generated from dry sliding of rubber on AT.

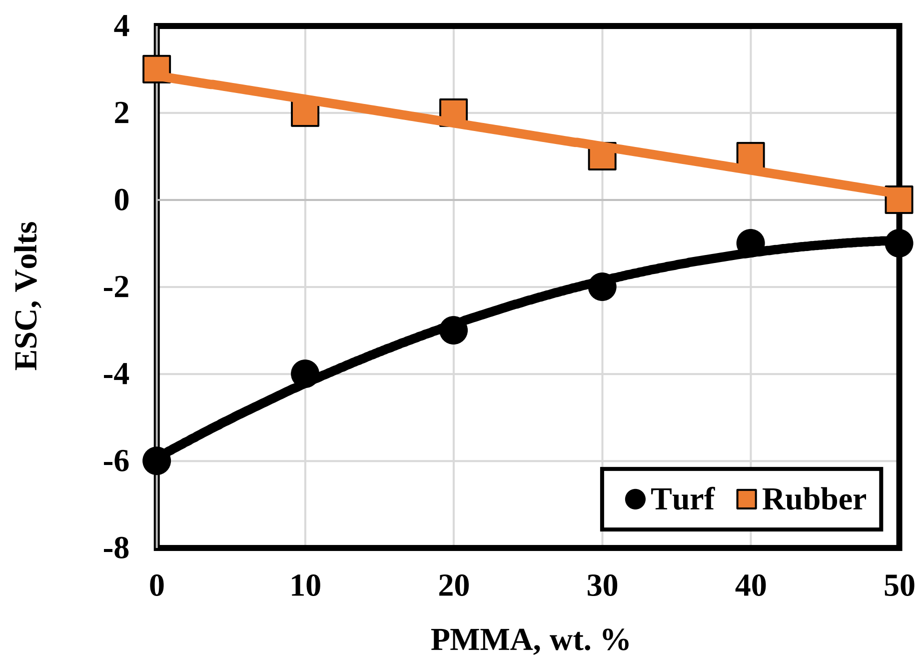


Fig. 9 ESC generated from water wet sliding of rubber on AT.

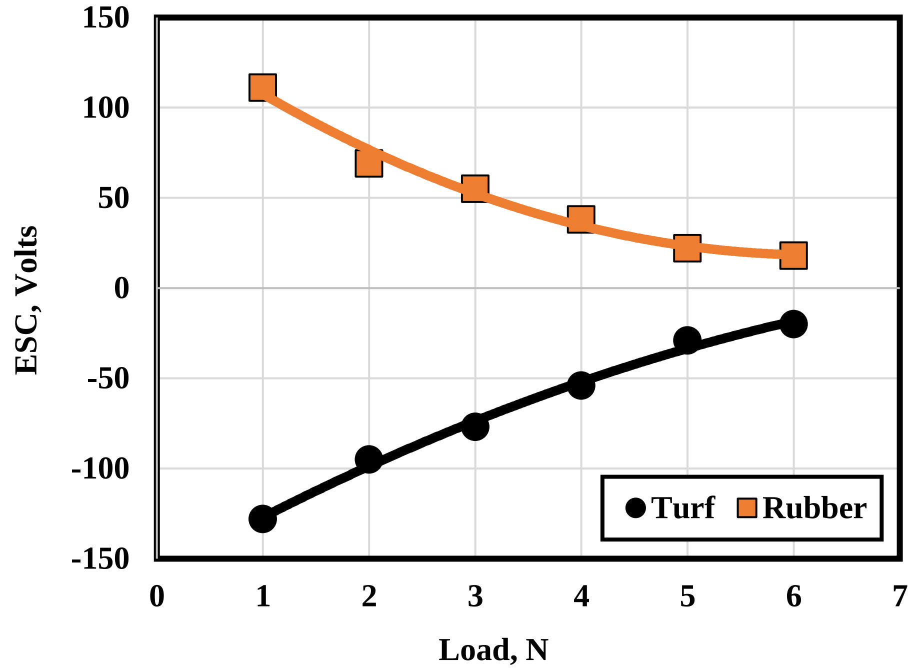


Fig. 10 Effect of applied load on ESC generated from dry sliding of rubber on AT.

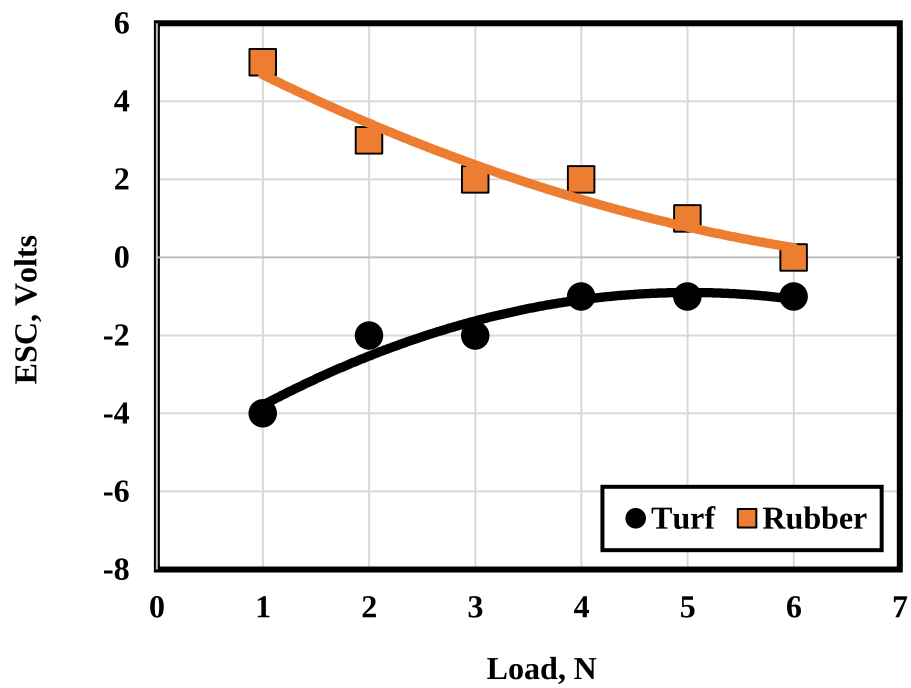


Fig. 11 Effect of applied load on ESC generated from water wet sliding of rubber on AT.

ESC generated on rubber and AT from sliding decreased with the increase of the load, Fig. 10. As mentioned above the interaction of PMMA fibers of positive ESC with the

surface of AT of negative ESC was responsible for the ESC decrease. The load increase enhanced the contact of the fibers with AT. The effect of load in the condition of water wet sliding on ESC is illustrated in Fig. 11. The values showed relatively low ESC values. The experimental results confirmed that PMMA strings blending AT is promising solution to reduce ESC generated after contact-separation and sliding. In addition to that, the best PMMA content was 50 wt. % of the AT.

CONCLUSIONS

1. Drastic ESC decrease was observed as the PMMA content increased, where the magnitude of ESC generated on AT was higher than that observed on the rubber surface.
2. ESC drastically decreased at contact-separation and sliding of rubber on AT when AT was rinsed by water.
3. ESC decreased with the increase of the load.
4. The values of ESC generated from dry sliding of rubber on AT were much higher than that observed in contact-separation.
5. When the content of PMMA increased up to 50 wt. % in the AT specimens decreased ESC.
6. ESC generated on rubber and AT from sliding decreased with the increase of the load.
7. It is recommended to blend AT by PMMA strings up to 50 wt. % of the AT.

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