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EFFECT OF SALT WATER ON THE FRICTION AND ELECTROSTATIC CHARGE GENERATED FROM SLIDING OF RUBBER ON ARTIFICIAL TURF

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ABSTRACT
Artificial turf (AT) replaces natural turf because it needs no water. AT is made of polyethylene (PE) fibers, where electrostatic charge (ESC) generated from friction with rubber records relatively higher values that badly influences the health of human beings. AT is sprayed by water to decrease its abrasion action. In order to save fresh water, the present work investigate the possibility of spraying AT by salt water through testing its influence on the friction and ESC generated from contact/separation and sliding of rubber on AT.

It was found that at dry sliding of rubber on AT, friction coefficient represented the highest values. When AT was sprayed by water, friction coefficient showed values for salt water higher than that observed for fresh water. ESC generated from water wet contact/separation and sliding showed drastic decrease due to the good electrical conductivity that facilitated the ESC transfer between the two contact surfaces, where the values of ESC generated in the presence of salt water were lower than that measured for fresh water. It can be concluded that spraying AT with salt water can be promising solution to save fresh water and reduce ESC generated after both contact/separation and sliding of rubber on AT.

KEYWORDS
Artificial turf, electrostatic charge, fresh, salt water, friction, rubber.

INTRODUCTION
The extensive use of (AT) to replace natural grass in kid schools, sport yards, and swimming pool surrounds increased the interest to investigate the friction as well as ESC generation of ESC after the contact/separation and sliding of rubber soles on AT, [1 - 4]. AT is made of PE fibers that gain high magnitude of ESC when rubbing human skin. Added to that, PE turf abrades human skin. Recently, AT has been

blended by polyamide (PA), where the ESC generated from the sliding of rubber on AT decreased with the increase of the content of PA, [5].

The effect of AT on the performance and safety of players was discussed. It was revealed that the infill materials of AT influence the performance of players, [6], as a result of the friction of AT with the human skin, [7, 8]. Abrasion of human skin by AT, [9 - 11], was studied through inspecting the surface properties of AT, [12 - 18]. The human skin was simulated by silicone and foam to study abrasion of the AT in sport, [19 - 21]. It was found that the materials of the substrate of AT significantly influences the magnitude of ESC, [22]. AT was blended by copper (Cu) textile showed drastic decrease in ESC, [23]. When aluminium (Al) film coated the soles ESC values decreased. That behavior was recommended to coat the surface of the outer soles by electric conductive material to leak ESC to Cu textile.

Besides, it was found that blending AT by fibers of materials that gain opposite ESC generated lower ESC compared to unblended AT, [24]. Polyurethane (PU) as well as yarns and textile of PA of positive ESC blending AT reduced ESC, [25]. Experiments were carried out to test ESC generated from the sliding of Cu textile, Al film and carbon fibers (CF) on AT blended by PU fibers and PA yarns, [26]. In addition, ESC was reduced by filling the soles made of PE by powders of Al, Cu and iron (Fe), [27 - 28].

The present study investigates the influence of fresh and salt water on the friction and ESC generated from contact/separation and sliding of rubber on AT.

EXPERIMENTAL

The AT test specimen in form of sheet of 300 × 300 mm^2 was adhered into the wooden base of the test rig to measure friction. The rubber sole of 60 Shore A hardness and 8 mm thickness was adhered to one surface of wooden cube of 20 × 20 × 20 mm^3. The load was applied by weights of 2, 4, 6, 8 and 10 N at dry and fresh and salt water sliding conditions. Friction coefficient displayed by the sliding of rubber test specimens on AT surface was determined by measuring the friction force and normal force. The base of the test rig was supported by two load cells in order to measure the friction and applied load. AT fibers were of 1.5 mm width and 0.25 mm thickness. Friction test was carried out at applied loads ranging from 0 to 10 N. The rubber surface was loaded against the tested artificial turf. Surface DC Voltmeter SVM2 (An Alpha Lab Inc.) was used to measure ESC generated on rubber and AT surfaces. The details of the test procedure and AT specimens are illustrated in Figs. 1, 2. Experiments were repeated ten times then the average was considered. The sliding distance of rubber on AT was 250 mm at 0.05 m/s velocity.

Fig. 1 AT test specimen.

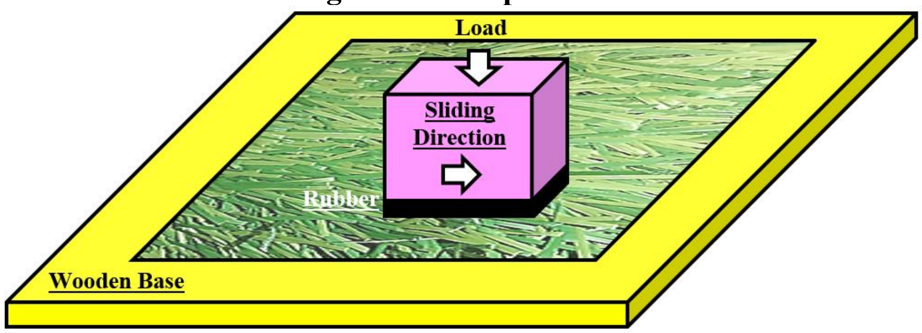


Fig. 2 The arrangement of the test procedure.

RESULTS AND DISCUSSION

The results of the present investigation are discussed. Friction coefficient showed relatively higher values at dry sliding, Fig. 3. As the applied load increased, friction coefficient drastically decreased. It seems that the load increase had increased the applied stress on the AT fibers up to its yield shear strength. Further load increase would decrease the value of friction coefficient. That behaviour can be explained due to the extra heat generated during sliding at higher loads. It is expected that a layer of low shear strength is formed at the interface. AT sprayed by salt water showed higher friction coefficient than that sprayed by fresh water. It seems that the conductivity of salt water was responsible for that behavior. This observation recommends the use of salt water. Friction coefficient influences the stability of walking and running on AT, where slip on AT may cause injuries induced by the friction between the skin and AT. Spraying AT by water could reduce the injuries by reducing friction.

It is well known that walking and creeping on AT generate ESC of magnitude depends on the materials of footwear and AT, [29, 30]. Because AT is made of polyethylene (PE) that has the tendency to develop ESC when being in contact with dissimilar materials such as rubber, human skin and polymers. PE has high electrical resistance that enables it to store ESC especially in dry sliding. ESC generated from dry contact/separation of AT and rubber is shown in Fig. 4. As the load increased, ESC generated on the surfaces of rubber and AT increased. Rubber gained positive ESC, while AT gained negative one due to their ranking in the triboelectric series,

Table 1. It seems that increasing the load increased the contact area between rubber and AT and consequently ESC increased. The highest ESC value was 1300 volts at 10 N load gained by rubber, while AT gained -4900 volts. In condition of sliding, the same trend was observed with higher voltage values, Fig. 5. The highest voltage values were 2000 and -7100 volts gained by rubber and AT respectively.

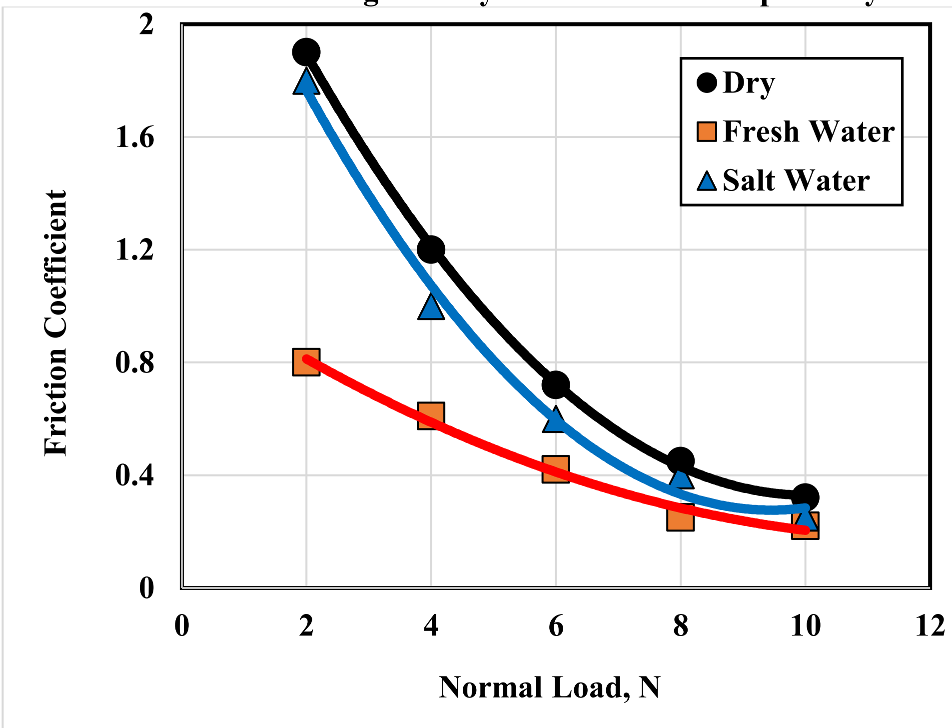


Fig. 3 Friction coefficient displayed by sliding rubber on artificial turf.

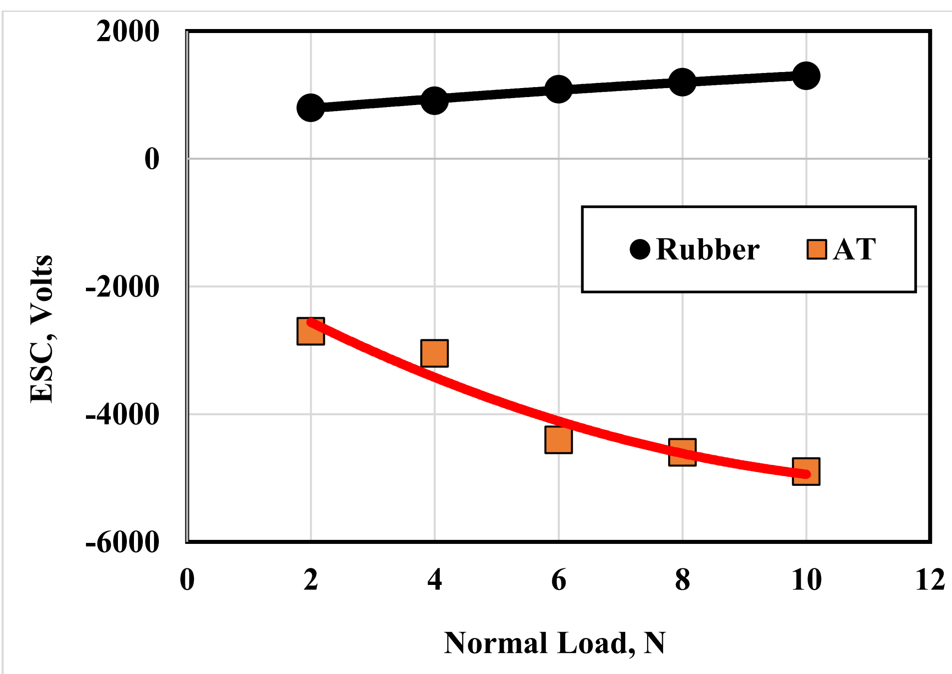
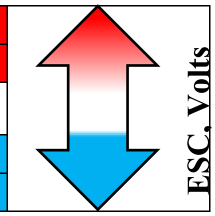


Fig. 4 ESC generated from dry contact/separation of AT and rubber.

Table 1 Triboelectric series of the tested materials.

Positive charge
Rubber
Polyethylene (PE)
Negative charge



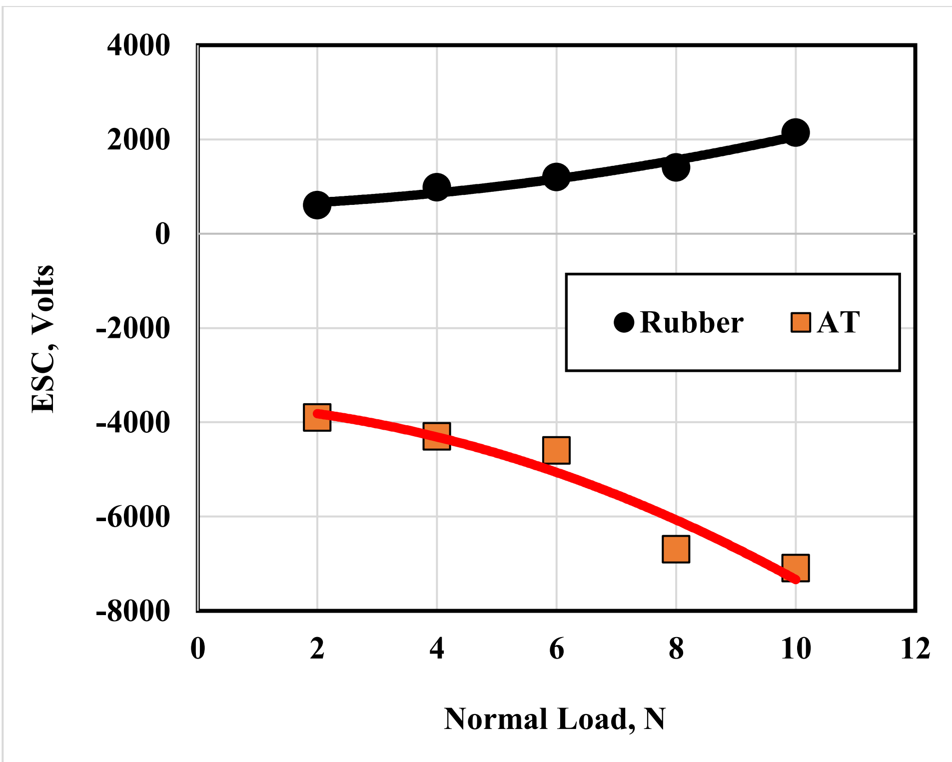


Fig. 5 ESC generated from dry sliding of rubber on AT.

For contact/separation of AT and rubber at fresh water wet condition, Fig. 6, ESC drastically decreased. This behavior can be attributed to the presence of water that worked as good electrical conductor that facilitated ESC transfer. ESC gained by rubber did not exceed 112 volts while AT gained -70 volts. This observation raised the need to spray AT by water. ESC generated from sliding of AT and rubber at fresh water wet condition showed relatively higher values than that observed for contact/separation, Fig. 7. Rubber and AT acquired voltage values of 180 and contact/separation at 10 N load respectively. AT gained -160 volts.

In the presence of salt water, ESC generated from contact/separation and sliding of rubber on AT and at salt water is displayed in Figs. 8 and 9 respectively. The recorded values of ESC were lower than that measured for fresh water that is because the relatively better electrical conductivity of salt water is responsible for that behavior due the easy interchange of the positive and negative ESC between rubber and AT. According to the experimental observation, it can be concluded that spraying AT with salt water can reduce ESC generated after both contact/separation and sliding.

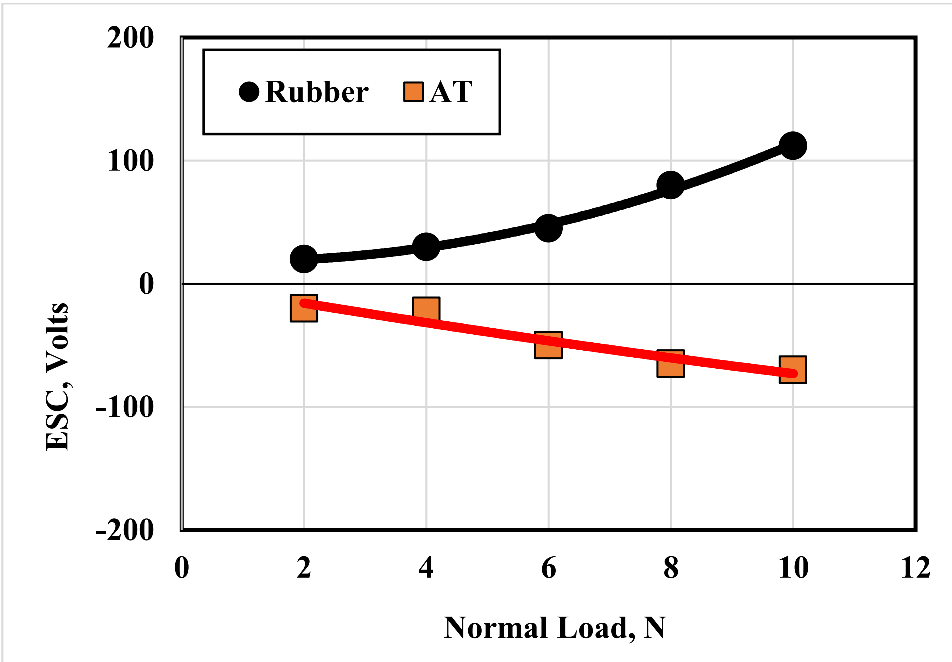


Fig. 6 ESC generated from contact/separation of AT and rubber at fresh water wet condition.

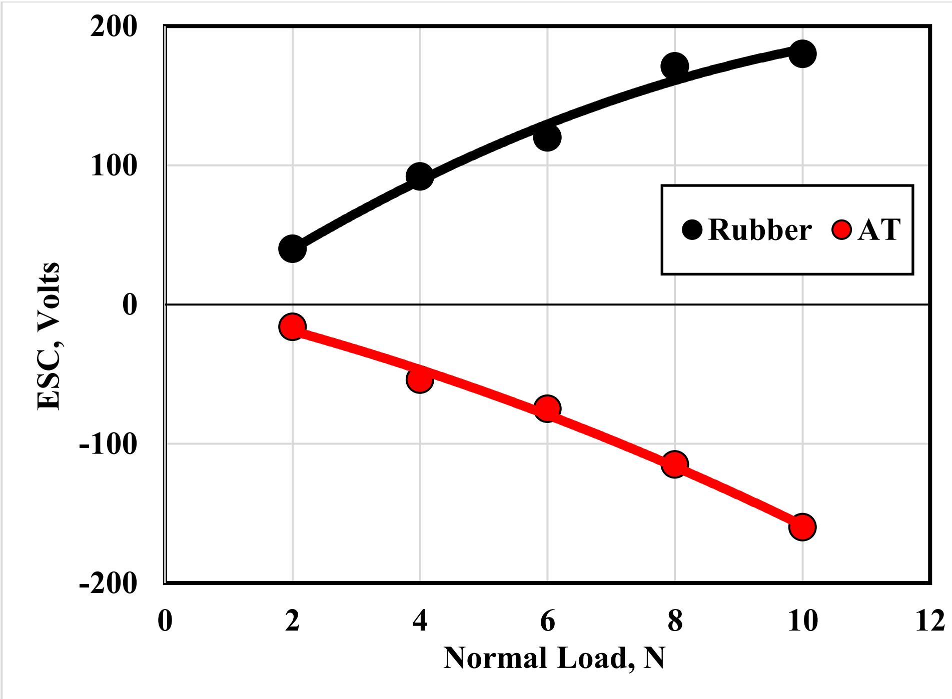


Fig. 7 ESC generated from sliding of AT and rubber at fresh water wet condition.

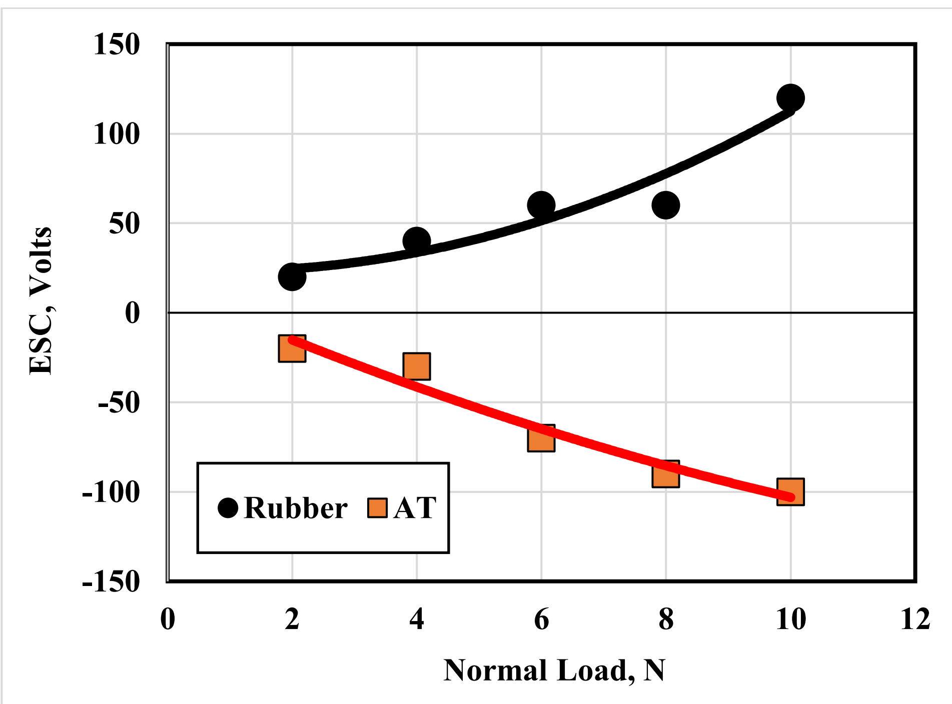


Fig. 8 ESC generated from contact/separation of AT and rubber at salt water wet condition.

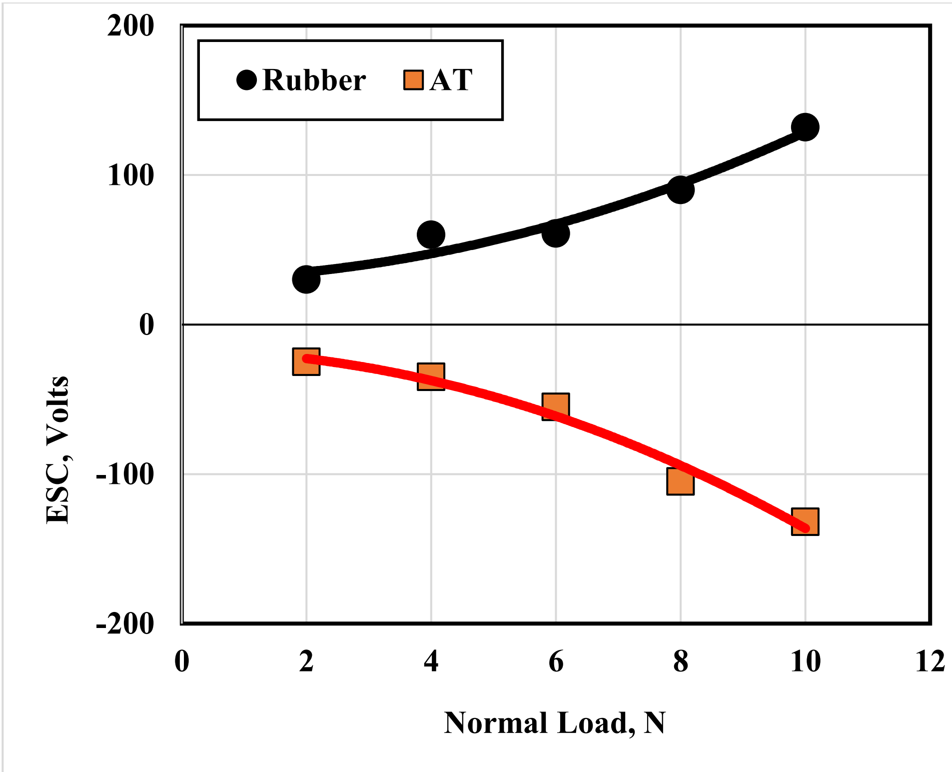


Fig. 9 ESC generated from sliding of AT and rubber at salt water wet condition.

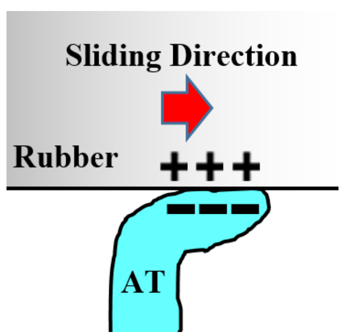


Fig. 10 Generation of ESC on the surfaces of rubber and AT.

The distribution of ESC on the surfaces of rubber and AT is illustrated in Fig. 10. The material of AT is PE that gains negative ESC after contact/separation and sliding on rubber, while rubber gains positive ESC. The transfer of positive and negative ESC generated on the two contact surfaces was enhanced by the presence of fresh and salt water. This explanation is confirmed by the rank of the materials in the triboelectric series, Table 1, where the materials are ranked according to their polarity and the magnitude of ESC they gained. The materials that gain positive ESC are ranked in the upper part (red) of the series, while the materials of negative ESC are found in the lower one (blue). The drop of ESC was observed for fresh and salt

water wetted contact/separation and sliding due the good electrical conductivity of the water.

CONCLUSIONS

1. At dry sliding, friction coefficient showed the highest values. As the applied load increased, friction coefficient drastically decreased with increasing the applied load.
2. In the presence of salt water, friction coefficient showed values higher than fresh water.
3. ESC generated from dry contact/separation and sliding of rubber on AT increased with increasing the load due to the increase of the contact area.
4. Contact/separation and sliding of rubber on AT in the presence of fresh and salt water showed drastic decrease in ESC due to the good electrical conductivity that facilitated the ESC transfer between the two contact surfaces.
5. The values of ESC generated in the presence of salt water were lower than that measured for fresh water due to the better electrical conductivity of the salt water that enabled the easy interchange of the positive and negative ESC between rubber and AT.
6. It can be concluded that spraying AT with salt water can be promising solution to save fresh water and reduce ESC generated after both contact/separation and sliding of rubber on AT.

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