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TRIBOELECTRIFICATION OF SYNTHETIC STRINGS

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ABSTRACT
The comfort and quality of cloths depends on the slipperiness and smoothness of textiles evaluated by the touch of human skin. The measure is the friction coefficient displayed by sliding of textiles against human skins or other textiles. The wide use of polymeric fibers in textile industry increased the interest in investigating their electrostatic effect during contact and separation as well as sliding on cotton and human skin. The electrostatic charge generated from the friction of polytetrafluoroehylene (PTFE) strings against cotton was tested.

The present work discusses three proposals to reduce ESC generated on the surface of PTFE strings. The first included mixing PTFE by different content of PA strings of 0.4 mm diameter, while the second was applied by using Al film as substrate to release ESC from the contact surface. The third group proposed reinforcing PTFE by aluminium (Al) wire, copper (Cu) wire and carbon fibers (CF). It was found that, reinforcing PTFE by cores of conducting materials such as Al, Cu wires and CF to release ESC from the surface represented the most effective proposal, where Cu core was the best followed by CF and Al.

KEYWORDS
Electrostatic charge, friction, polytetrafluoroehylene, polyamide, cotton, strings.

INTRODUCTION
Triboelectrification of textiles specifies the quality of cloths. Voltage generated from electrification of the human body by sliding of the polymeric textiles against cotton should not exceed certain limit to avoid serious health problems. ESC of the polymeric textiles is very sensitive to the friction. They have tendency to develop static charge when rubbed with dissimilar materials like other textiles. Polymeric fibers have good insulation with an extremely high electrical resistance. Due to this high resistance, charge on polymeric textiles is not easily dissipated, especially in dry environments.

Several researches were carried out to propose developed textile materials with low or neutral electrostatic charge that can be used for industrial application especially as textile materials, [1 - 5]. The results showed that addition of wool, cotton and nylon fibers into PTFE textiles remarkably decreases the electrostatic discharge and consequently the proposed composites will become environmentally safe textile materials. Besides, the surface characteristics vary with the types of textiles, the weave

and the finish. Friction coefficient is considered one of the important factors that qualify the use of textiles when they are touched by the human skin, [6 – 8]. Experiments were carried out to measure ESC generated from the friction of different polymeric textiles sliding against cotton under varying sliding distance and velocity as well the load. It was found that increasing velocity increased ESC. The increase may be attributed to the increase of the mobility of the free electrons to one of the rubbed surfaces. The fineness of the fibers much influences the movement of the free electrons. Research on ESD ignition hazards of textiles is important for the safety of humans.

The possibility of having minimum electric static charge generated from the friction between the proposed polymeric composites consisting of PTFE and PA fibers when sliding against cotton textiles was investigated, [9 - 16]. The idea depends on the fact that PTFE gains negative electric static charge when sliding against all the other materials, while PA gains positive charge. The control of the content of the materials of the proposed composites is thought to control the value and signal of the generated electric static charge. Experiments were carried out to measure the electric static charge and friction coefficient. PTFE gains negative charge while PA gains positive charge, the resultant voltage would depend on the combination of both PTFE and PA. This observation confirmed that the intensity of electric static charge depended on the load. Further increase in PA content gave positive voltage. It was observed that, fiber diameter of PA had critical effect on the generated voltage. Voltage generated at sliding was higher than that recorded for contact and separation. Knowing that in application, contact and separation is accompanied by sliding. Therefore, it can be suggested to use mean values to determine the proper PA content at which zero voltage can be obtained. It is proposed to make further experiments to determine the effect of the fiber diameter of both PA and PTFE on the generated voltage. Besides, microfibers as well as nanofibers should be tested.

In the present work, it is planned to reduce the ESC generated from the triboelectrification of PTFE sliding against cotton. Several methods are proposed and investigated.

EXPERIMENTAL

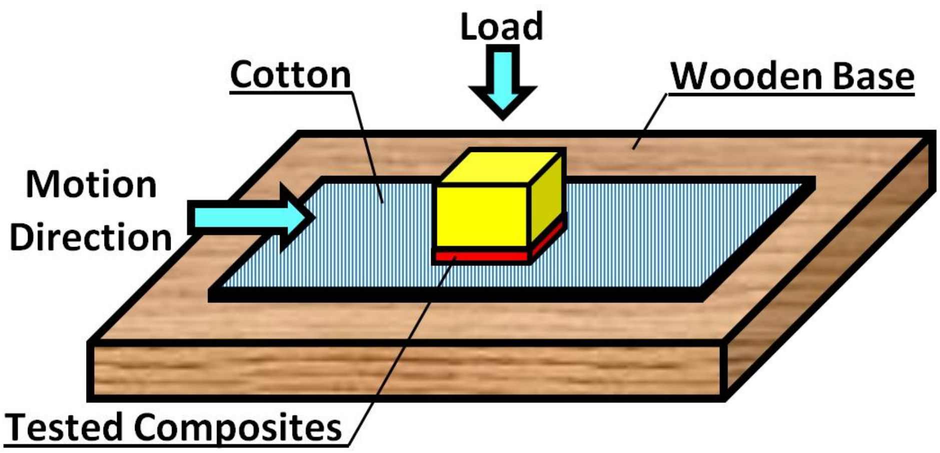


Fig. 1 Details of test procedure.

Electrostatic charge effects occur when an excess of either positive or negative charge becomes confined in a small volume, isolated from charges of the opposite polarity. Because of mutual repulsion, the charges try to escape. As a result, the charges may move or redistribute themselves, sometimes rapidly, such as with a spark. This redistribution usually causes problems.

The electrostatic fields (voltage) measuring device was used to measure the electrostatic charge (ESC) for test specimens. The specimens were prepared and arranged for the tests and measurements in the surface of a wooden block of 50 × 50 × 50 mm. Test specimens consisted of PTFE of 2.0 mm wide and 0.5 mm thick reinforced by wool, cotton and polyamide fibers of 0.5 mm diameter in volumetric ratio of 0, 10, 20, 30, 40 and 50 vol. %. PTFE composites were shaped in forms of plain weaves textiles, Fig. 1. Tests were carried out at room temperature under the range of 2.5 to17.5 N normal loads. The counterface material was cotton. Experiments were carried out by contact and separation as well as sliding the test specimens against cotton.

Three groups of specimens have been tested to reduce ESC generated from contact and separation as well as sliding of PTFE on cotton. The first group included mixing PTFE by different content of PA strings of 0.4 mm diameter, Fig. 2. Aluminium (Al) film of 0.25 mm thickness as has been used as substrate to release ESC from the contact surface of the second group, Fig. 3. The third group contained Al wire copper (Cu) wire and carbon fibers (CF) inserted inside the PTFE of 0.2 mm diameter, Figs. 4 and 5.

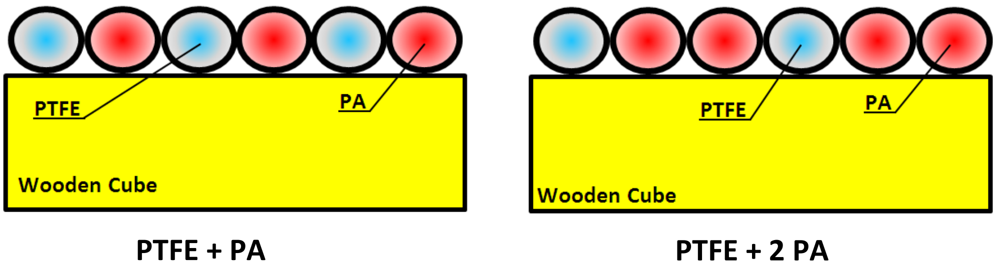


Fig. 1 Mixing PTFE by PA.

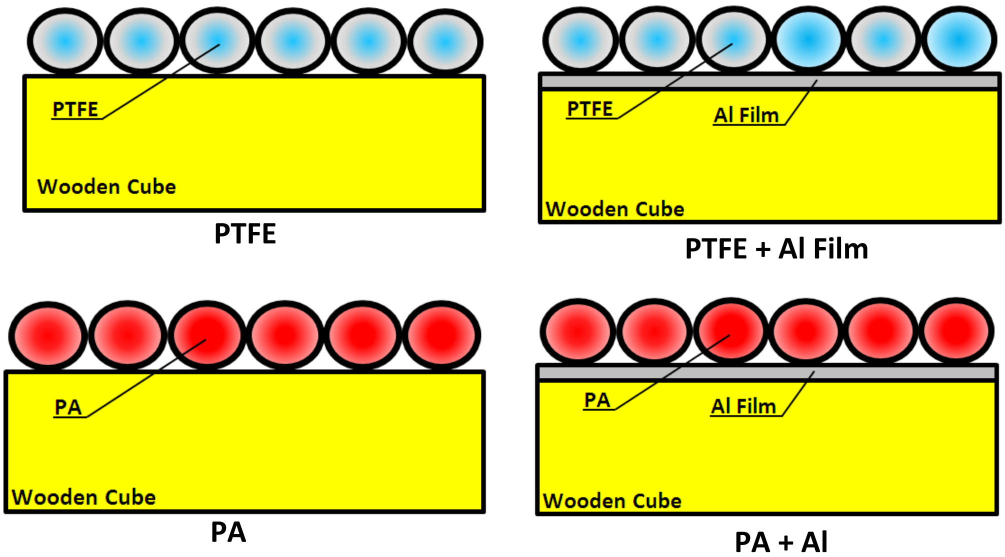
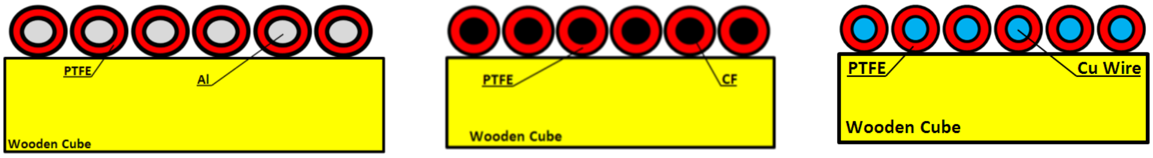


Fig. 2 Test specimens used in the second groups.



Aluminium core. **Carbon fiber core.** **Copper core.**

Fig. 3 Test specimens used in the third groups.

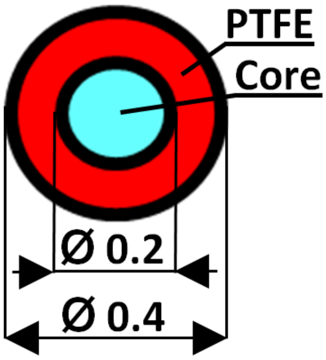


Fig. 4 Details of test specimens used in the third groups.

RESULTS AND DISCUSSION

The effect of the mixing PTFE by PA on ESC generated as result of the contact and separation is discussed in Fig. 5. The results revealed that PTFE generated the highest values of the negative charge, where the increase of load remarkably increased the ESC. This may be a result of the increased contact area with increasing applied load. As the content of PA increased the positive generated ESC increased then neutralized the negative ESC generated from PTFE. Further PA increase caused significant increase in the positive ESC. It seems that the reduction in negative charge can be attributed to the high positive charge generated from PA sliding against cotton.

The same trend was observed during sliding, Fig. 6, where the effect of PA was more pronounced. ESC of PTFE showed relatively higher negative behavior, but with the increase of PA content in PTFE composites the negative charge (voltage) drastically decreased. This can be explained on the basis on the nature of rubbing between cotton of neutral charge and PA of positive charge, this action generated positive charge on the cotton surface and influenced the negative charge of PTFE composites. This result recommends these composites of higher content of PA than that used in contact and separation to be used in applications that require textiles of relatively low surface charge.

The results of the second procedure to reduce ESC was to apply an Al substrate to release ESC from the surfaces of both PTFE and PA strings are shown in Figs. 7 and 8 for contact and separation as well as sliding respectively. The explanation of the effect is illustrated in Fig. 9, a & b. The figures showed that applying Al substrate decreased ESC distributed on the strings surfaces due to its release through the Al film. That behavior was observed for PTFE and PA strings. As the load increased the effect decreased due to the decrease of the mobility of the free electrons to one of the rubbed surfaces. It seems that strings of the rubbed PTFE, PA and cotton, charged by free

electrons easily exchanged the electrons of dissimilar charges where the resultant became relatively lower.

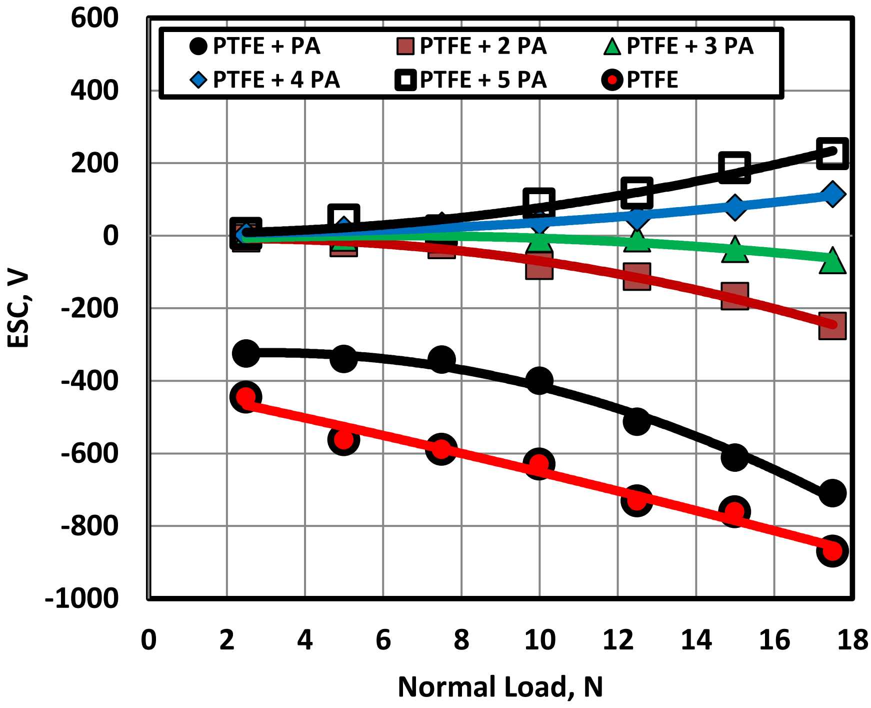


Fig. 5 ESC generated from the contact and separation of the tested composites with cotton.

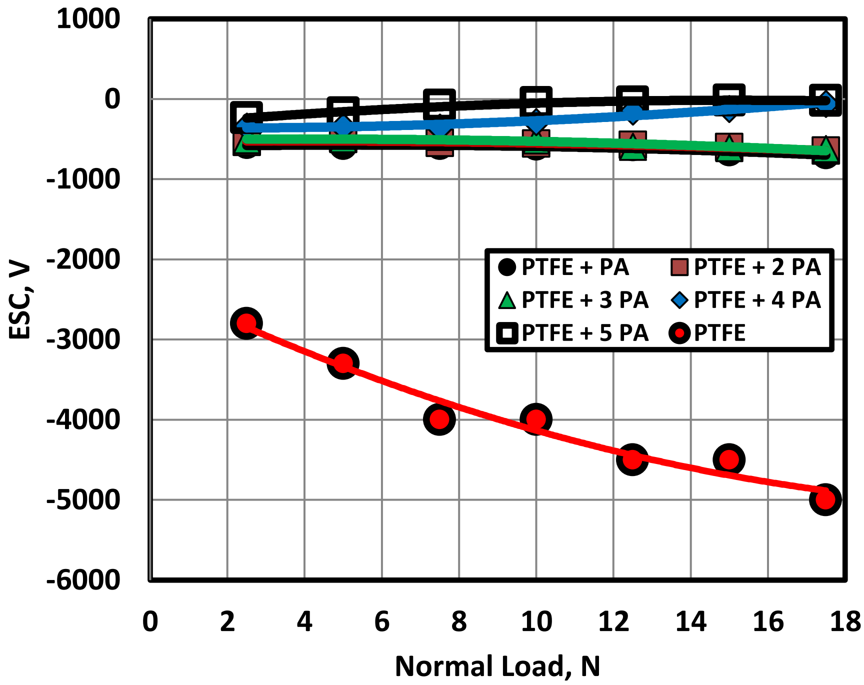


Fig. 6 ESC generated from the sliding of the tested composites with cotton.

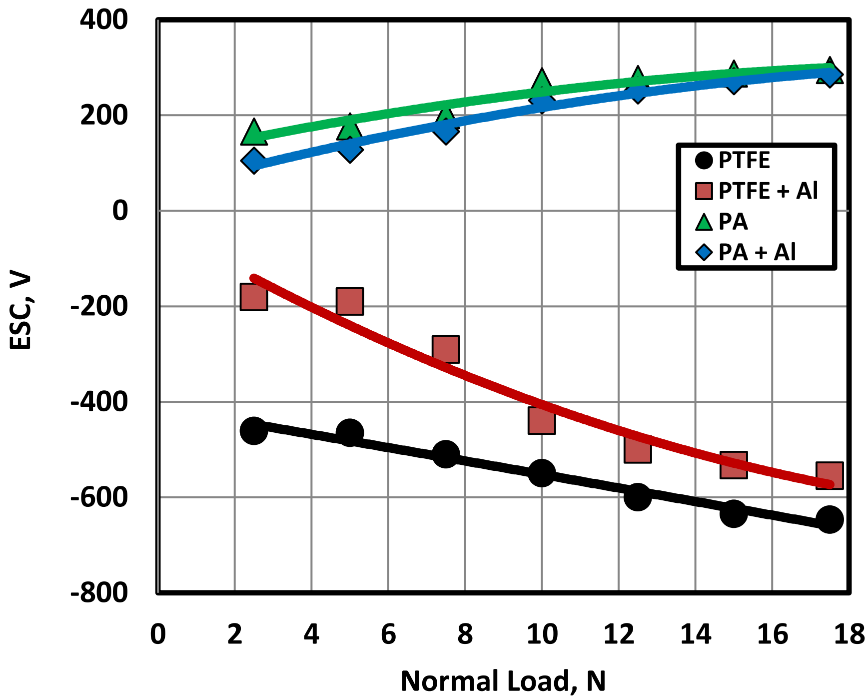


Fig. 7 ESC generated from the contact and separation of the tested composites with cotton in the presence of Al substrate.

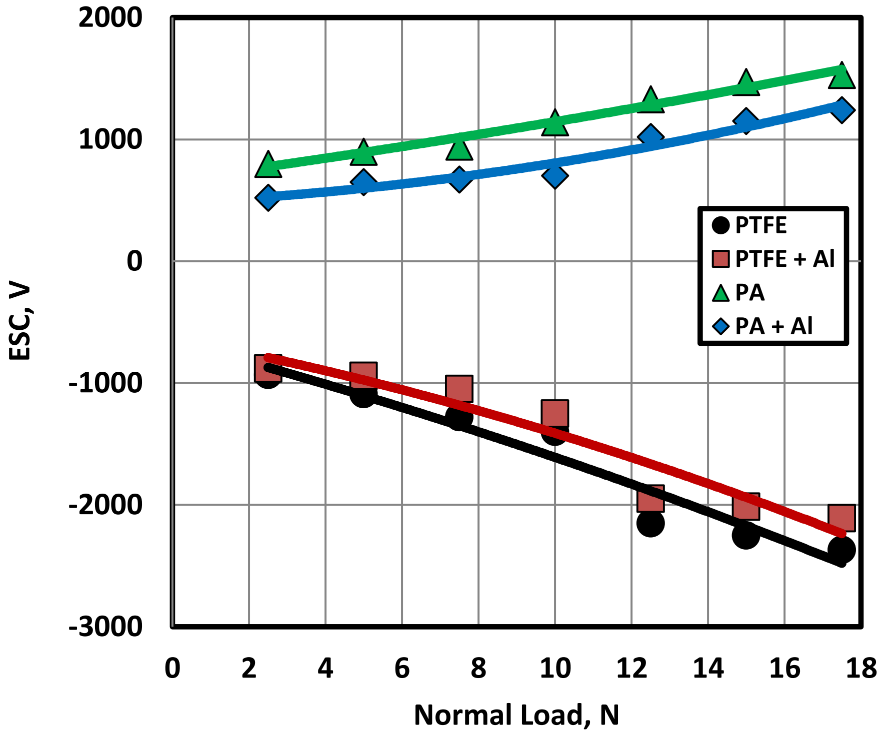


Fig. 8 ESC generated from the sliding of the tested composites with cotton in the presence of Al substrate.

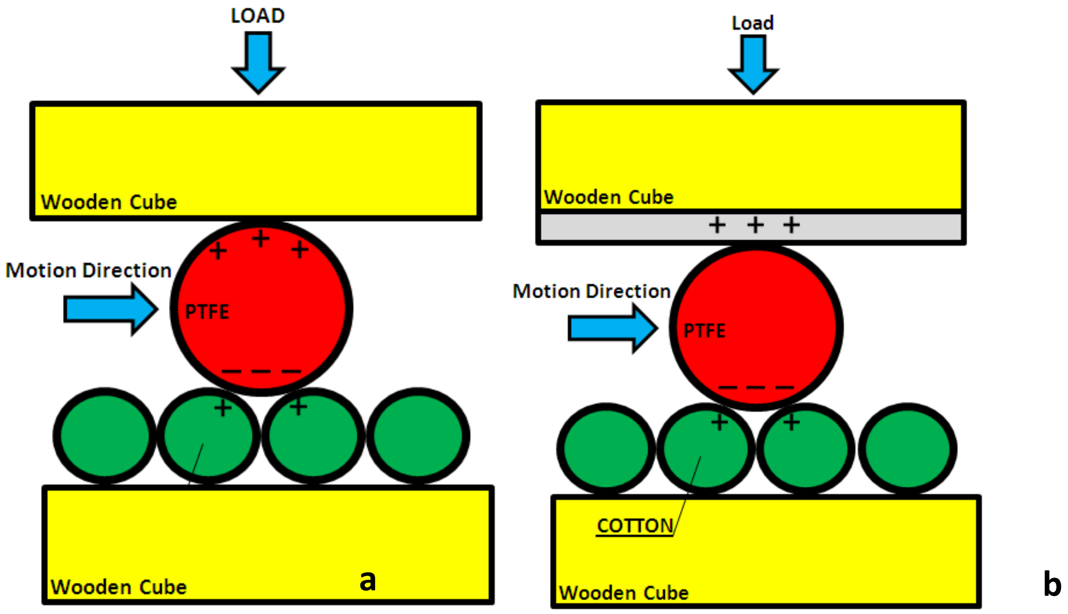


Fig. 9 The effect of aluminium substrate on ESC.

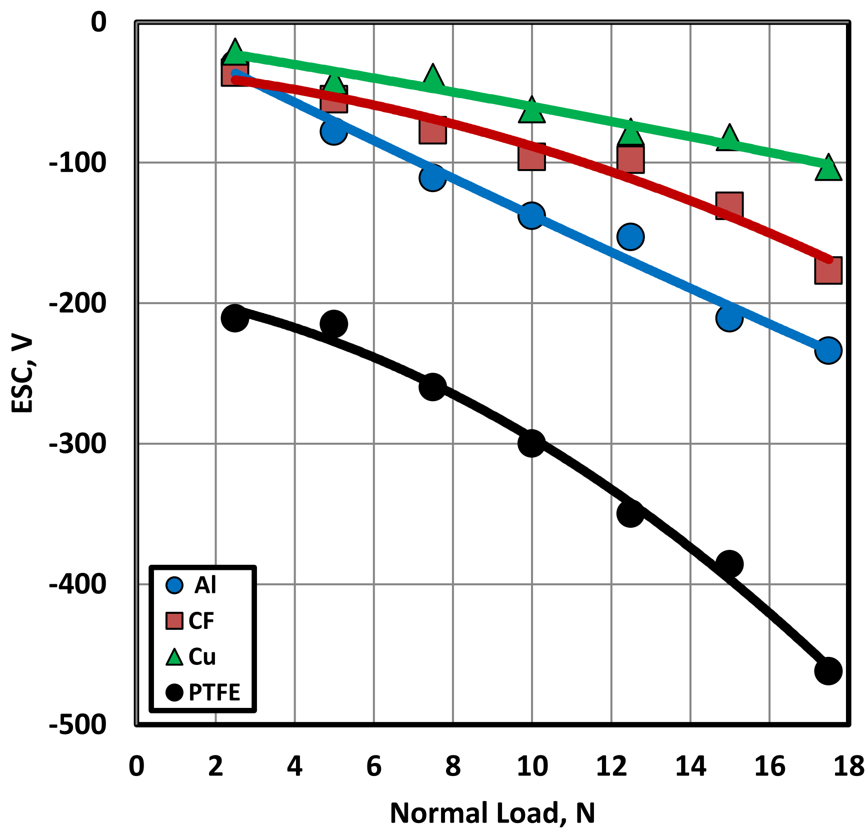


Fig. 10 ESC generated from the contact and separation of PTFE reinforced by different core materials with cotton.

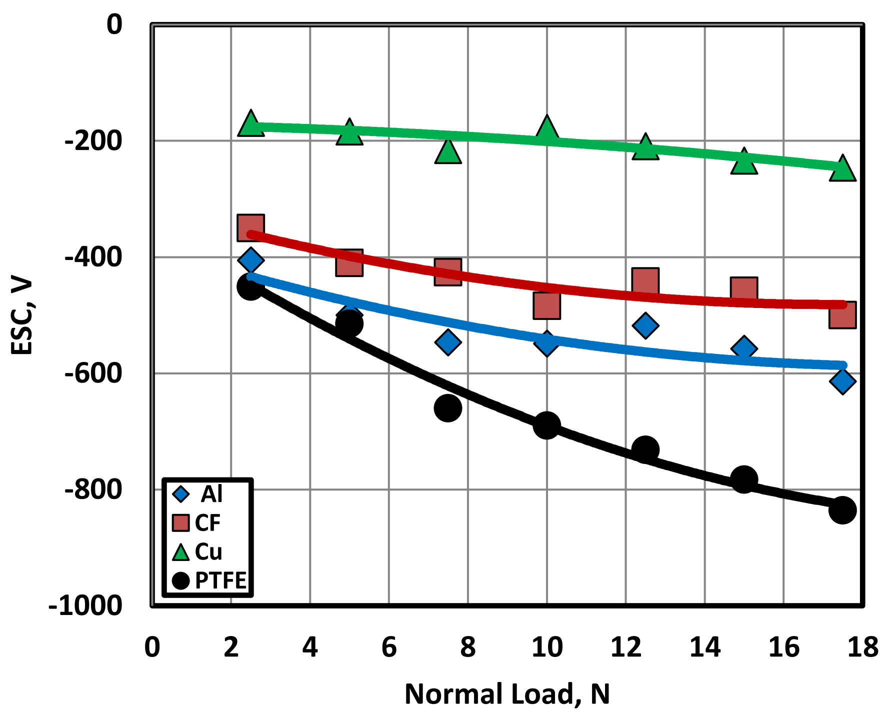


Fig. 11 ESC generated from the sliding of PTFE reinforced by different core materials with cotton.

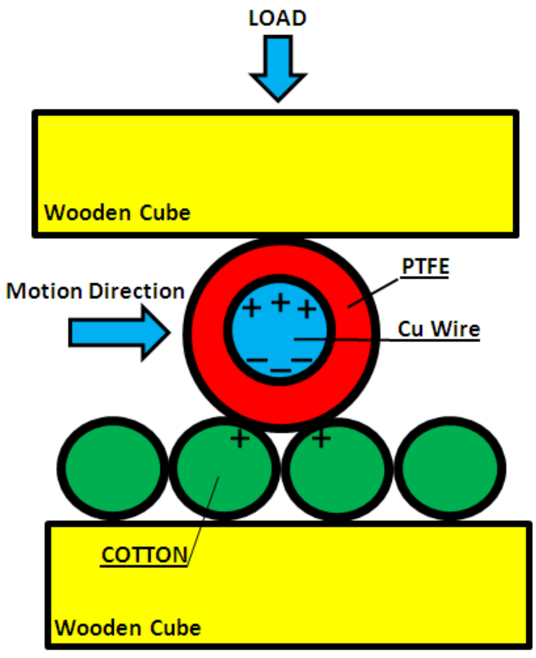


Fig. 12 Release of ESC from the PTFE surface into the copper wire core.

Figure 9, b illustrates the release of ESC from PTFE surface into the Al film. This behavior could be attributed to the fact that PTFE and cotton are different materials and according to the triboelectric series, friction between the two surfaces causes the object in the upper position of the series to be positively charged (cotton) and that in the

lower position to be negatively charged (PTFE). It is known that different polarity means attraction. Also, it could be attributed to that the long distance gives higher chance to exchange more charges (electrons) between the two different materials rubbing each other. As the PTFE touches the Al film, charges must move out of PTFE into Al film.

The third proposal to decrease ESC generated on the surface of PTFE strings is to apply cores of conducting materials such as Al, Cu wires and CF to release ESC from the surface, where the results are shown in Figs. 10 and 11. The results showed that Cu wire was the most effective core the reduced ESC followed by CF, while Al came the last. It is clearly shown that the intensity of ESC can be easily reduced by reinforcing PTFE strings by Cu or CF. Polymers are insulators that trap ESC generated on their surfaces. ESC cannot move along the surface, but it can be removed from the surface by a conductor contacting the surface through allowing ESC to move freely inside and on the surface, Fig. 12. Presence of conducting core inside PTFE allows electrons to leave the surface. This effect happens at the interface between PTFE and cotton.

CONCLUSIONS

1. Mixing PTFE by PA decreased the generated ESC, where the effect of PA was more pronounced during sliding than contact and separation. ESC of PTFE showed relatively higher negative behavior, but with the increase of PA content in PTFE composites the negative ESC drastically decreased.
2. ApplyingAl substrate to release ESC from the surfaces of both PTFE and PA strings decreased ESC distributed on the strings surfaces due to its release through the Al film. As the load increased the effect decreased due to the decrease of the mobility of the free electrons to one of the rubbed surfaces.
3. Reinforcing PTFE by cores of conducting materials such as Al, Cu wires and CF to release ESC from the surface represented the most effective proposal, where Cu core was the best followed by CF and Al.

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