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INFLUENCE OF PRE-TRIBOELECTRIFICATION ON FRICTION COEFFICIENT DISPLAYED BY POLYETHYLENE SLIDING ON POLYURETHANE

Ali A. S.[1] and Ali W. Y.[2]

[1]Petrojet Company, Cairo, Egypt,
[2]Production Engineering and Mechanical Design Department, Faculty of Engineering,
Minia University, Egypt.

ABSTRACT

Tactile property of surfaces controls the safety of materials handling. Operators need gloves to keep their hands safe and enhance their ability to handle materials. This ability can be developed by controlling the friction property of the gloves. Sometimes, operators rub their hands so that the gloves may get charged by triboelectrification. Electrostatic charges (ESC) generated from friction of the gloves has a negative effect friction coefficient. The present work aims to investigate the influence of pre-triboelectrification on friction coefficient displayed by polymeric materials by sliding of polyethylene (PE) on polyurethane (PU) at dry sliding. PU in form of 0.5 mm coating was adhered into polypropylene (PP) as well as copper substrates.

The experiments showed that the intensity of ESC generated on the sliding surfaces depends on their ranking of material in the triboelectric series. As the gap between the two rubbing materials increases, the intensity of the ESC increases. The influence of the gap on friction coefficient and intensity of ESC is found to be higher than that observed for the pre-triboelectrification process of the two contacting surfaces. Besides, friction coefficient for surfaces without pre-triboelectrification displayed the highest values. It is concluded that adhesion depends on the double layer of ESC of equal intensity, where excess of ESC on one surface does not affect the adhesion, where the adhesion between the two contact surfaces will be relatively weaker than that observed in condition of absence of pre-triboelectrification. In addition to that, it was found that metallic substrate of polymeric coatings leak some of the ESC outside the sliding surface causing drastic decrease in friction coefficient. Finally, pre-triboelectrification of surfaces before sliding by rubbing each other reduces the values of friction coefficient.

KEYWORDS

Electrostatic charge, friction coefficient, polyethylene, polyurethane, polypropylene and copper substrates.

INTRODUCTION

The influence of pre-triboelectrification on friction coefficient displayed by polymeric materials by sliding of PP on PET at dry sliding was investigated, [1]. The experiments showed that PET provided by thin steel sheets displayed the highest friction values

followed by steel textiles, CF, copper textiles, steel fibres and aluminium film. When PET surface was rubbed by PA and gained negative ESC, friction coefficient represented relatively lower values than that recorded in the first condition, while PET surface rubbed by PTFE gained positive ESC, followed by extra ESC generated from rubbing with PP gave the highest friction values. ESC generated on the PET surface significantly increased with increasing normal load and slightly increased with increasing the sliding distance. The highest values of ESC were recorded by inserting steel fibres in the back of PET sheet followed by copper textile and steel sheet, while Al film under PET sheet showed no effect on ESC generated on the two sliding surfaces. The same trend was observed for ESC generated from PP and PET when CF and steel textiles were inserted behind PET.

The dependency of friction coefficient on electrostatic charge (ESC) generated from sliding of polyethylene (PA) on polytetrafluoroethylene (PTFE) was investigated, [2]. It was found that ESC generated on PA and PTFE reinforced by CF and friction coefficient increase as CF content increases. This observation strengthens the dependency of friction coefficient on ESC. Therefore, specific information about the value of ESC can be useful in controlling friction coefficient. This behavior can be explained on the bases that increasing ESC can increase the adhesion between the two contact surface and consequently friction coefficient increases. Besides, ESC can be controlled by applying magnetic or electric field. This behavior can be used in controlling friction coefficient of polymeric material when they are contacting each other.

Tactile behaviour is one of the critical properties that control the safety of materials handling. The tested materials based on their friction coefficient in order to increase the safety of glass handling were screened, [3]. Friction measurements were carried out to eight different materials by sliding against glass sheet at dry, water wet and oily conditions. Sensors that can reveal tactile were developed in order to equip robot hands with such a sense, [4, 5]. Development of the materials used in robots is a critical factor for increased safety and efficiency. Gripping forces may be reduced using high-friction surfaces, [6]. Thus, we selected foamy polymers as a suitable type of friction-enhancing material for grippers of the climbing robot. Friction coefficient of the contacting surfaces can control the safety of material handling through increasing the gripping force. The friction coefficient of the tactile sensor was tested, [7].Variety of materials such as foamy polymers and sandwich-like microstructures were tested as shoe soles for potential robot, [8, 9]. The friction coefficient displayed by hands sliding against the surface of the steering wheel covers was discussed, [10]. Measurement of friction coefficient is of critical importance in assessing the proper friction properties of steering wheel covers and their suitability to be used in application to enhance the safety and stability of the steering process during car driving.

It is well established that there is an increasing rate in car accidents. An acceptable value of friction should be obtained to prevent slip between the hands of the driver and the surface of the steering wheel. The knowledge of steering-wheel grip force characteristics of the drivers may benefit the automobile designers and manufacturers to improve the quality of their products in terms of comfort and driving performance. The steering-wheel grip force of male and female drivers driving an automobile was studied, [11, 12]. Results indicated that the vehicle speed and the road condition did not significantly affect these response variables.

Gloves designed for football goalkeepers provide them with high efficient catching and holding the ball. They enable the goalkeeper to catch and punch a ball away. Gloves have also come into widespread use in sports such as football. Quantitative measurements of the friction coefficient displayed by the sliding of the ball on glove surface were carried, [13]. It was concluded that neoprene coated glove recorded relatively higher friction coefficient values up to 1.13. The high friction values highlight the importance of proper choice of the glove materials. Besides, the materials tested as surface coatings for the gloves of the football goalkeepers can be ranked based on friction coefficient displayed by sliding against football. The high friction difference at low and high loads confirms the importance of proper choice of glove materials of consistent friction trend with increasing the applied load.

It is necessary for the goalkeeper to wear gloves to enable him to catch the ball. The material of the gloves should provide grip properties, protect the hands, act as a shock damper and improve ball retention properties, [14, 15]. The gloves should be designed to prevent bending backwards of the fingers when saving, [16], and allow the fingers to flex forwards to catch the ball. In football, goalkeeper needs gloves to keep his hand safe and enhance his ability to catch the ball. Quantitative measurements of the electrostatic charge generated from the sliding of the ball against the glove surface were carried out, [17]. It was found that the gripping ability of the glove is one of the main factors to evaluate its quality. It should provide an adequate grip and tactile response under a wide range of conditions. The other factor is the health of goalkeepers which is of great concern. The materials of the ball as well as the gloves of goalkeepers should be selected on the basis of generation of low ESC. The experiments showed that ESC generated on the glove surface could be controlled by proper selection of the materials of appropriate surface qualities for practical use. ESC values generated from the sliding of the ball on the gloves of the goalkeeper can be doubled and accumulated so that they affect his physical condition during the match.

Little attention was considered for the generation of ESC of the sliding of the ball on the gloves of the goalkeeper. It is necessary to study the electrification of polymeric materials. It is well known that when two different materials contact each other, they may get charged, [18]. This tribocharging phenomenon is also known as triboelectrification when materials rub each other.

Triboelectric static charges built up on human skin and or clothes in direct contact with human body are very harmful and can create serious health problems, [19]. Based on the experiments carried out, it was found that, at dry sliding, iron nanoparticles addition into epoxy matrix increased friction coefficient with increasing iron content. Voltage drastically decreased with increasing iron content. Voltage showed the maximum values for epoxy free of iron.

The electrical charges have been taken into account on friction between the two insulating materials. The change, in friction and electric charge of alumina sliding against polytetrafluoroethylene (PTFE) under boundary lubrication conditions, was measured, [20]. Specific information about the value of the electrical charge can be useful in controlling friction coefficient.

The aim of the present experiments is to investigate the effect of pre-triboelectrification on friction coefficient displayed by sliding of PE on PU coating.

EXPERIMENTAL

Experiments have been designed to investigate the effect of pre-triboelectrification on the friction coefficient during sliding of polymeric materials. The test specimens were prepared from wooden block of 50 × 50 mm^2 and 30 mm height, where the sliding surface was covered by PE sheet of 0.25 mm thickness. Two types of counterfaces were used. The first was PU coating adhered to polypropylene sheet, while the second was PU coating adhered to copper sheet. PE surface was pressed and slid against PU surface, Fig. 1.

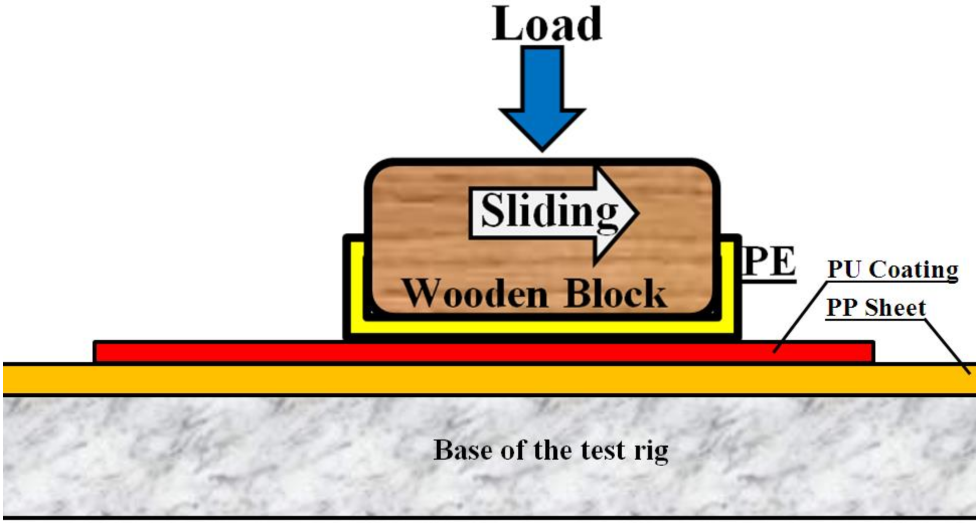


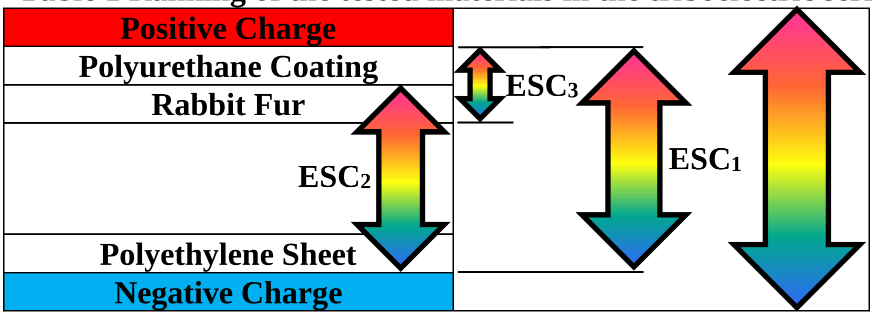
Fig. 1 Arrangement of the tested materials.

The applied force was ranging from 3 to 18 N. The sliding distance was 200 mm. After sliding, ESC generated on the two sliding surfaces was measured. The friction force was measured by the deflection of the load cell of the test rig, [20]. The ratio of the friction force to the normal load was considered as friction coefficient. The load was applied by weights. The test speed was nearly controlled to be 2 mm/s. All measurements were performed at 30 ± 2º C and 50 ± 10 % humidity. The electric static fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens which is considered in the text as ESC.

RESULTS AND DISCUSSION

The ranking of materials in the triboelectric series depends on their intensity of triboelectrification. The higher positioned materials will gain positive charge when contacted with a material at lower position along the series. As the gap between the two rubbing materials increases, the intensity of the ESC increases. Table 1 illustrates the triboelectric series of the tested materials. The two contact surfaces are polyethylene coating while the pre-electrification process was performed by rubbing the tested surfaces by rabbit fur.

Table 1 Ranking of the tested materials in the triboelectric series.



Measurement of ESC on both PE and PU surfaces are shown in Figs. 2 and 3 respectively. On PE surface, pre-triboelectrified PE surface gained the highest negative ESC followed by pre-triboelectrified PU, Fig. 2. PU coating gained positive ESC, Fig. 3, showed the highest values for pre-triboelectrified PU followed by pre-triboelectrified PE. That behavior can be explained by the means of Figs. 4 – 6. The illustration of the ESC distribution for sliding of PE on PU without pre-triboelectrification is shown in Fig. 4, where the intensity of the charge depends on the ranking of both PE and PU in the triboelectric series. ESC distribution on the friction surfaces for triboelectrified PE by rabbit fur is shown in Fig. 5 following the steps of the experimental procedure such as pre-triboelectrification and sliding, where the resultant intensity shows that PE gained relatively high negative ESC, while PU gained lower positive ESC. That assumption is confirmed in Fig. 2. When PU was pre-trboelectrified by fur and slid against PE, the resultant positive ESC generated on PU surface was higher than the negative ESC gained by PE. The data shown in Fig. 3 are in agreement with that assumption.

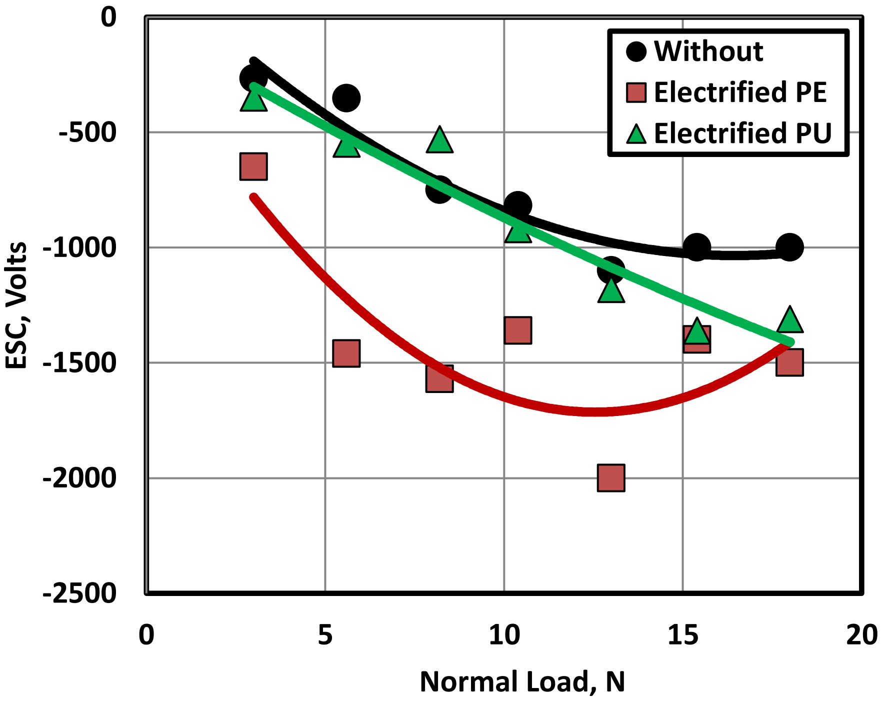


Fig. 2 ESC generated on the PE surface.

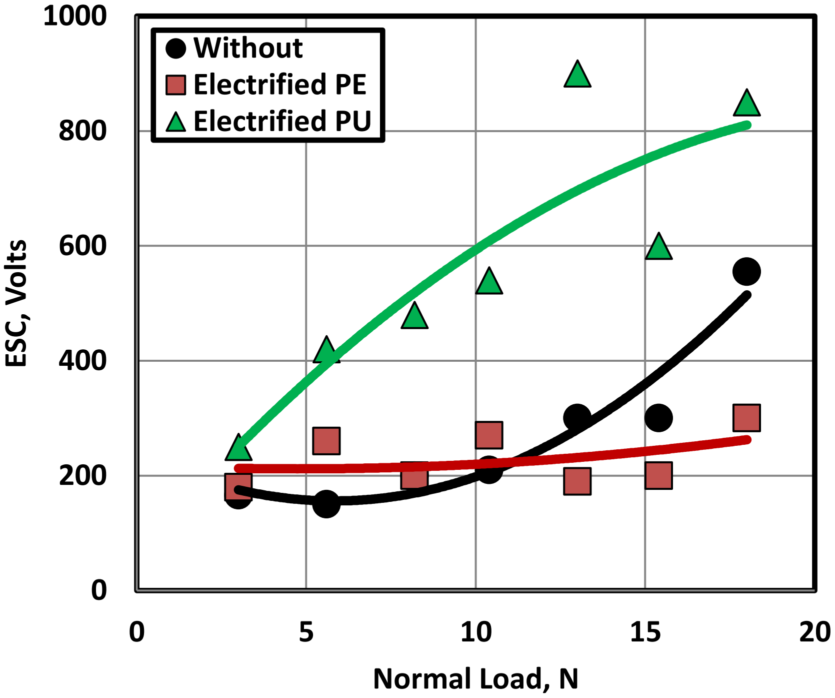


Fig. 3 ESC generated on the PU surface.

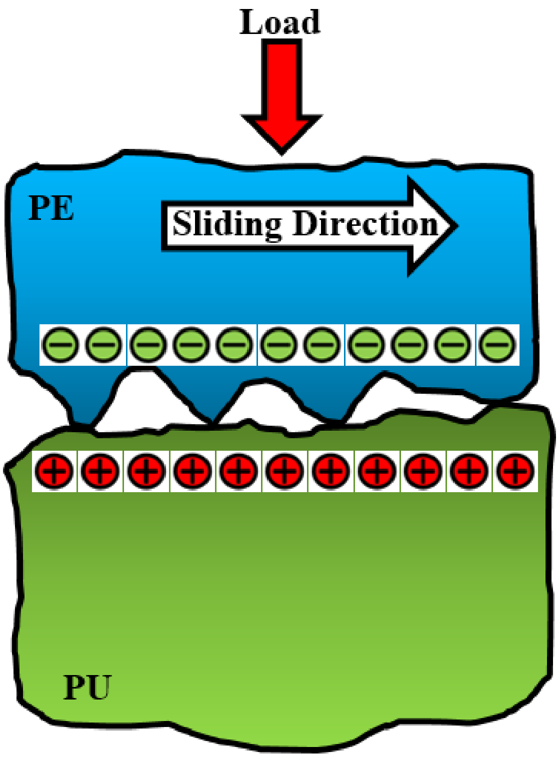
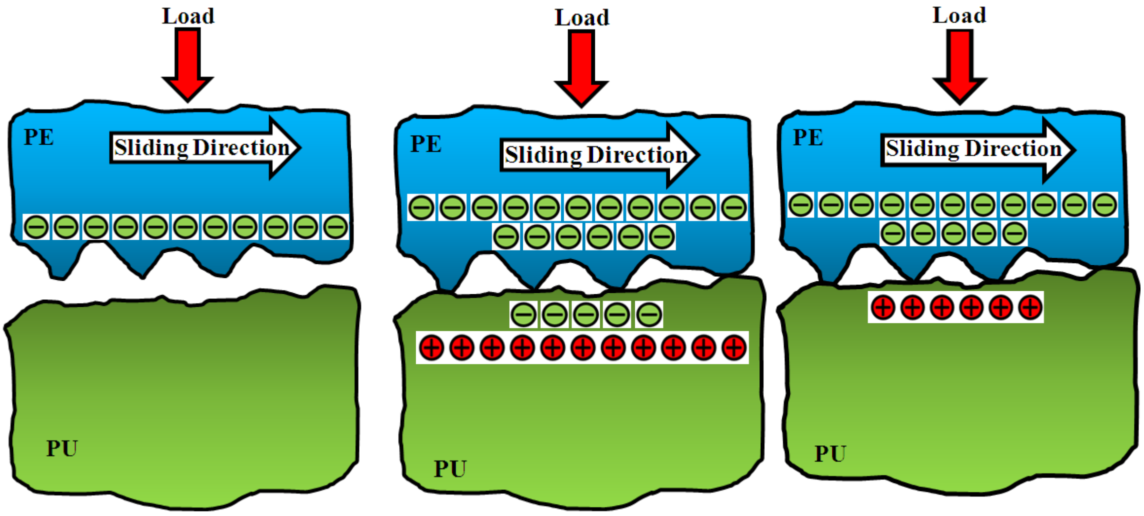
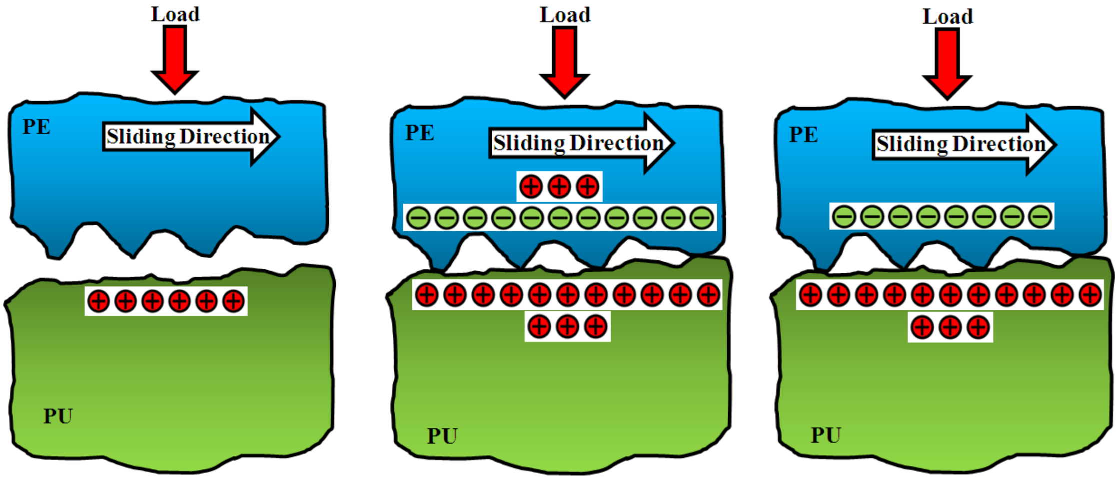


Fig. 4 ESC distribution on the friction surfaces.



Pre-triboelectrified PE. After sliding. Resultant ESC.

Fig. 5 ESC distribution on the friction surfaces for triboelectrified PE by rabbit fur.



Pre-triboelectrified PU. After contact and sliding. Resultant ESC.

Fig. 6 ESC distribution on the friction surfaces for triboelectrified PU by rabbit fur.

Friction coefficient for surfaces without pre-triboelectrification displayed the highest values due to the highest generated ESC, Fig. 7. That observation confirms that the adhesion between the two surfaces depends on the intensity of the generated ESC on their surfaces. Besides, it is necessary to consider that adhesion depends on the double layer of ESC of equal intensity. Excess of ESC on one surface does not affect the adhesion, where the adhesion between the two contact surfaces will be relatively weaker than that observed in condition of absence of pre-triboelectrification, Fig. 1.

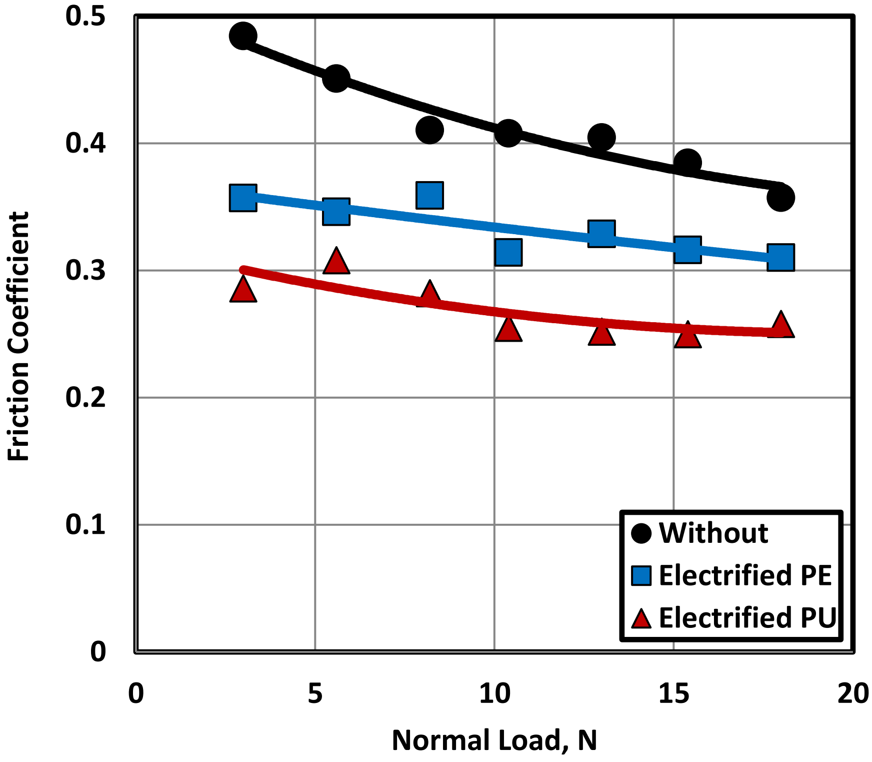


Fig. 7 Friction coefficient displayed by sliding of PE against PU coating on PP substrate.

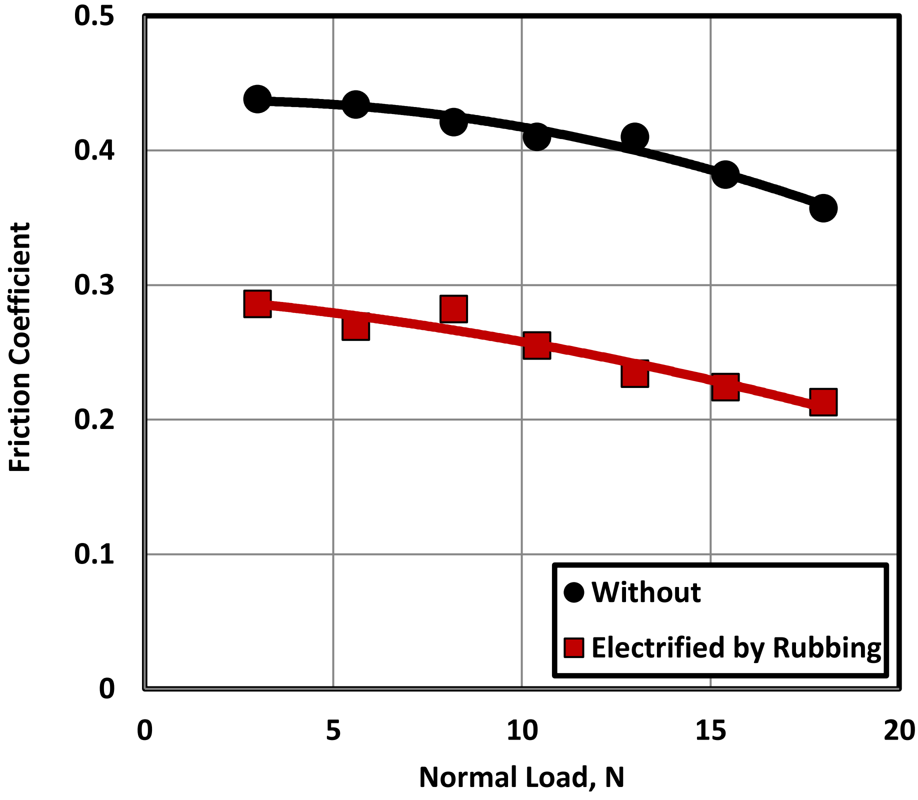


Fig. 8 Friction coefficient displayed by sliding of PE against PU.

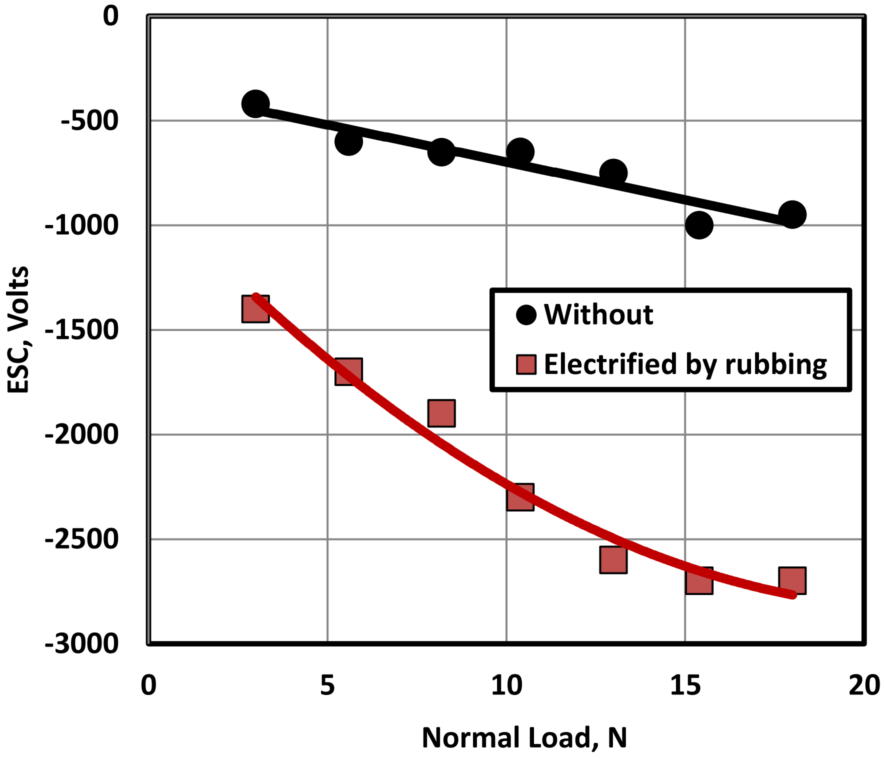


Fig. 9 ESC generated on the PE surface.

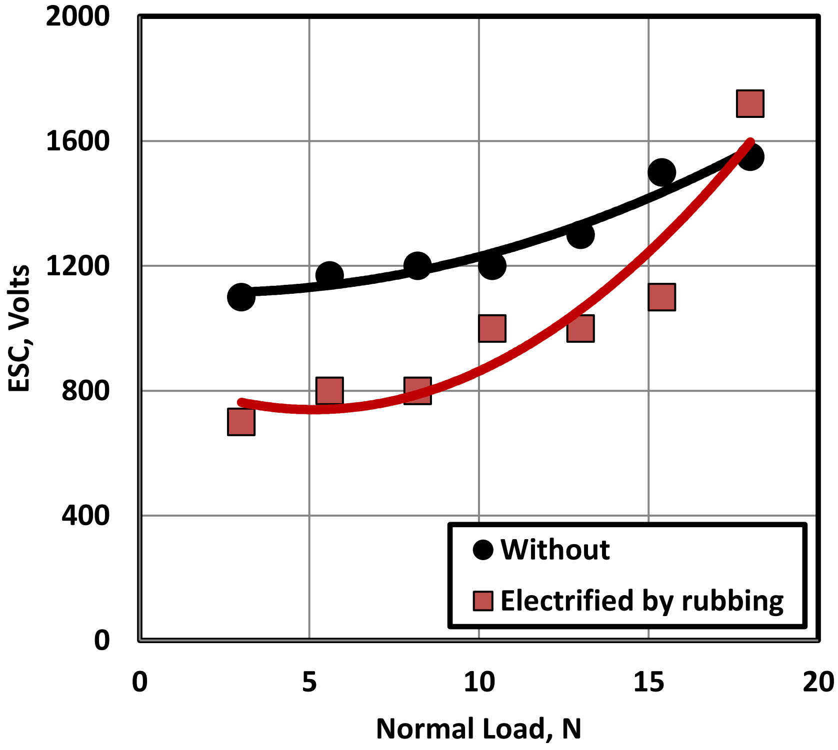
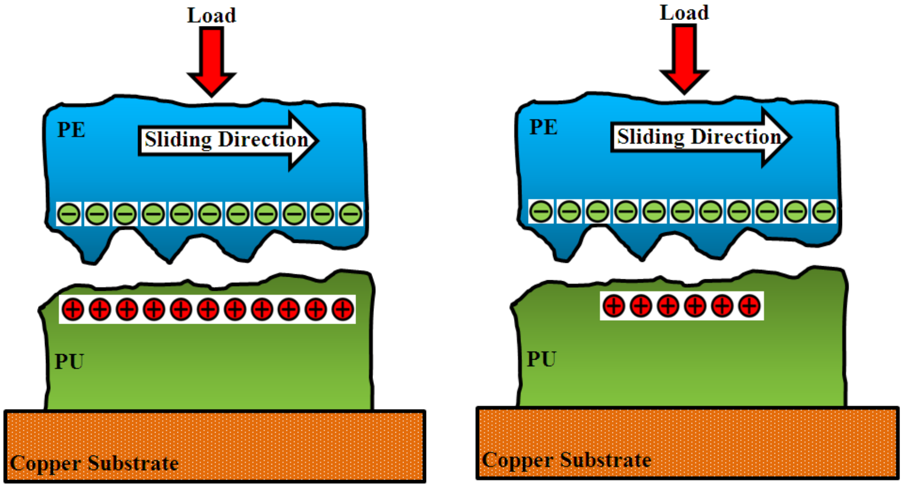
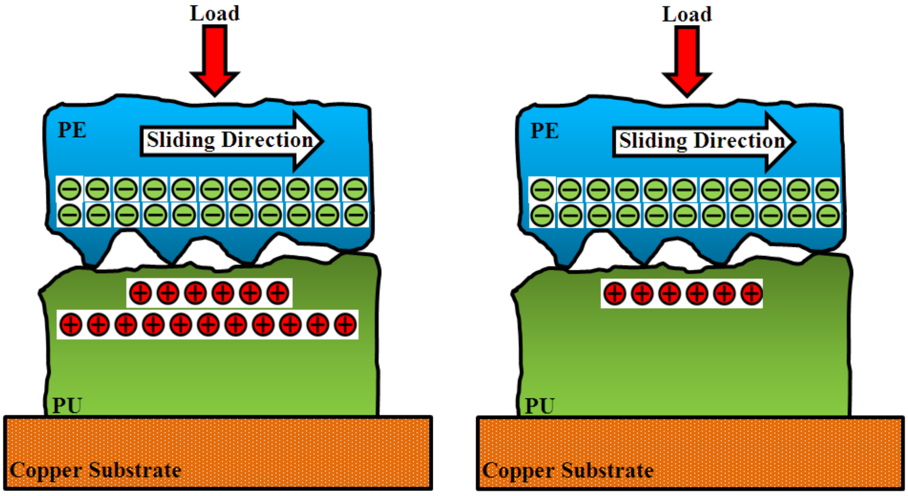


Fig. 10 ESC generated on the PU surface.



1. Pre-triboelectrified. 2. After leakage.



3. After sliding. 4. After leakage.

Fig. 11 ESC distribution on the friction surfaces for pre-triboelectrified PE and PU by each other.

The influence of the material of PU coating substrate on friction coefficient and ESC is shown in Figs. 8 – 10. Both PE and PU surfaces were rubbed together before sliding. Friction coefficient displayed by sliding of PE against PU is shown in Fig. 8, where surfaces without pre-triboelectrification displayed higher values than that pre-triboelectrified by rubbing. Besides, friction values were lower than that observed for PU coating deposited on PP substrate. This behavior can be attributed to the leakage of ESC through the copper substrate. ESC generated on the PE surface, Fig. 9, experienced higher negative values for pre-triboelectrified surfaces, while ESC generated on the PU surface showed lower values, Fig. 10. The illustration of the distribution of ESC on the sliding surfaces is in agreement with the results mentioned in Figs. 9 and 10. ESC distribution on the friction surfaces for pre-triboelectrified PE and PU by each other is illustrated in Fig. 11. The symbolic representation of the intensity of the ESC can help in interpreting the results plotted in Figs. 9 and 10 and hence the friction coefficient displayed by the two rubbing surfaces can be explained.

CONCLUSIONS

1. Measurement of pre-triboelectrified PE surface showed the highest negative ESC, while pre-triboelectrified PU gained the highest positive ESC.

2. Friction coefficient for surfaces without pre-triboelectrification displayed the highest values due to the highest generated ESC. That observation confirms that the adhesion between the two surfaces depends on the intensity of the generated ESC on their surfaces.

3. Adhesion between the sliding surfaces depends on the double layer of ESC of equal intensity. Excess of ESC on one surface does not affect the adhesion.

4. Metallic substrates leak ESC and decrease the values of friction coefficient.

5. Pre-triboelectrification of surfaces before sliding by rubbing each other reduces the values of friction coefficient.

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