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INFLUENCE OF ELECTROSTATIC CHARGE ON FRICTION OF GRIPPER IN HANDLING MATERIAL

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ABSTRACT

In the present work, the influence of application of electric field on the electrostatic charge (ESC) and the friction of the gripper in material handling is investigated. It was found that in the presence of electric field, values of ESC were higher than that recorded at no electric field. It seems that the presence of electric field increases ESC that causes an increase in friction due to the increase in the adhesion force between the two contact surfaces. When the hardness of the rubber increases, friction coefficient decreases.

The dependency of friction and ESC can be used in controlling friction coefficient. Besides, ESC can play significant role in adhesion and influence friction by the effect of the trapped charges on the defects of the sliding surfaces caused by friction. It is expected that high voltage will be generated providing extra ESC on the sliding surfaces. Based on that, adhesion between the two surfaces increases and consequently the friction increases.

KEYWORDS

Electrostatic charge, friction, rubber, gripper, textile.

INTRODUCTION

There is an increasing demand to avoid objects slipping and increase the safety of gripper in material handling through concentrating on the proper selection of the coating materials of those grippers. It was noticed that tactile action is one of the most essential properties that control the safety of the material handling. The tested materials based on their coefficient of friction in order to increasing the safety of objects that handled like fruits for example. To increase safety and efficiency, it is important to develop materials that used in robots. The force of gripping may be reduced by using surfaces high friction so, it was recommended to use suitable types of rubber act as friction reinforcing material for grippers. During increasing the force of gripping, the safety of material handling can be controlled by coefficient of friction of the contacting surfaces, [1].

Grasping, placing and carrying of objects are common operations for robots and manipulators. Grippers provide a temporary contact with the grasped objects in robot manipulations, [2]. Current grippers are specifically designed for a certain application because it is difficult to conform with wide variety of sizes and shapes. In Industrial Internet soft grippers have been developed to handle products with high surface complexity. There were some challenges still exist such as long response time and low controllability. Rigid robot grippers showed good characters like accuracy, short response time and robustness, [3]. Rubber is used in making soft grippers in order to grip several types of objects [4]. Slipping and falling of objects from gripper are caused by low friction coefficient displayed by the objects sliding on the outer surface of grippers. The risk which associated with fall and slip is related to the coating materials of gripper, pollution condition, and the geometric design of the gripper and handled objects, [5]. Rubber shows greater coefficient of friction than plastic, [6]. It was found that coefficient of friction increased with increasing the content of cotton in textile, [7]. The contact of any two surfaces make the generation of ESC phenomena, [8]. The generation of electrostatic charge decreases in the presence of stainless steel at dry contact. By increasing the number of strips, the voltage increases, [9]. When the diameter of copper wires or copper strips increased, the friction coefficient increased. In the presence of copper strips electric field is generated caused an extra generation of electrostatic charge.

The adhesion force between two contact surfaces increased with increasing the electrostatic charge, [10]. In a lot of applications which have been developed by using the electrostatic it may be very useful. When the metallic content increased, the friction coefficient slightly increased also, [11]. The experiments showed that by proper selection of convenient surface that qualities for practical use, ESC generated on sliding surfaces could be controlled. With increasing load, ESC recorded increasing trend, [12]. It is difficult to predict the behavior of electrostatic charge but in general the experiments showed that displacement had an important effect on the electrostatic charge as increasing velocity increased the voltage, [13].

In the present work, the effect of electric field on ESC and friction of the gripper in material handling is investigated.

EXPERIMENTAL

The electric field of variable strength was applied on the surface of the gripper. Then ESC generated from contact and separation as well as dry sliding of the tested objects was measured. ESC gained by contact and separation of gripper coated by latex and four outer surfaces of vegetables such as apple, potato, aubergine and zucchini that will be referred as I, II, III and VI respectively, was determined by using electrostatic meter device (Surface DC voltmeter). Friction force was measured by test rig shown in Fig. 1. At sliding, two rubber test specimens were tested of 9.7 and 11.2 Shore A hardness, Fig. 2, where the counterface was textile, Fig. 3. The two rubber test specimens in 40 × 40 mm^2 dimensions were adhered into a wooden block and rubbed against the tested textile assembled to the base of the test rig. The friction force was measured by two load cells, the first one measures the vertical force (applied load) and the second one measures

horizontal force (friction force). The friction coefficient is calculated from the ratio of friction force and normal load. During test, electric field was applied on the friction surface by copper coil, where the voltage was ranging between 0 and 7.0 volts. The applied load was ranging between 2.0 to 32.0 N.

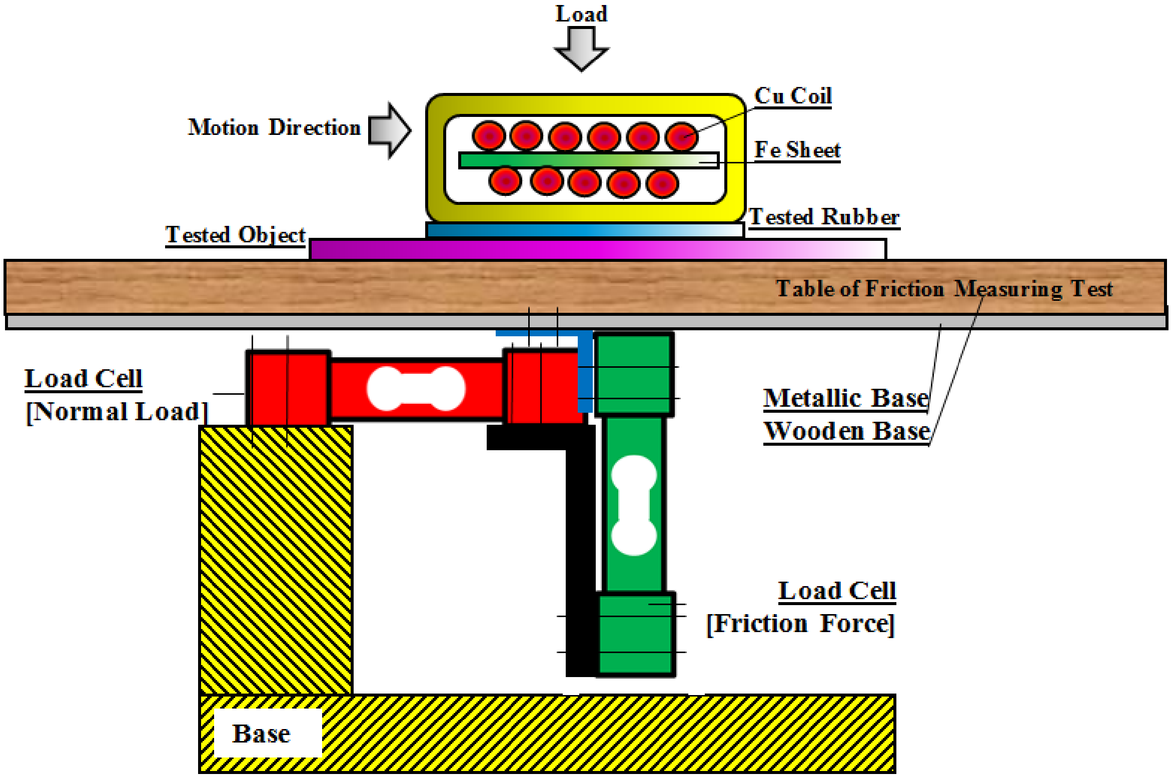
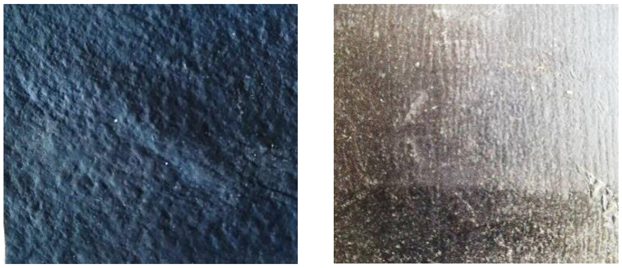


Fig. 1 The details of the test rig.



A. (9.7 Shore A) **B. (11.2 Shore A)**

Fig. 2 The tested rubber specimens.

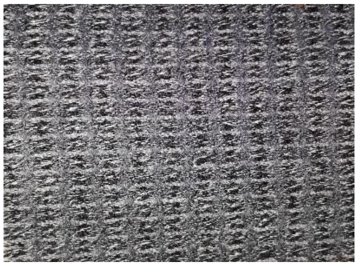


Fig. 3 The tested textile specimen.

RESULTS AND DISCUSSION

The results of the measurement of ESC generated on the two surfaces after contact and separation are shown in Figs. 4 – 11. The measurements were carried out under the effect of the electric field. The gripper surface was coated by latex, while the four counterfaces (I, II, III and IV) were the surface of the tested vegetables. ESC generated from the contact and separation of the tested gripper and object I without electric field, Fig. 4, showed that object I and the gripper gained +70 and -62 volts respectively. In the presence of electric field, Fig. 5, ESC increased to approach +98 and -98 volts for gripper and object I respectively. The same trend was observed for the three other objects II, III and VI, Figs 6 – 11. Generally, ESC significantly increased with increasing the normal load due to the increase of the contact area. The results of the experiments showed that the presence of electric field led to an increase in the ESC that increased the friction coefficient due to the increase in the adhesion force between the two contact surfaces.

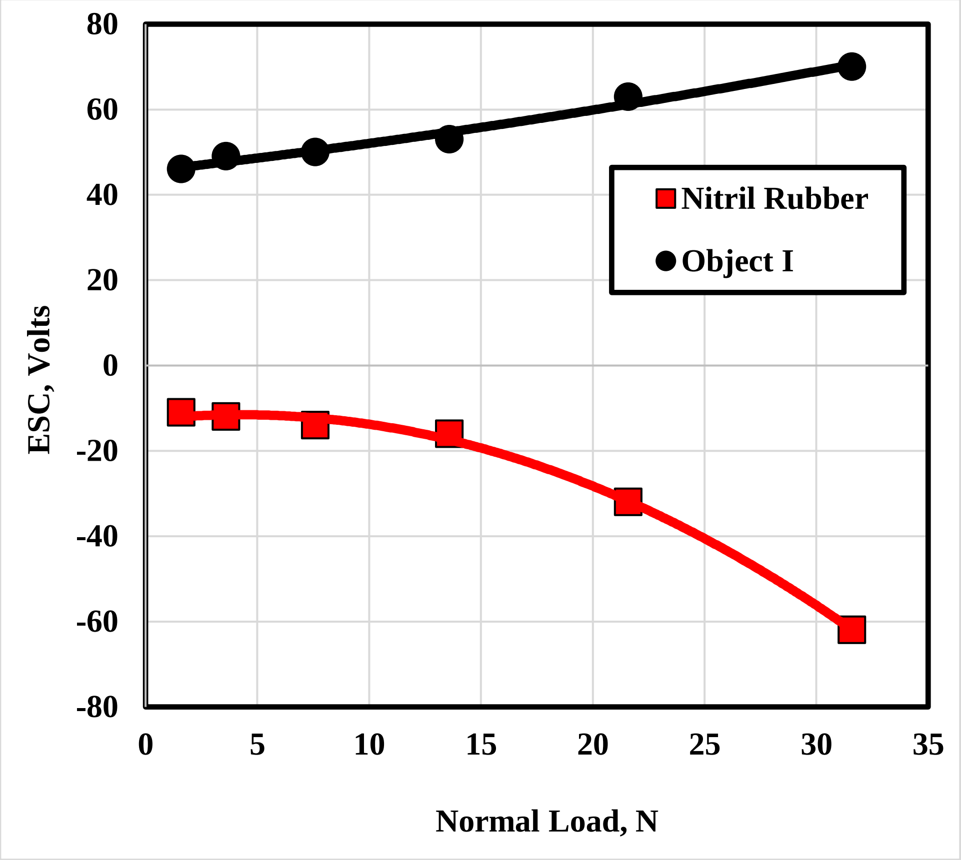


Fig. 4 ESC generated from the contact and separation of the tested gripper and object I.

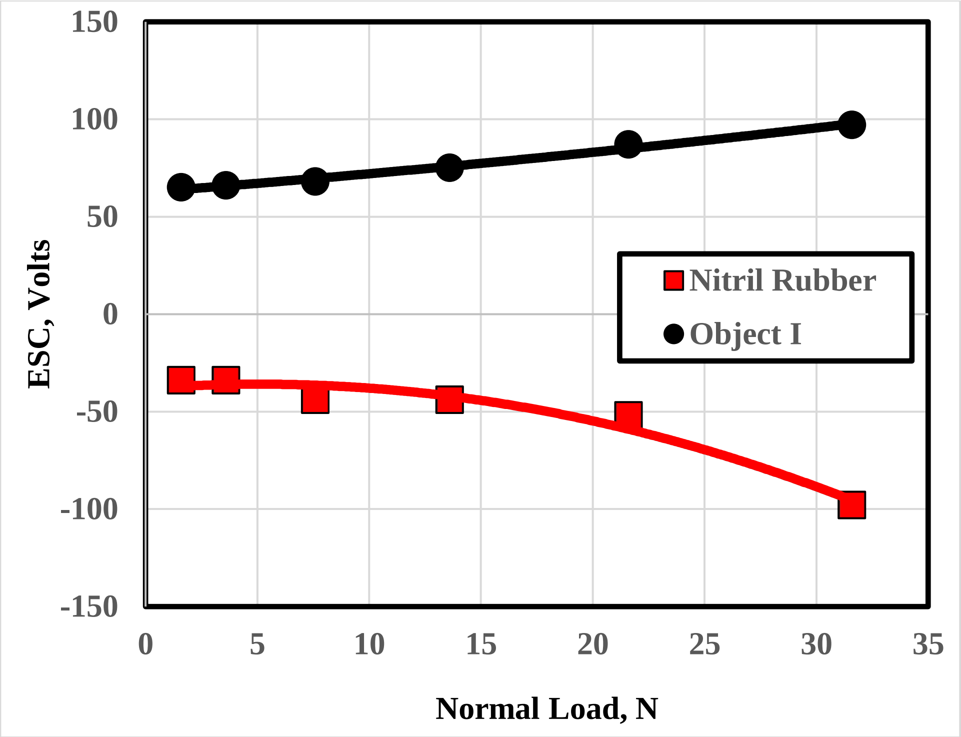


Fig. 5 ESC generated from the contact and separation of the tested gripper and object I at 7.0 volts.

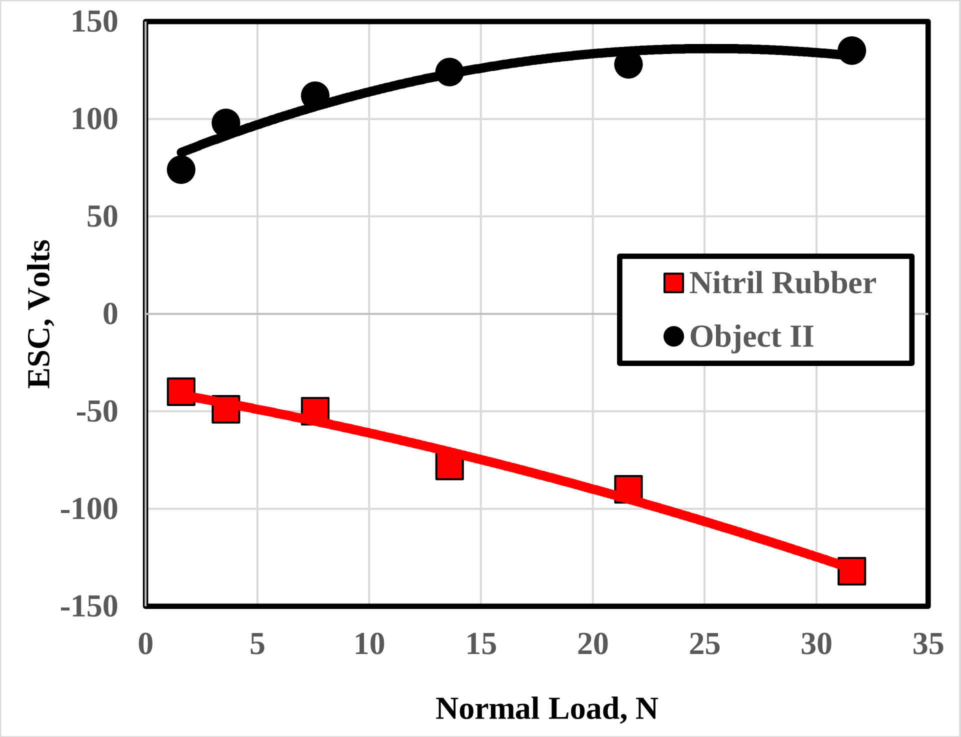


Fig. 6 ESC generated from the contact and separation of the tested gripper and object II.

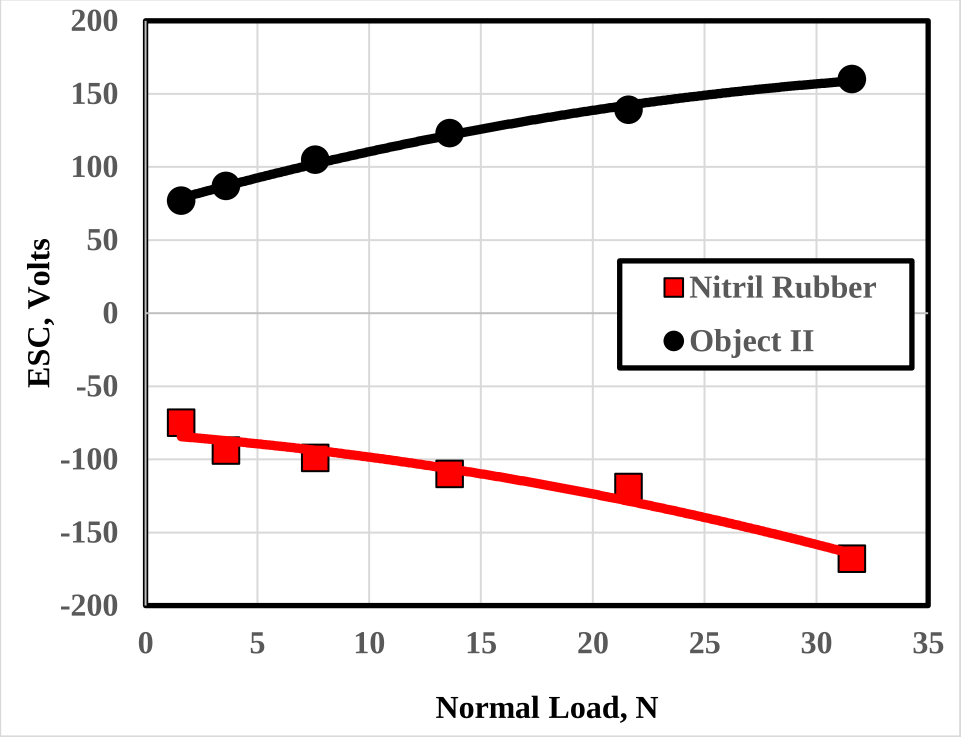


Fig. 7 ESC generated from the contact and separation of the tested gripper and object II at 7.0 volts.

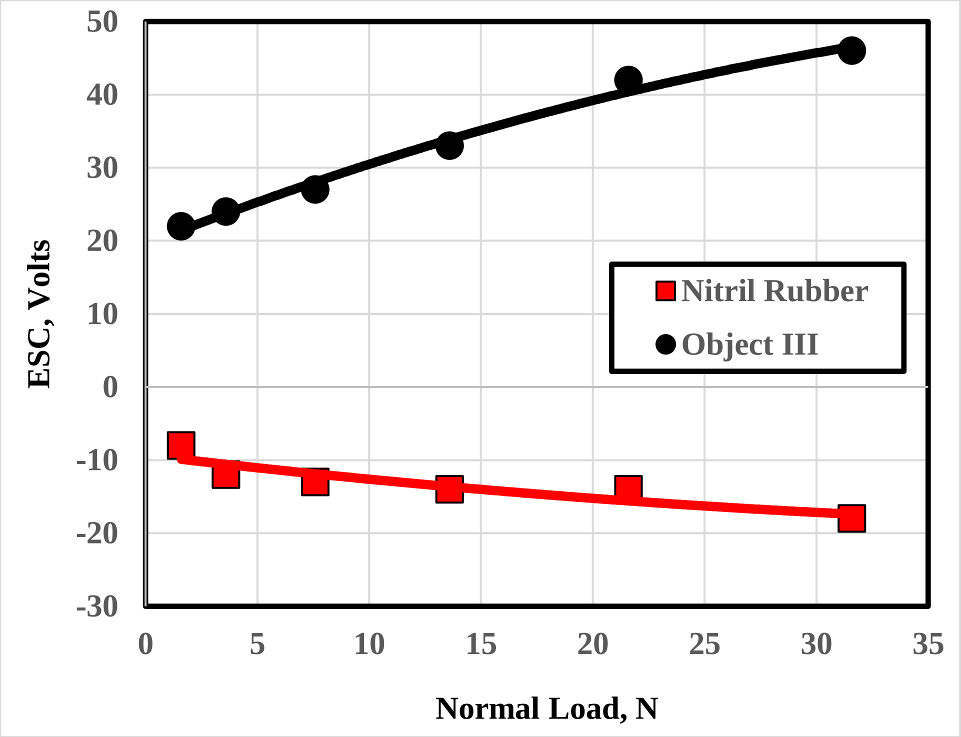


Fig. 8 ESC generated from the contact and separation of the tested gripper and object III.

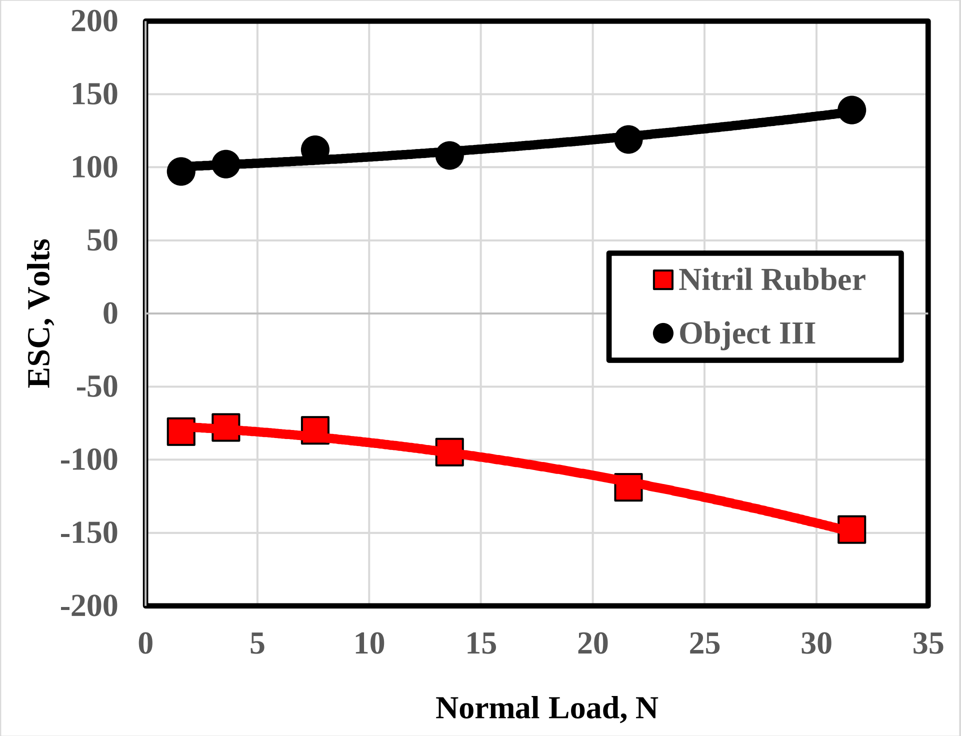


Fig. 9 ESC generated from the contact and separation of the tested gripper and object III at 7.0 volts.

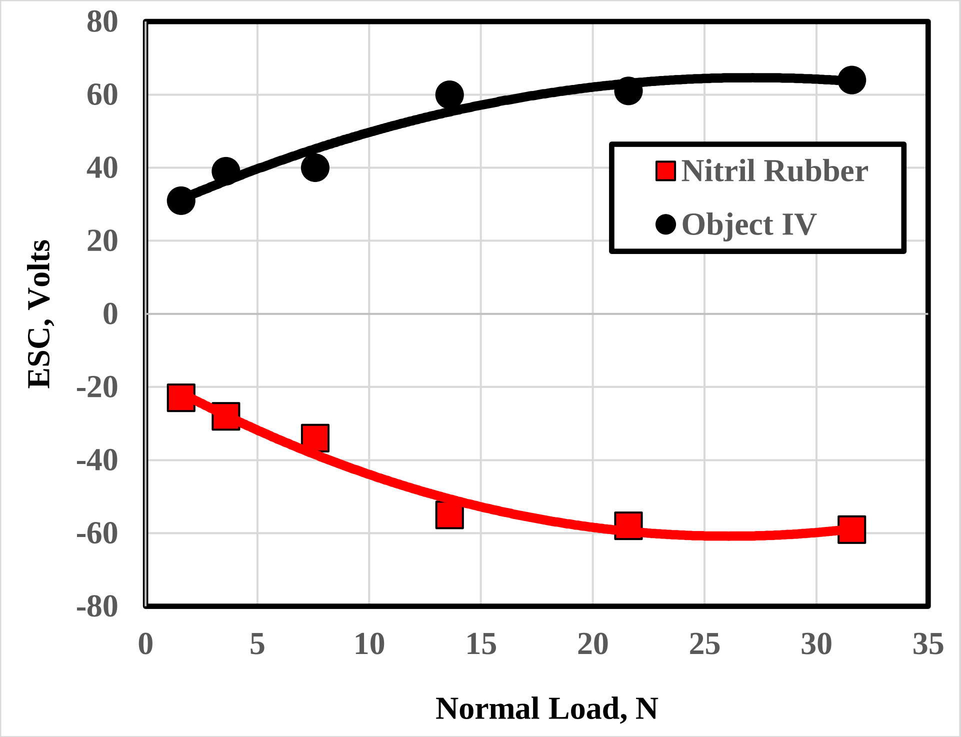


Fig. 10 ESC generated from the contact and separation of the tested gripper and object IV.

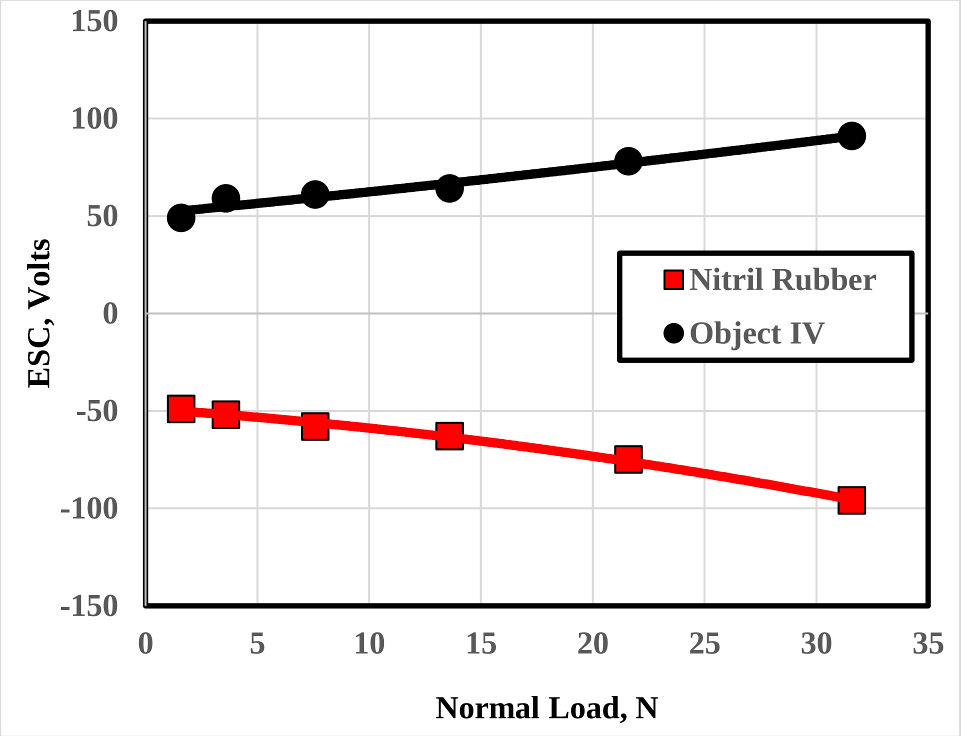


Fig. 11 ESC generated from the contact and separation of the tested gripper and object IV at 7.0 volts.

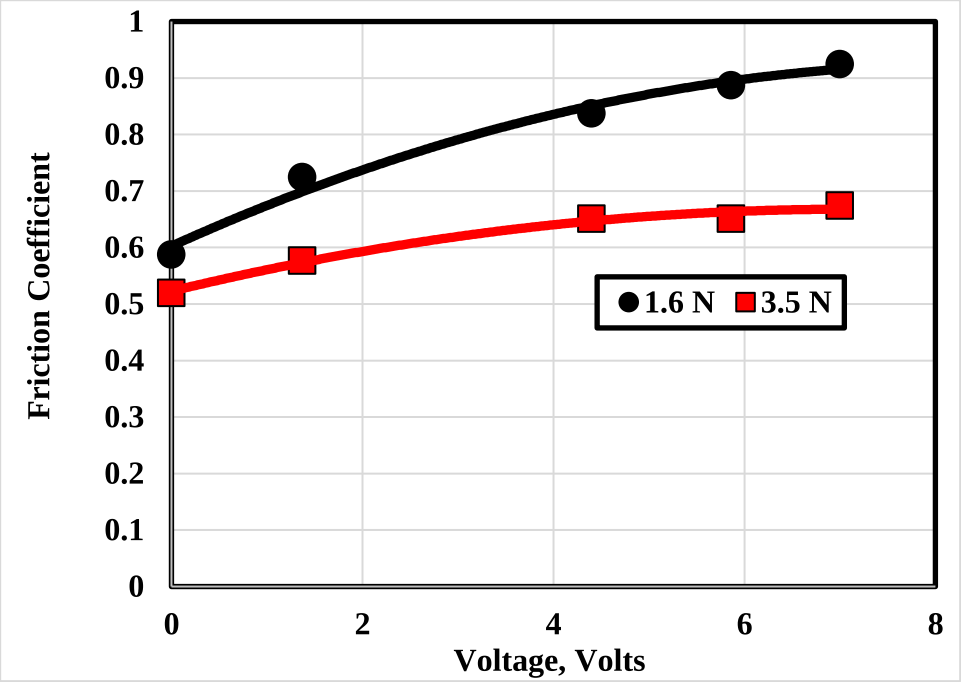


Fig. 12 ESC generated from the sliding of rubber of 7.9 Shore A hardness and the tested textile.

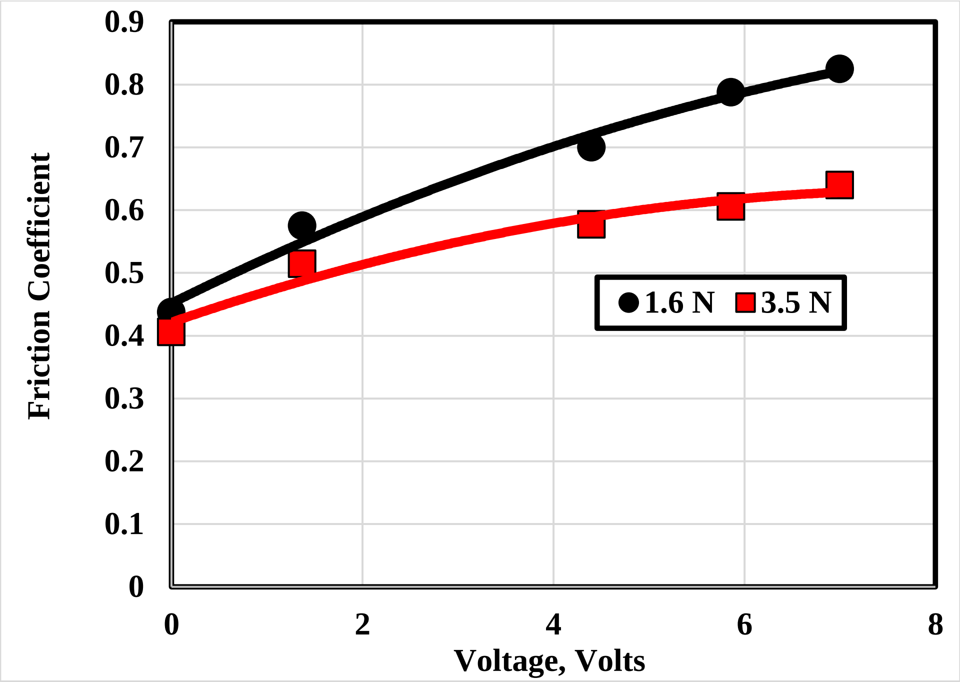


Fig. 13 ESC generated from the sliding of rubber of 11.2 Shore A hardness and the tested textile.

The relationship between friction coefficient of the rubber test specimen of 9.7 Shore A hardness against the tested textile under the application of the electric field and applied normal load of 3.5 N is shown in Fig. 12. It was observed that when the normal load increased, friction coefficient decreased. As the input voltage of the electric field increased friction coefficient increased. The same trend was observed in Fig. 13 for relatively harder rubber (11.2 Shore A hardness), where friction coefficient recorded relatively lower values. It seems that friction coefficient remarkably increased with increasing the applied voltage because of the presence of magnetic field that increased the adhesion between the two surfaces.

The experimental observations in the present work revealed that ESC increases with increasing the strength of the electric field. It is known that sliding of materials as well contact and separation transfer charge to build up on the rubbing surfaces. The charge transfer increases with increasing the number of sliding events, [14 - 16]. ESC may increase and may decrease. That variation versus sliding distance could be due to the surface transfer of previously ESC. The deformation, material transfer and surface distortion influence charge transfer.

Faraday’s law states that when an electric field moves across conductors than insulators, the magnet produces a current. The strength of the electric field is proportional to the charge generated on the friction surface. The Faraday fundamental states that if the electric conductor is moved across magnetic field, electric current flows into the conductor. Voltage can be generated by the relative motion between a conductor and magnetic field. ESC significantly increases due to the presence of the electric field. ESC has been taken into consideration on friction between the insulating materials. The

dependency of friction and ESC of alumina sliding against polytetrafluoroethylene (PTFE) under boundary lubrication conditions, was investigated. It is known that specific information about ESC can be used in controlling friction coefficient.

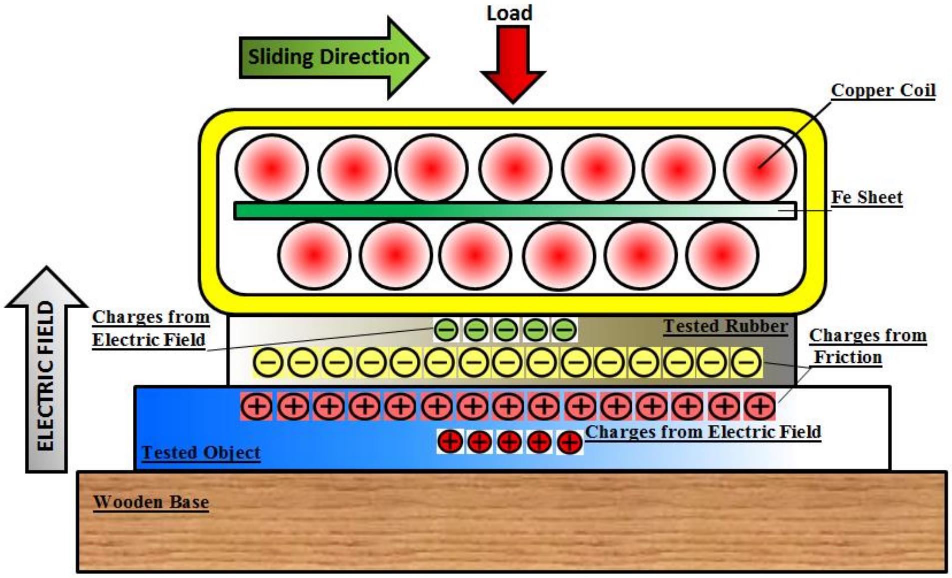


Fig. 14 Illustration of the generation of extra ESC on the sliding surface as result of the electric field.

It was proved that ESC generated on the surfaces of insulating materials can trap charges. Then ESC can play a major role in adhesion and influence friction by the effect of the trapped charges. During sliding, the deformation of the surface leads to ionic and atomic polarization, [18 - 20]. This behavior leads to generate electric field. ESC can be trapped on defects where the surface becomes charged, [21, 22]. Friction induces transfer of ESC by triboelectrification, [23, 24], followed by generation of electric field.

Triboelectrification depends on the friction, pressure, sliding distance, contact area and sliding history. During the contact of the two surfaces, only the summits of the asperities will be in contact while the most areas of the surfaces will be separated. It is expected that the true area of contact will be much lower than the apparent area. As the load increases or the surface becomes rougher, the pressure on the asperities approaches the plastic yield strength. For repeated sliding, electrons may be released from surface traps, [25 – 27]. New traps are introduced in the sliding surfaces. As mentioned before, when an electric field and a wire move relative to each other the voltage is induced. In the present study, copper coil represents the wire, and the electric field is generated from ESC generated from friction. It is expected that voltage will be generated on the sliding surface providing extra ESC on the sliding surfaces, Fig. 14. Based on that, adhesion between the two surfaces increases and consequently the friction increases.

CONCLUSIONS

1. ESC significantly increased with increasing the normal load due to the increase of the contact area.

2. In the presence of electric field, values of ESC was higher than that recorded at no electric field. It seems that the presence of electric field led to an increase in the ESC that increased friction coefficient due to the increase in the adhesion force between the two contact surfaces.

3. Friction coefficient significantly increased with increasing the applied voltage due to the increase of the intensity of the electric field that increased the adhesion between the two surfaces.

4. When the hardness of the rubber increases, friction coefficient decreases.

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