EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 16, No. 3, July 2019, pp. 15 – 25 ISSN 2090 - 5882
(Received February 25. 2019, Accepted in final form May 05. 2019) www.egtribjournal.com

INCREASING FRICTION COEFFICIENT DISPLAYED BY SLIDING BETWEEN THE FOOTBALL AND THE GLOVES OF THE GOALKEEPER

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ABSTRACT
The present work aims to investigate the friction coefficient between different gloves and football surfaces in order to provide a suitable high friction and safe coating surface for goalkeeper gloves. It is planned to make use of the generated electrostatic charge (ESC) on the rubbed surfaces to increase friction coefficient. The experimental work has been divided into three branches; the first to explore the best material with the highest friction coefficient. The second is to investigate the correlation between friction coefficient and ESC. Thirdly, to make use of the generated ESC to enhance the grip force or the friction coefficient between the glove and the ball surfaces.

Experimental results showed correlation between friction coefficient and the electrostatic ESC of the rubbed surface. Inserting copper coil inside the inner lining located underneath the glove surface enhanced friction coefficient. Besides, inserting a lining made of a paper sheet covered by iron microparticles slightly enhances the friction coefficient. The results for iron particles yet showed lower results than those of copper wires.

KEYWORDS
Friction coefficient, electrostatic charge, sliding, football, gloves, goalkeeper, copper wires, iron particles.

INTRODUCTION
In football game it is unavoidable and unforgivable mistake for the goal keeper to get off the ball from his hand. Goalkeeper needs gloves to keep his hand safe and enhance his ability to catch the ball. This ability can be developed by controlling the friction between gloves and the football. Quantitative measurements of friction coefficient between gloves and the ball surfaces, [1], as well as electrostatic charge (ESC) generated on the surface of the gloves, [2]. 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.

In Australia Football players are allowed to wear gloves to keep their hand safe. The friction between hand and ball in rugby was studied, [3, 4], using three different gloves

and the bare hand. Visualization of the handling of four pimple patterns of the ball at dry and wet conditions was discussed, [5, 6]. Friction coefficient increases up to maximum then decreases with increasing velocity or normal force, [7]. Friction testing machine was developed to test the interaction between soccer ball materials and artificial turfs, [8]. The friction is measured by monitoring changes in torque through the use of an inline torque transducer. 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, [9, 10]. The gloves should be designed to prevent bending backwards of the fingers when saving, [11], and allow the fingers to flex forwards to catch the ball. Gripping forces may be reduced using high-friction surfaces, [12]. Thus, foamy polymers were selected 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, [13]. Variety of materials such as foamy polymers and sandwich-like microstructures, [14 and 15], were tested as shoe soles for potential robot.

The electrostatic charge generated from the friction of polytetrafluoroethylene (PTFE) textiles was tested to propose developed textile materials with low or neutral electrostatic charge which can be used for industrial application especially as textile materials, [16]. Research on electrostatic discharge (ESD) ignition hazards of textiles is important for the safety of astronauts. The likelihood of ESD ignitions depends on the environment and different models used to simulate ESD events, [17]. Materials can be assessed for risks from static electricity by measurement of charge decay and by measurement of capacitance loading, [18]. The effect of reinforcing PE by copper wires on the generation of ESC when slid against PTFE, polypropylene (PP), and polyamide (PA) has been investigated, [19 - 22]. It was found that, reinforcing PE by carbon fibers and metallic wires sliding against PA recorded relatively higher values of ESC than that observed for unreinforced PE. Steel wires showed the highest values followed by carbon fibers while the lowest values were displayed by copper wires. That behviour can be interpretted on the basis that the double layer of the electrostatic charge (ESC) generated on the sliding surfaces of PE and PA would generate an E-field inside the matrix of PE. Presence of carbon fibers or metallic wires inside PE matrix would generate extra electrostatic charge on the sliding surfaces. Besides, ESC generated from PE reinforced by copper wires sliding against PA increased with increasing wire diameter. It seems that the intensity of the E-field increased with increasing the copper diameter due to the increase of electric current flowing through the wire leading to the increase of the E-field.

The aim of this experimental research was to investigate the friction of the gloves against a football surface in order to provide a suitable high friction and safe coating surface for goalkeeper gloves. In addition, studying the effect of ESC generated from friction on the friction coefficient between glove surface and football.

EXPERIMENTAL

Three gloves of different outer layer were tested, cotton, polyester and styrene butadiene copolymer. Copper wires of 0.1 mm diameter were wrapped on paper sheet of 0.5 mm thickness and 50 × 50 mm^2 area of 100 turns and inserted in the inner lining close to the palm. Besides, the copper wires were replaced by iron particles of 30 – 50 μm particles size

adhered to paper sheet. The friction coefficient was evaluated using a test rig, Fig. 1, through measuring the friction force and applied normal force. The tested gloves are placed in a base supported by two load cells, the first measures the horizontal force (friction force) and the second measures the vertical force (applied load), where friction coefficient was determined by the ratio between the two forces. Loads of values up to 100 N, are applied by hand pressing the ball into the surface of the glove and sliding the ball on it, Fig. 2. The friction force was measured just after the sliding of the ball to calculate the static value of friction coefficient. Tests were carried out for unfilled gloves and those inserted by copper wires and iron particles. The outer cover of football is made of polyurethane. The details of inserting copper wires and iron particles are shown in Figs. 3 and 4. Precautions were considered in order not to influence the topography of the glove upper surface.

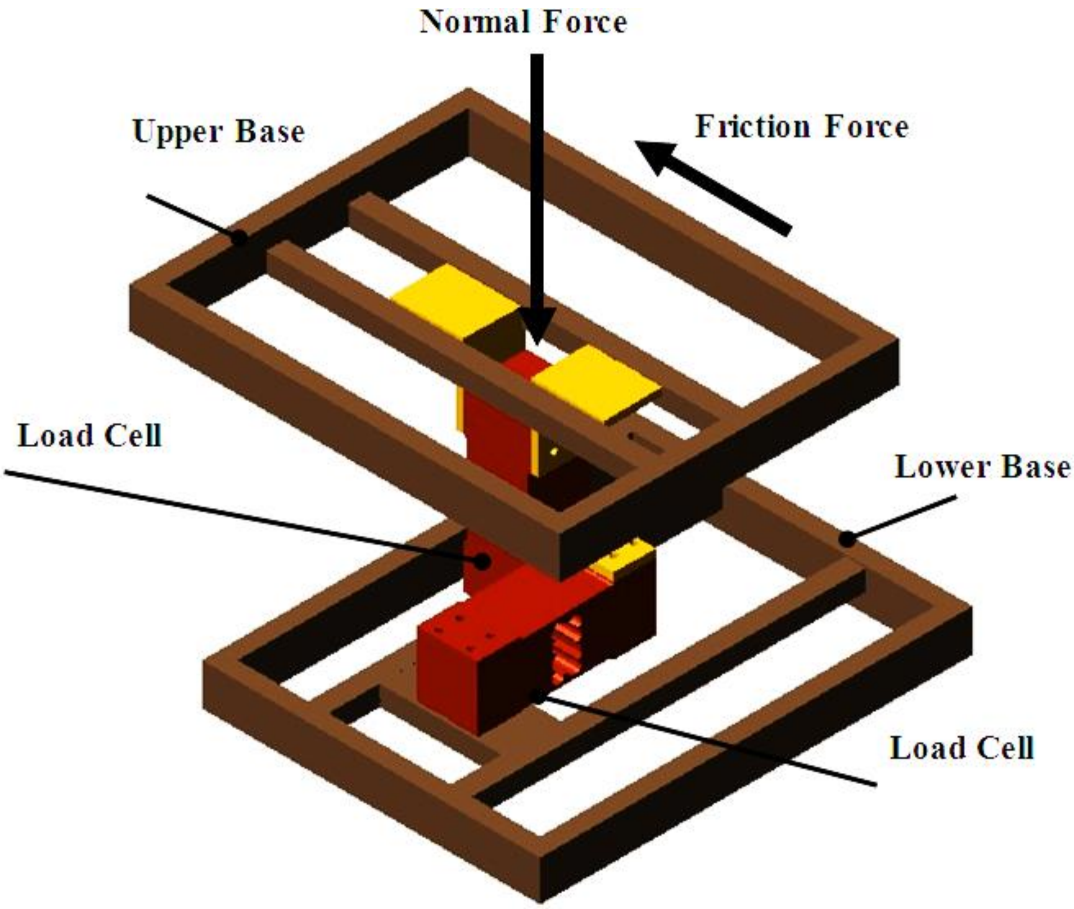

Fig. 1 Arrangement of test rig.

Fig. 2 Measurement of friction force between the football and the glove.

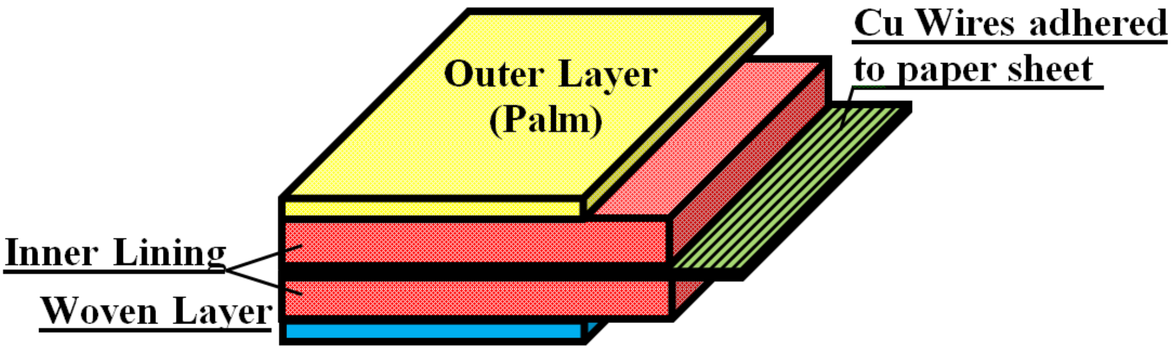

Fig. 3 Illustration of inserting copper wires inside the inner lining.

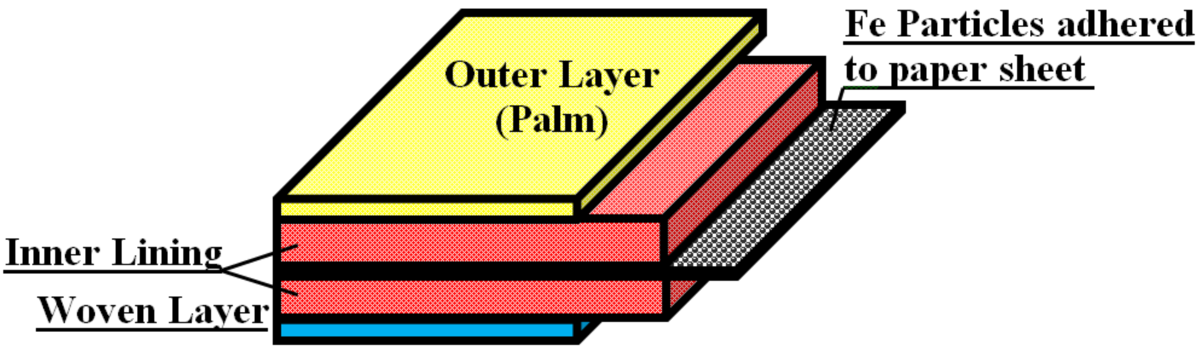

Fig. 4 Illustration of inserting iron particles inside the inner lining.

RESULTS AND DISCUSSION

The experimental results of measuring friction coefficient showed that cotton coated gloves displayed decreasing trend of friction values, Fig. 5, with increasing applied load. This behavior is familiar for cotton, where the load increases the pressure applied on the

fiber fringes, flattens them and makes their surface smoother. In consequence, friction coefficient decreases, [23]. The second explanation indicated that the fringe behaves more like a sheet of fibers, presenting more uniform area of contact, [24, 25], and leading to the decrease of friction coefficient. Presence of Fe particles caused significant friction increase, while presence of copper wires pronounced higher friction. This behavior is confirmed by the measurement of ESC generated on the glove surface represented in Fig. 6. Inserting Copper wires inside the inner lining generated the highest value of ESC followed by glove containing Fe particles.

It was observed that ESC increases in the presence of Cu wires. Sliding of materials cause the charge to build up, then the charge eventually diminishes again and becomes zero. The charge variations during sliding distance suggest that, the charge does not always build up uniformly as sliding proceeds. These variations could be due to random contamination of the surface transfer of previously charged surface. Material transfer and surface distortion plays significant role in charge transfer. The deformation occurs during sliding must surely disturb the positions of the surface molecules by large amounts.

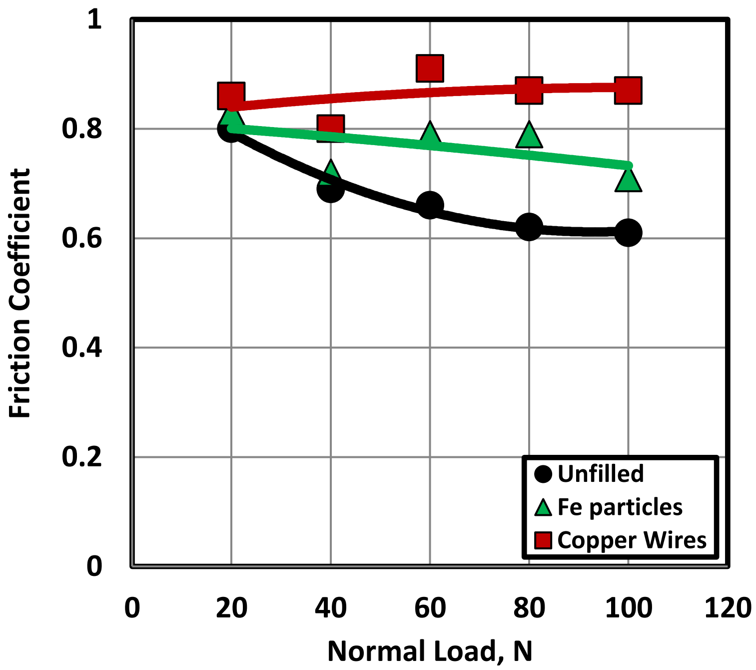

Fig. 5 Friction coefficient displayed by the football sliding against cotton coated gloves.

Based on Faraday's law when an electric field moves past different materials, the magnet will produce a larger current when moving past conductors than insulators. Presence of copper wires or Fe particles will increase the current flowing in the wires. According to Faraday, electric fields are created in any region of space where a magnetic field is changing with time, while according to Maxwell, magnetic field is created in any region of space where an electric field is changing with time.

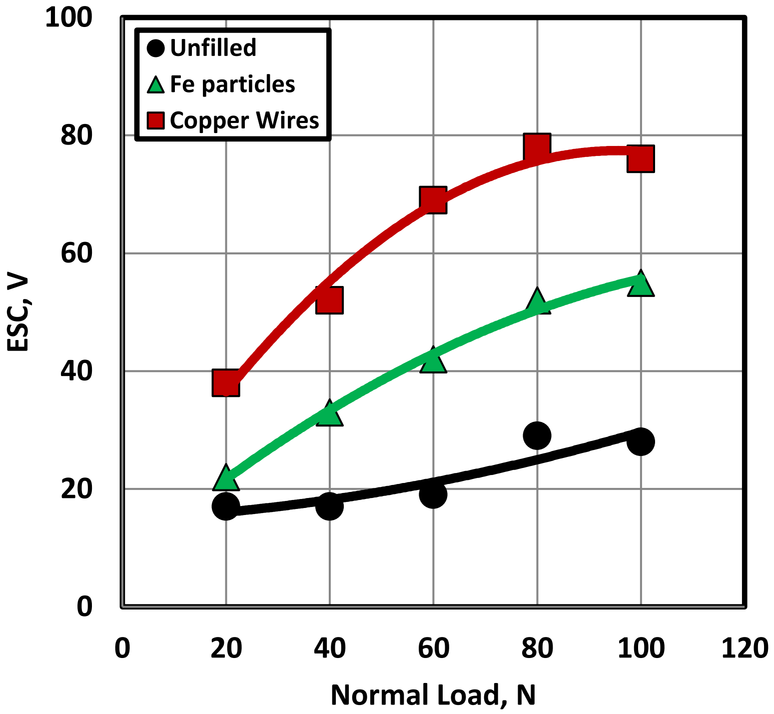

Fig. 6 ESC generated on the surface of cotton coated glove.

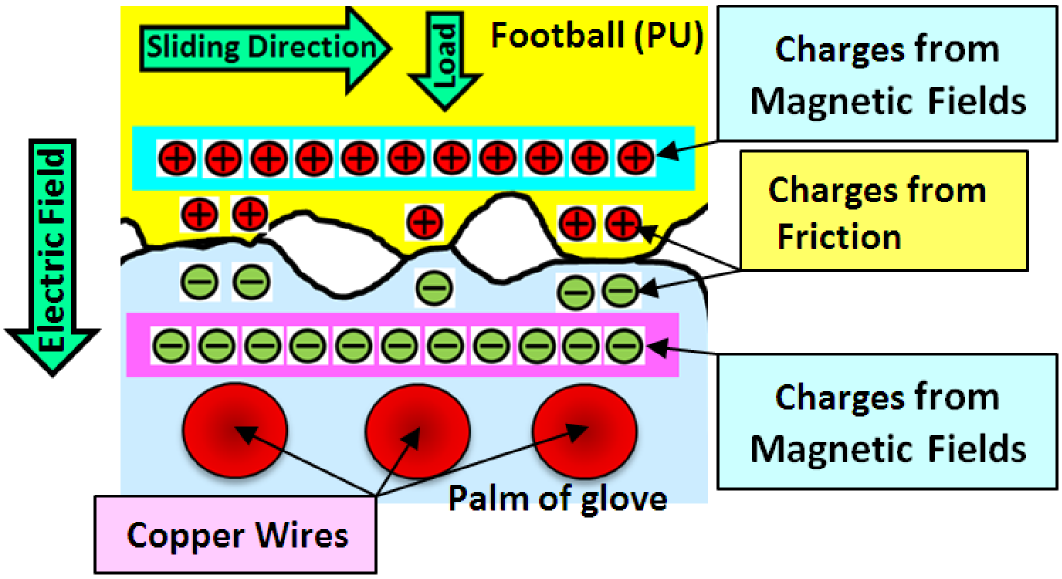

Fig. 7 Illustration of generation of ESC on the surfaces of football and gloves.

The strength of the electric field inside the polymer matrix is proportional to how much charge is generated on the friction surface. Faraday indicated that the change of the flux over time may induce a current in the copper wires and thus create a source of EMF (voltage, potential difference). The Faraday principle states that if an electric conductor is moved through a magnetic field, or a magnetic field moves through the conductor, electric current will be induced and flow into the copper wires. The induced current creates an induced magnetic field. Since an electric current could cause a magnetic field, a magnetic field should be able to produce an electric current. Voltage is induced in the wire loop whether the magnetic field moves past the wire or the wire moves through the magnetic field, Fig. 7. Voltage can be induced by the relative motion between copper wires and magnetic lines of force.

Gloves covered by polyester layer displayed lower friction values than that recorded for cotton gloves, Fig. 8. Applying Fe particles as well as copper wires exhibited friction increase up to 41 % and 59 % respectively. That result can be explained on the basis of generating high intensity of ESC as shown in Fig. 9. The strong ability of polyester to generate higher ESC is responsible for the increase of friction coefficient. At 100 N load, unfilled glove coated by polyester generated ESC of 2800 volts. Then ESC increased to 3800 and 9900 volts for gloves inserted by Fe particles and copper wires respectively.

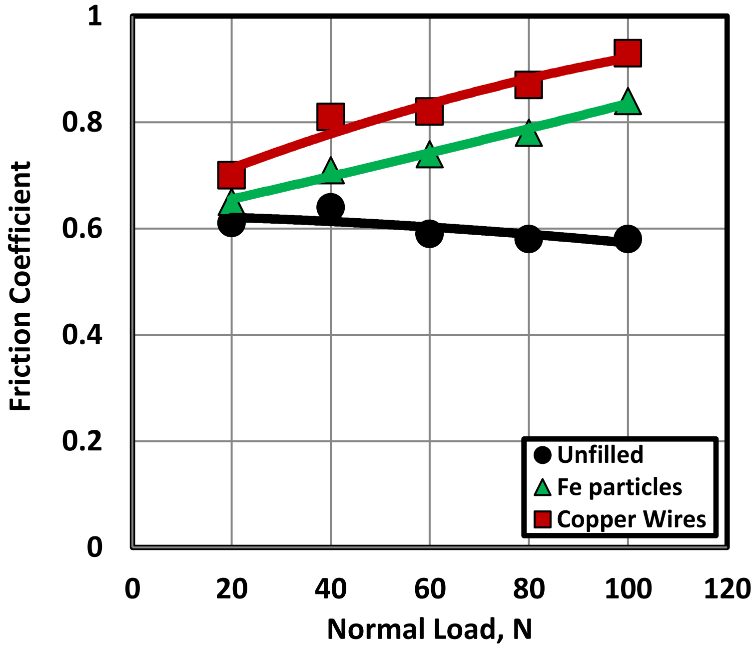

Fig. 8 Friction coefficient displayed by the football sliding against polyester coated gloves.

Styrene butadiene coated glove displayed decreasing friction trend with increasing load, where friction coefficient decreased from 0.86 to 0.57 at 20 and 100 N load respectively, Fig. 10. Inserting Fe particles increased friction values with load increase. In the other side, copper wires caused significant friction increase, where the highest value exceeded 1.1 at 100 N load, while the lowest values were close to 0.9 at 20 N load. The relatively high friction difference confirms the suitability of applying the copper wire insertion inside the sport gloves. Values of ESC values, Fig. 11, generated on the glove surface were lower than that observed for polyester coated glove and higher than that measured for cotton coated one.

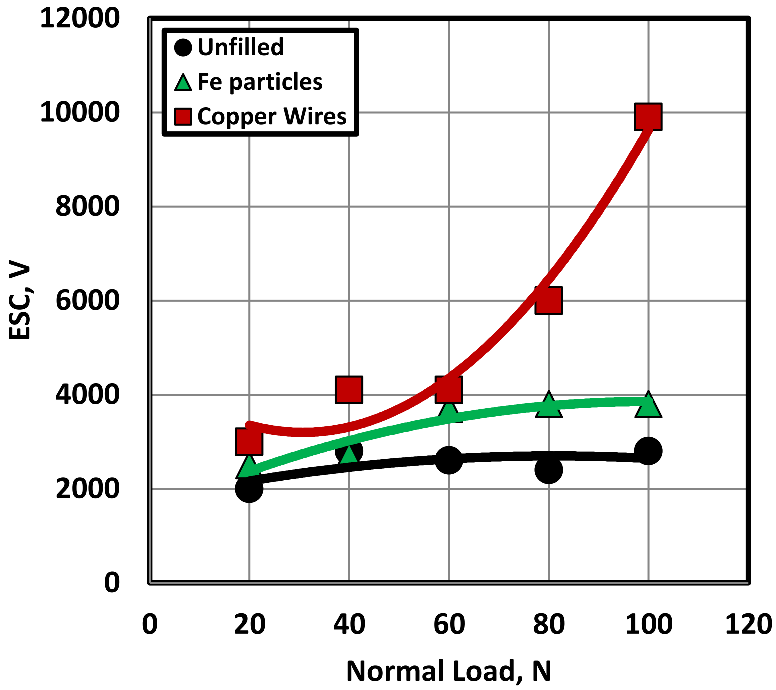

Fig. 9 ESC generated on the surface of polyester coated glove.

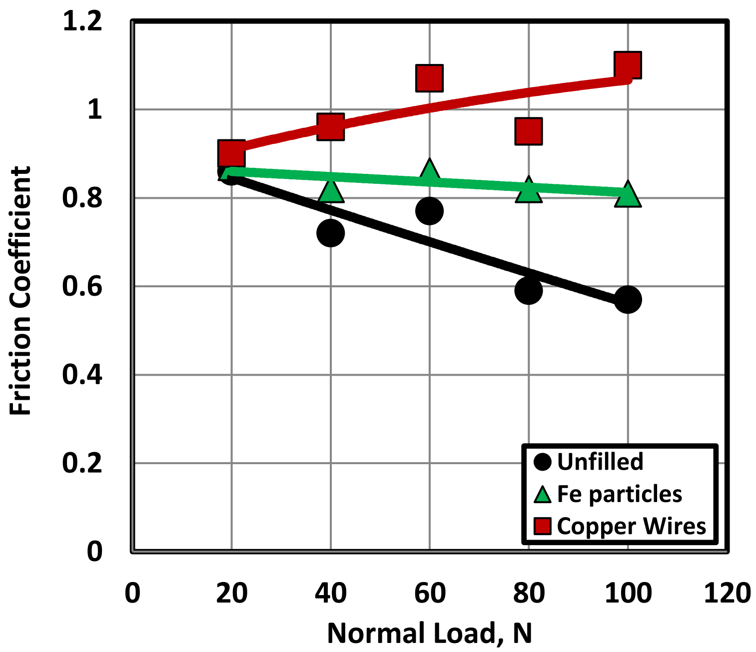

Fig. 10 Friction coefficient displayed by the football sliding against styrene butadiene copolymer coated gloves.

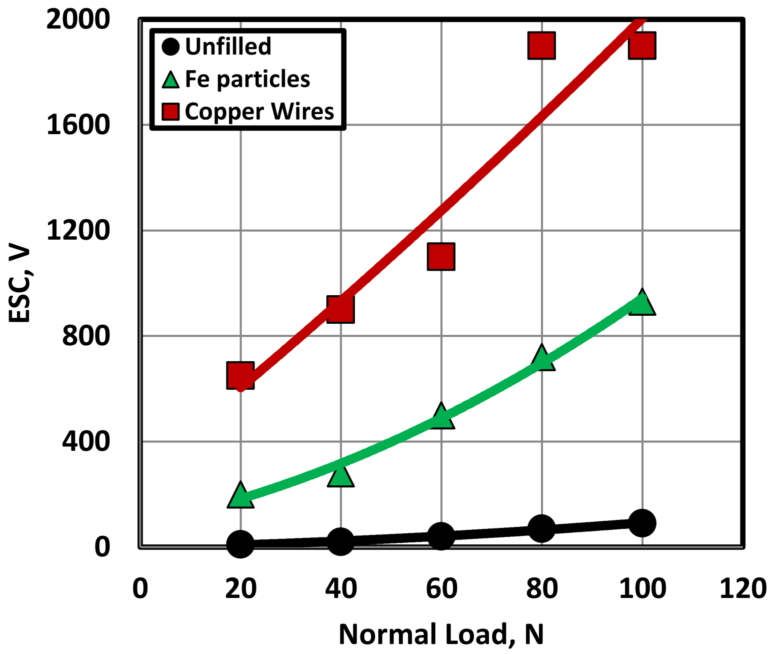

Fig. 11 ESC generated on the surface of styrene butadiene copolymer coated glove.

It is necessary that gloves designed for football goalkeepers should provide them with high efficient catching and holding of the ball and enable the goalkeeper to catch and punch a ball away. The gripping ability of the glove is the main factor to evaluate its quality. It should provide an adequate grip and tactile response under a wide range of conditions. Finally, football can be more competitive and exciting by providing highly advanced polymer coated gloves that enable one-handed catches. On the other side, the health of goalkeepers 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.

CONCLUSIONS

1. Unfilled gloves displayed decreasing trend of friction values with increasing applied load.
2. Presence of Fe particles caused significant friction increase, while presence of copper wires pronounced relatively higher friction.
3. ESC increases in the presence of Cu wires.
4. Gloves covered by polyester layer displayed lower friction values than that recorded for cotton gloves. Applying Fe particles as well as copper wires exhibited significant friction increase.
5. Styrene butadiene copolymer coated glove displayed the highest friction values. Inserting Fe particles increased friction values with load increase.
6. Inserting copper coil inside the inner lining located underneath the glove surface increased the friction coefficient. Fe particles showed weaker effect than that of Cu wires.

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