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ELECTROSTATIC CHARGE GENERATED FROM THE SLIDING OF THE FOOTBALL ON THE GLOVES OF THE GOALKEEPER

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ABSTRACT
It is necessary to study the electrification of engineering materials. The increased uses of polymeric materials raised the importance of studying that effect. It is well known that when two different materials contact each other, they may get charged. Electrostatic charges (ESC) generated from friction of engineering materials have a negative effect in the health of the peoples. In football, goalkeeper needs gloves to keep his hand safe and enhance his ability to catch the ball. The aim of the present work is to make quantitative measurements of the electrostatic charge generated from the sliding of the ball against the glove surface.

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.

KEYWORDS
Electrostatic charge, sliding, football, gloves, goalkeeper.

INTRODUCTION
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, [1]. 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.

The friction between hand and ball in rugby was studied, [2, 3], 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, [4, 5]. Friction coefficient increases up to maximum then decreases with increasing velocity or normal force, [6]. Friction testing machine was developed to test the interaction between soccer ball materials and artificial turfs, [7]. 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, [8, 9]. The gloves should be designed to prevent bending backwards of the fingers when saving, [10], and allow the fingers to flex forwards to catch the ball.

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. This tribocharging phenomenon is also known as triboelectrification when materials rub each other, [11]. The mechanism of charge transfer in tribocharging can be explained by three mechanisms: electron transfer, ion transfer, and material transfer. The electric static charge generated from the friction of different polymeric textiles sliding against cotton, which used as a reference material, was discussed, [12]. Experiments were carried out to measure the electric static charge 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 increase of cotton content decreased the generated voltage. Besides, as the load increased voltage generated from rubbing of 100 % spun polyester specimens increased. Besides, mixing polyester with rayon (viscose) showed the same behavior of mixing it with cotton. Generally, increasing velocity increased the voltage. The voltage increase with increasing velocity may be attributed to the increase of the mobility of the free electrons to one of the rubbed surfaces. The fineness of the fibres much influences the movement of the free electrons.

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, [13]. Test specimens of composites containing PTFE and different types of common textile fibers such as cotton, wool and nylon, in a percentage up to 50 vol. % were prepared and tested by sliding under different loads against house and car padding textiles. Ultra surface DC Voltmeter was used to measure the electrostatic charge of the tested textile composites. The results showed that addition of wool, cotton and nylon fibers remarkably decreases the electrostatic discharge and consequently the proposed composites will become environmentally safe textile materials.

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, [14]. Materials can be assessed for risks from static electricity by measurement of charge decay and by measurement of

capacitance loading, [15]. Tribology is the science and technology of two interacting surfaces in relative motion and of related subjects and practices. The popular equivalent is friction, wear, and lubrication, [16]. Tribological behavior of polymers is reviewed since the mid-20th century to the present day. Surface energy of different coatings is determined with contact adhesion meter. Adhesion and deformation components of friction were discussed. It was shown how load, sliding velocity, and temperature affect friction. Different modes of wear of polymers and friction transfer were considered, [17]. The ability to engineer a product's tactile character to produce favorable sensory perceptions has the potential to revolutionize product design. Another major consideration is the potential for products to produce friction-induced injuries to skin such as blistering, [18, 19]. Sports activities may cause different types of injuries induced by friction between the skin and sport textiles. Focusing on runners who are often bothered with blisters, the textile–foot skin interface was studied in order to measure and predict friction. The characteristics of mechanical contacts between foot, sock and shoe during running were determined. It was found that textiles with conductive threads did not give ignitions provided they were adequately earthed, [20]. When isolated, all textiles were capable of causing ignitions regardless of the anti-static strategy employed.

Friction coefficient displayed by clothes sliding against car seat covers was discussed, [21]. The frictional performance of two groups of covers, the first contained five different types of synthetic leather and the second contained nine different types of synthetic textiles, was measured. Measurement of friction coefficient is, therefore, of critical importance in assessing the proper friction properties of car seat covers and their suitability to be used in application to enhance the safety and stability of the driver. Less attention was considered for the triboelectrification of the textiles. Friction coefficient and electrostatic charge generated from the friction of hair and head scarf of different textiles materials were measured, [22]. Test specimens of head scarf of common textile fibres such as cotton, nylon and polyester were tested by sliding under different loads against African and Asian hair. The results showed that friction coefficient generated from the sliding of the cotton head scarf against hair displayed higher values than that showed by polyester head scarf. The nylon head scarf when sliding against hair showed relatively lower friction coefficient than that observed for polyester and cotton scarf. Electric static charge measured in voltage represented relatively lower values. This behaviour may be attributed to the ranking of the rubbing materials in the triboelectric series where the gap between human hair and nylon is smaller than the gap between hair and cotton as well as hair and polyester. Generally, at higher loads, the difference in friction values was insignificant. African hair displayed relatively higher voltage. Nylon displayed relatively higher friction coefficient than polyester when slid against human hair, while cotton proposed the highest friction coefficient especially at lower loads. The nylon head scarf showed slight decrease in friction coefficient compared to scarf. The decrease might be from the difference in the weave form although the both two textiles are made of nylon. The weaves form has significant effect on friction coefficient and voltage generated.

The effect of blending polyester textiles by cotton and viscose, on the friction coefficient and triboelectrification, was investigated, [23]. It was found that polyester textiles generated the highest voltage which decreased with increasing normal load. The

maximum values of electric static charge were measured when wool was the counterface. Blending polyester by cotton/viscose decreases the generation of the electric static charge.

The aim of the present study is to measure the electrostatic charge generated from the sliding of the football against the goalkeeper. Ten different types of materials were tested by sliding against football surface at dry conditions.

EXPERIMENTAL

The tested gloves are adhered to an electrically insulated base, Fig. 1. Loads are applied by hand pressing the ball into the surface of the glove and sliding the ball on it, Fig. 1. The electrostatic fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) is used to measure the electrostatic charge (electrostatic field) generated on the surfaces of both the gloves and the ball. It measures down to 1/10 volt on a surface, and up to 20 000 volts (20 kV). Readings were normally done with the sensor 25 mm apart from the surface being tested. The outer cover of football is made of polyurethane, which protects it from wear and gives the ball its appearance. Ten different types of materials were used. The tested materials including polymers are arranged in a ‘‘triboelectric series’’ which lists the materials in the order of their relative polarity, Table 1. In the triboelectric series, the higher positioned materials will acquire a positive charge when contacted with a material at a lower position along the series. The triboelectric series can be used to evaluate the relative charge polarity of the materials.

Fig. 1 Measurement of ESC generated from the sliding of the football against the glove.

Table 1 Triboelectric series of the tested materials.

Positive Charge	
	Polyamide
	Silk
	Cotton
	Neoprene
	Polyurethane elastomer
	Styrene Butadiene
	Acrylonitrile Butadiene
	Polypropylene

	Polyvinile Chloride
Negative Charge	

RESULTS AND DISCUSSION

ESC generated on ball and glove 1 is illustrated in Fig. 2. Glove 1 is made of polyamide synthetic fibres which offers strong grip and makes gloves suitable for use in different applications. The glove gained positive charge of 260 volts as resulted from the ball sliding. The value of ESC on the ball was much higher and exceeded -700 volts. The ESC increased with increasing the applied load.

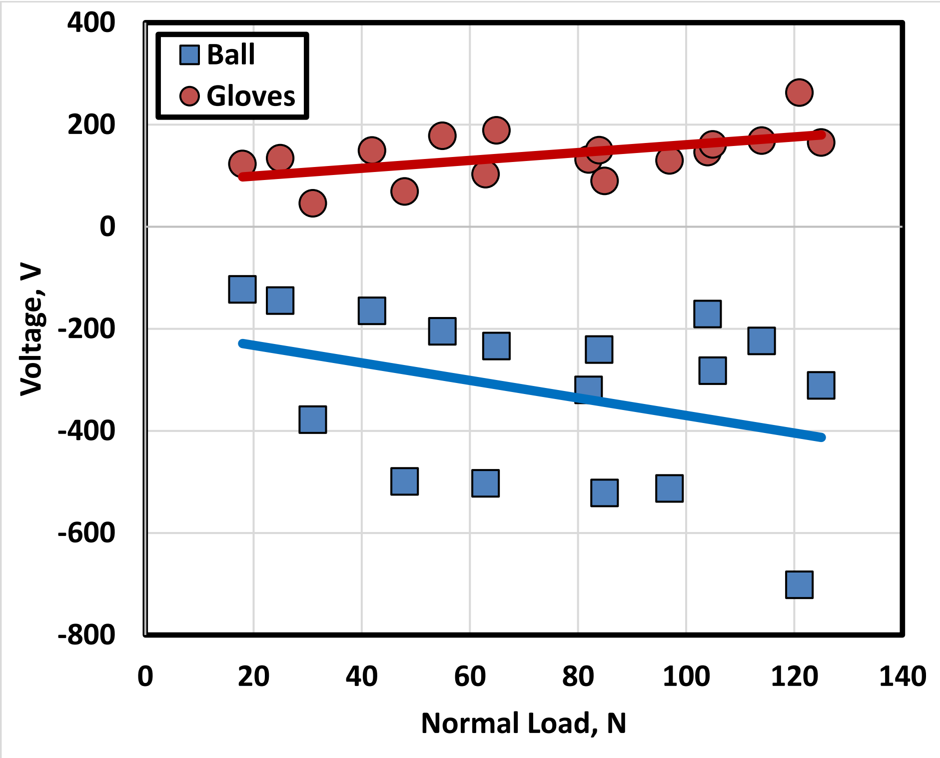

Fig. 2 ESC generated on ball and glove 1.

Glove 2 is covered by a layer made of rubber to provide non-slip gripping. It comprises a textile which includes a plurality of small dots of rubber disposed on its surface to facilitate improved gripping. It is made of neoprene which is a part of the chloroprene. It exhibits good chemical stability and maintains flexibility over a wide temperature range. ESC generated from glove 2 and the ball showed the trend observed for glove 1, Fig. 3. Values of ESC were less than that observed for glove 1.

Glove 3 is made of polypropylene which is a thermoplastic polymer used to coat the outside of gloves in order to provide high grip as well as protection from chemicals, punctures, cuts and abrasion. The highest value of ESC gained by the surface of the glove reached -780 volts at 104 N load, while the lowest values were close to -200 volts at 18 N load, Fig. 4. The relatively high ESC confirms the importance of the proper choice of glove materials of low ESC especially at relatively higher loads.

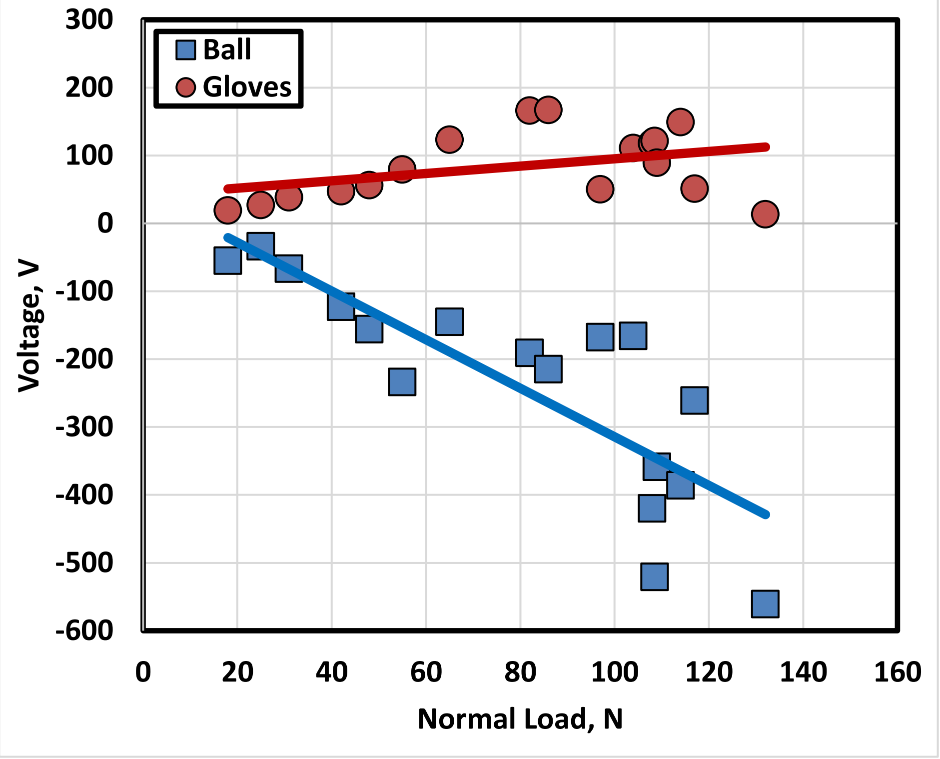

Fig. 3 ESC generated on ball and glove 2.

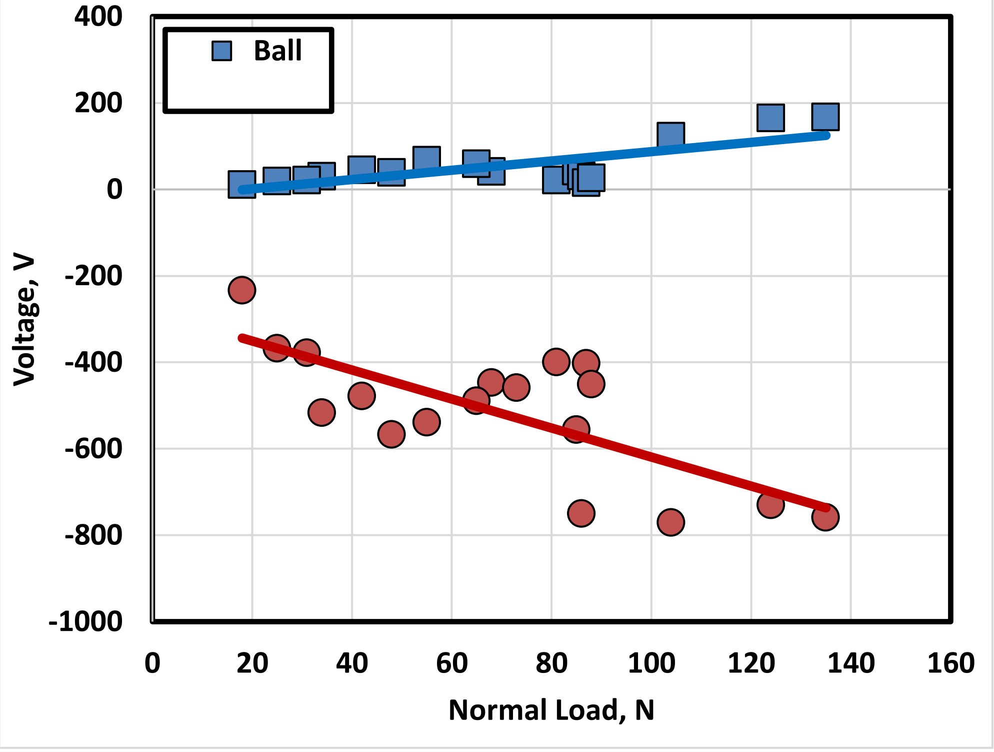

Fig. 4 ESC generated on ball and glove 3.

ESC generated by ball sliding against glove 4 that made of nitrile rubber is shown in Fig. 5. The values of ESC gained by the glove are ranging between -90 and -570 volts and increasing with increasing the applied load. Nylon knit nitrile coated glove generated relatively low ESC values (310 volts) on the glove, while the negative charge generated on the ball exceeded up to -1000 volts, Fig. 6.

Styrene butadiene copolymer, as glove 6 material, displayed relatively moderate ESC values, Fig. 7. ESC generated on the glove surface can be controlled by proper selection of the materials of appropriate surface qualities for practical use. Silk woven nitrile coated glove 7 showed relatively higher ESC values, Fig. 8, where the highest value was -1200 and 950 volts gained by ball and glove respectively.

Polyvinyl chloride like kevlar (glove 8) showed the highest ESC values values, Fig. 9. ESC values gained by the glove reached -3700 volts, while that gained by the ball recorded -1250 volts. Such values can be doubled and accumulated so that they affect the physical condition of the goal keeper during catching the ball. That material should be coated by layer made of rubber to provide lower ESC.

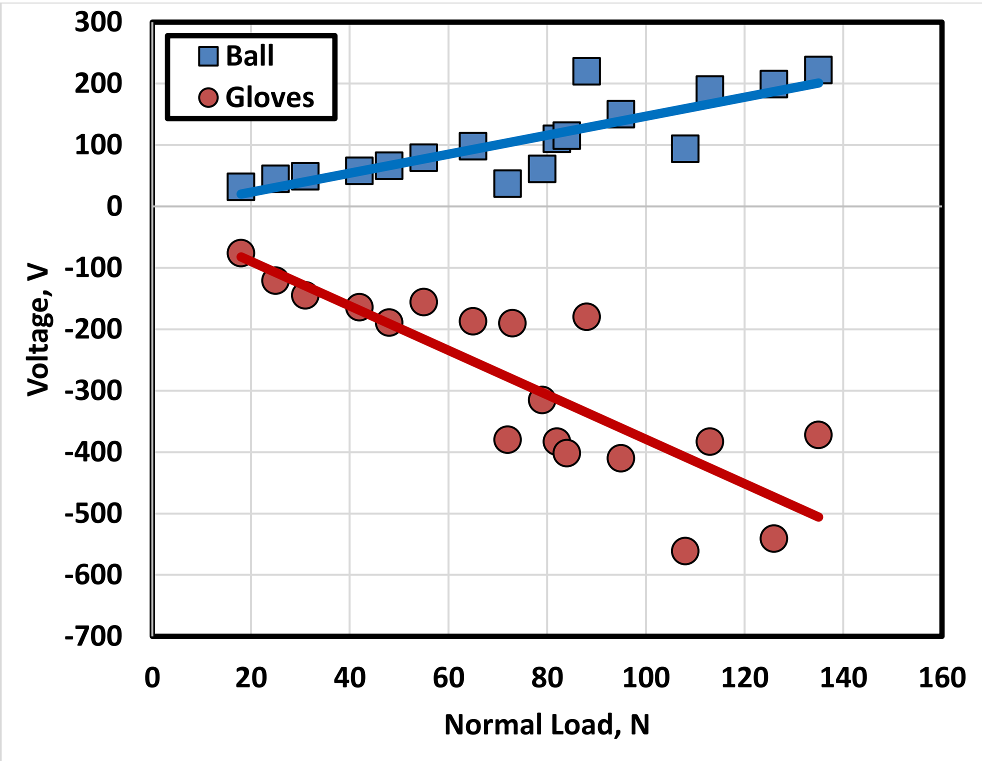

Fig. 5 ESC generated on ball and glove 4.

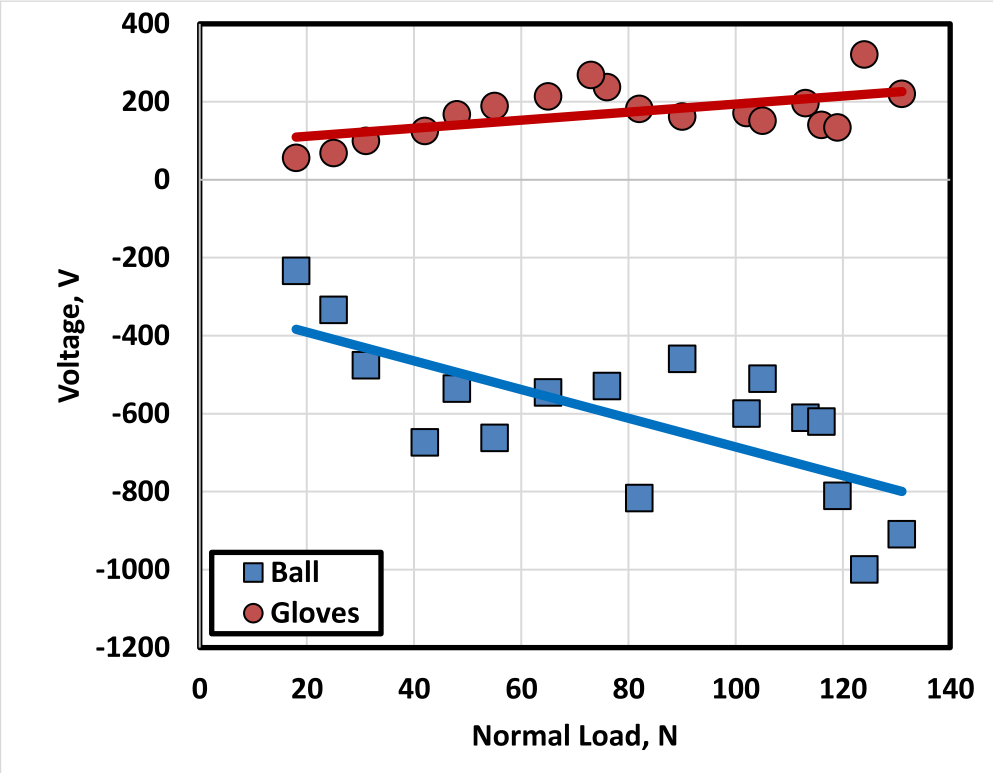

Fig. 6 ESC generated on ball and glove 5.

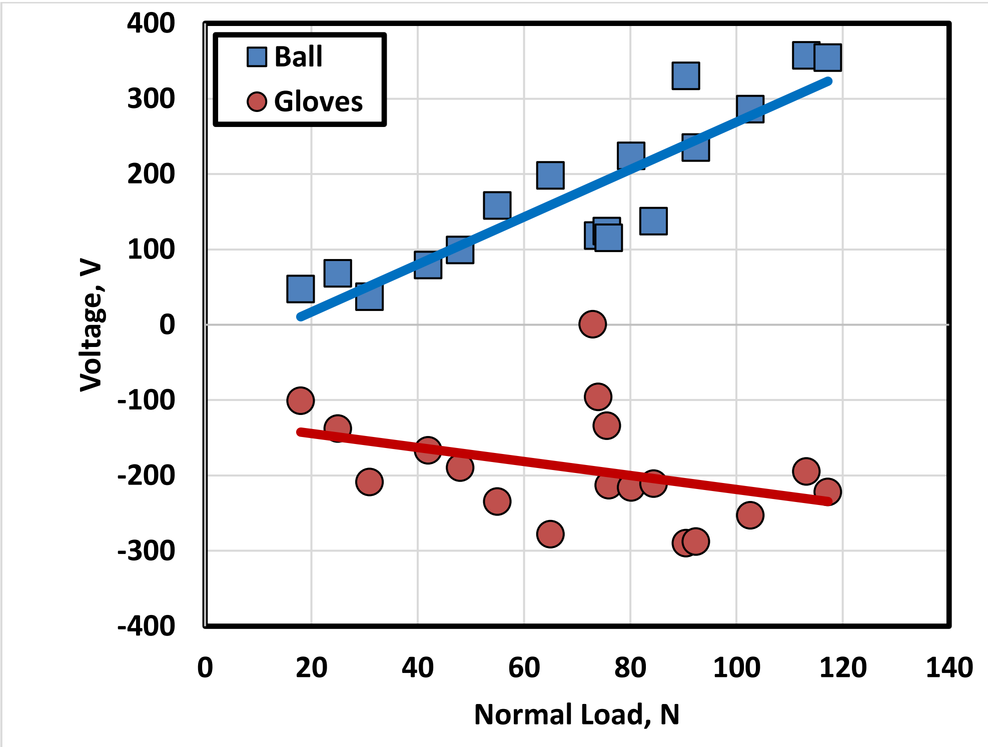

Fig. 7 ESC generated on ball and glove 6.

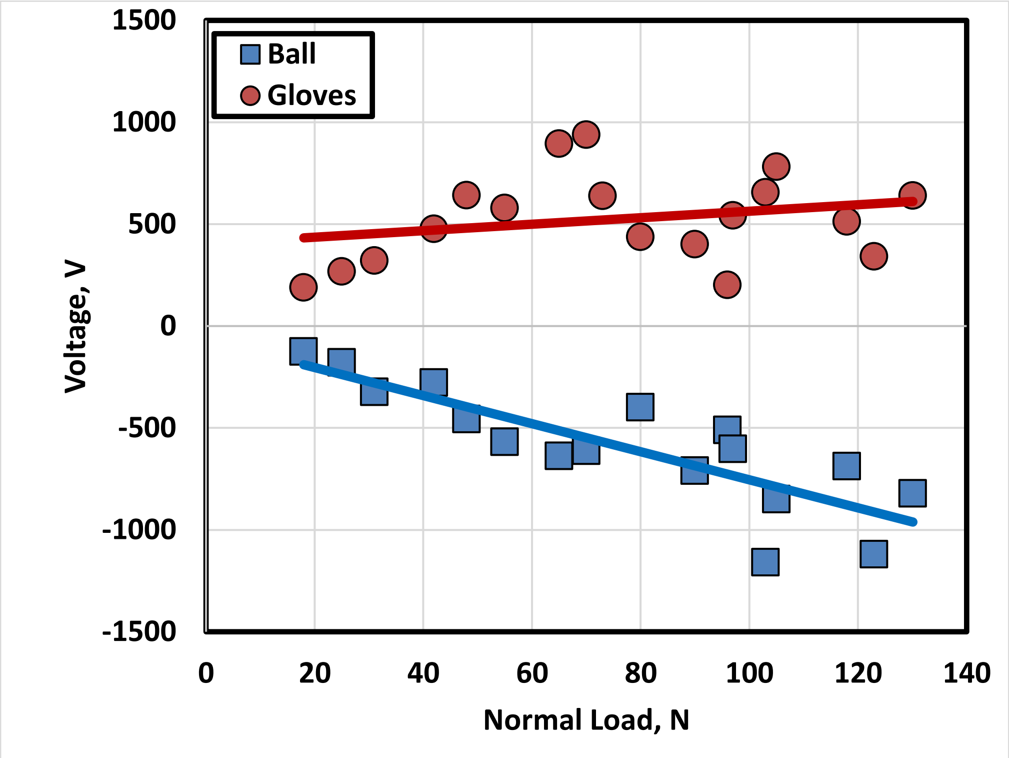

Fig. 8 ESC generated on ball and glove 7.

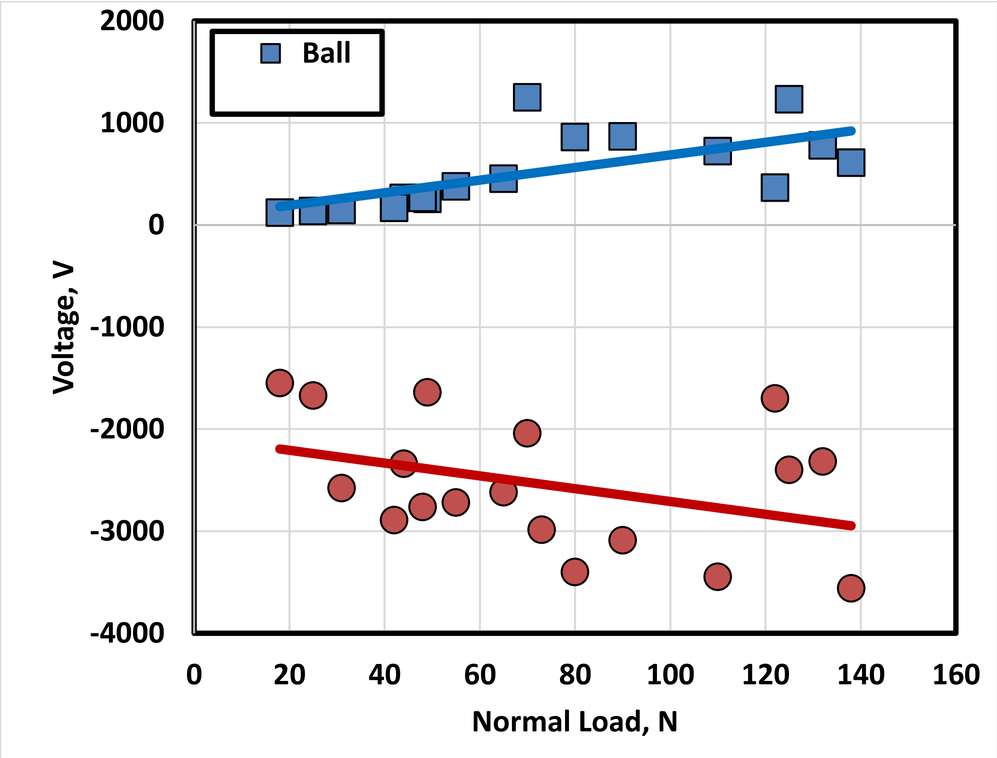

Fig. 9 ESC generated on ball and glove 8.

Cotton glove 9 showed high values of ESC, Fig. 10. This behavior may be attributed to the fact that as the load increases the pressure applied on the fibre fringes increases, flattens the fringes and increases the contact area.

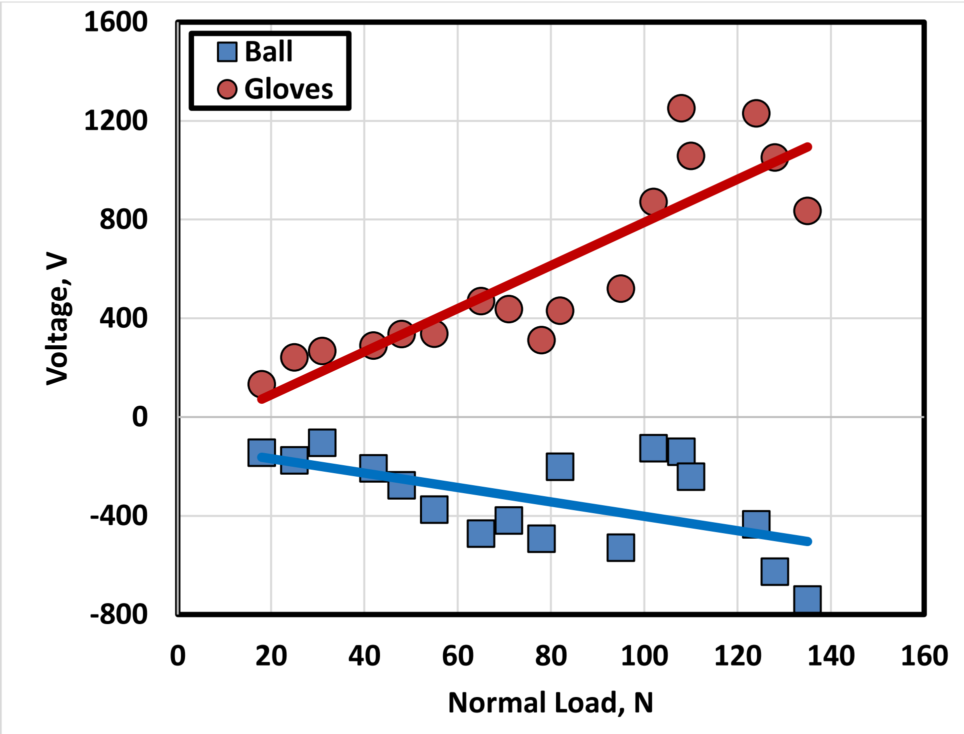

Fig. 10 ESC generated on ball and glove 9.

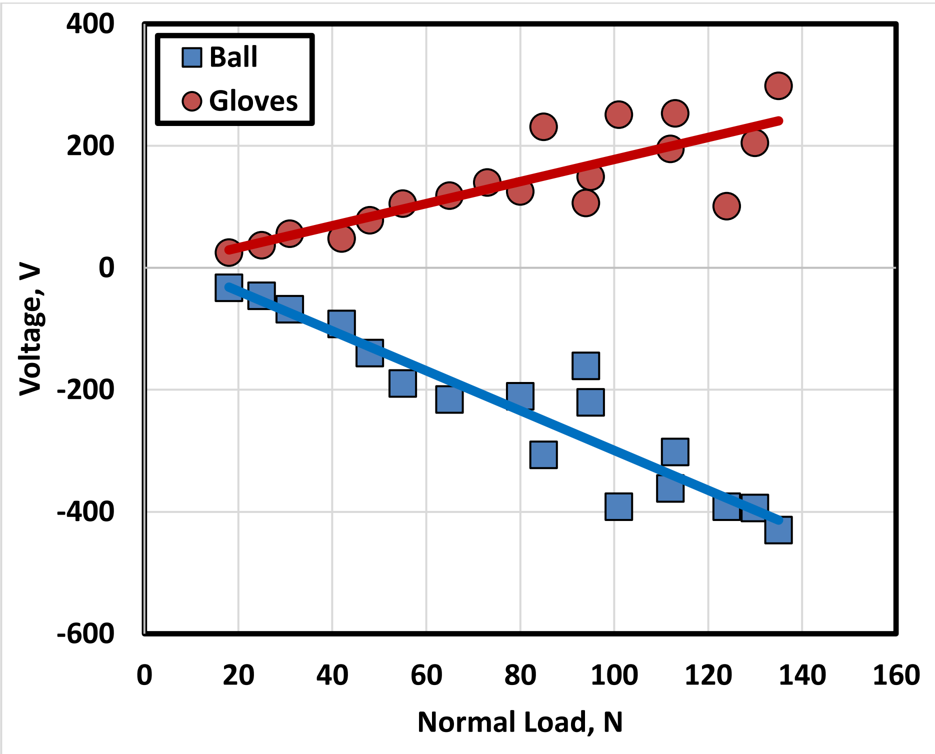

Fig. 11 ESC generated on ball and glove 10.

Gloves designed for football goalkeepers provide them with high efficient catching and holding of 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. 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. Wool (glove 10) has very high grip capability, while its sliding against football displayed relatively low values of ESC, Fig. 11. Finally, football can be more competitive and exciting by providing highly advanced polymer coated gloves that enable one-handed catches. The sport gloves should amplify the grip of the goalkeepers on the football, enabling them to make successful catches. This can be done by increasing adhesion between football and gloves. 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. The materials tested as surface coatings for the gloves of the football goalkeepers can be ranked based on generation of ESC when slid against football. Those materials are neoprene, polyamide, styrene butadiene copolymer, wool, nylon knit nitrile coated, nitrile, polypropylene, silk woven nitrile coated, and polyvinyl chloride. The first four types are recommended for application.

2. ESC showed increasing trend with increasing load.

3. The proposed sport gloves that are covered by a rubber layer to provide non-slip gripping should generate relatively low values of ESC when slid against the ball.

4. Although polyvinyl chloride coating the outside of gloves provides high grip it should be avoided due to the high level of ESC. The relatively ESC confirms the importance of proper choice of glove materials.

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