EGTRIB Journal

JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 13, NO. 3, July 2016, pp. 34 - 45 **ISSN 2090 - 5882**

TRIBOELECTRIFICATION OF LATEX AND POLYETHYLENE GLOVES

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ABSTRACT

The aim of the present study is to determine the electrostatic charge generated from the dry sliding of the latex and polyethylene single and double gloves against polyamide, polypropylene and polytetrafluoroethylene. It was found that electrostatic charge increases with the increase of the sliding distance. Double NBR and PE layers gained relatively higher charge than that gained by single layer. This observation can be interpreted on the fact that the two layers of NBR or PE can form voids which trap the electrostatic charge formed at their internal surfaces. The application of the mechanical stress on the polymer layers increases the possibility of charge formation due to contact and separation. The assumed charge formation of the internal surfaces is detected by the significant charge increase measured by double layers of the tested polymers.

Based on the observations in the present experiments, it can be concluded that the advantages of wearing double gloves to reduce the postoperative infections in surgical patients, the number of perforations of the gloves and the risk of contamination are limited by the fact that double gloving generates excessive electrostatic charge which may increase the intensity of extremely low frequency electromagnetic fields that measured during surgery. Electrostatic charges cause electromagnetic fields influencing their applications. The electromagnetic fields found in hospital operating rooms can be quite hostile to electronic medical devices. This observation can limit the usage of double gloving in surgery.

KEYWORDS

Triboelectrification, latex, polyethylene, single, double gloving.

INTRODUCTION

During surgery as well as handling of toxic materials in labs, there is a high risk of transfer of the handled materials through contact. The patients, the surgical team and the workers in labs need to be protected from this risk. This risk can be reduced by wearing two pairs of surgical gloves to provide better protection. Acrylonitrile butadiene rubber (Latex) is a useful material for disposable lab, cleaning, and examination gloves. Besides, polyethylene is used in labs and food handling and industry. Double gloving is the practice of wearing two layers of medical gloves to reduce the danger of infection from glove failure. It has shown that double gloving offers significantly more protection

against inner glove perforation in surgical procedures, [1]. The benefits and harms of extra gloves for preventing percutaneous exposure incidents among healthcare workers versus no intervention or alternative interventions was discussed, [2, 3]. The preventive effect of double gloves on percutaneous exposure incidents in surgery was confirmed. Wearing two pairs of sterile surgical gloves suffers from poor fit and loss of tactile sensitivity.

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, [4]. The materials of the gloves based on their friction coefficient in order to increase the safety of material handling were ranked, [5]. Five different glove materials were tested by sliding against steel, glass and wood sheets at dry, water and detergent wet conditions. The experiments revealed that polyamide, polyester and polyethylene glycol gloves are suitable to handle steel sheets, while polyethylene glycol and aniline formal resin coated gloves are convenient for handling glass. Handling wood surfaces can achieve safely by polyethylene glycol and polyamide gloves. The relatively high variation in the friction values in different sliding conditions confirms the proper selection of the glove materials.

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, [6, 7]. 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, [8]. 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, [9]. Variety of materials such as foamy polymers and sandwich-like microstructures were tested as shoe soles for potential robot, [10, 11]. The friction coefficient displayed by hands sliding against the surface of the steering wheel covers was discussed, [12]. 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. Experiments showed that friction coefficient displayed by the dry sliding of hand against the tested steering wheel covers decreased with increasing normal load. Besides, friction coefficient showed significant increase for covers compared to wheel without cover. In addition to that, friction coefficient drastically decreased due to the presence of the grease film covering the sliding surfaces.

Electric static charges generated from friction of engineering materials cause electromagnetic fields influencing their applications. The electromagnetic fields found in hospital operating rooms can be quite hostile to electronic medical devices. The electric static charge generated from the dry and water wet contact and sliding of surgical gloves and the covers of the cloths of people who are working in hospitals has been investigated, [12]. It was found that friction coefficient displayed by dry sliding of latex glove against cover decreased with decreasing normal load. Friction values guaranteed the good adhesion of the glove against cover. At sliding, the charge value was higher than that recorded for contact and separation. At water wet contact, the values of friction and electric static charge were lower than that observed for dry contact due to the ability of water to conduct the charge from the contact surfaces. Based on the experimental

observations, it can be concluded that materials of both glove and cover generated very high electric static charge values. It is therefore necessary to select the materials of low electric static charge.

The aim of the present study is to measure the electrostatic charge generated from the dry sliding of the latex and polyethylene single and double gloves against polyamide, polypropylene and polytetrafluoroethylene.

EXPERIMENTAL

The present work investigated the measurement of electric static charge generated by the contact and separation as well as dry sliding of latex (NBR) and polyethylene (PE) gloves against polyamide PA, polypropylene (PP) and polytetrafluoroethylene (PTFE). The electric static fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens. Tests were carried out at room temperature under varying normal loads. The test specimens were prepared from latex (nitrile butadiene rubber) and polyethylene gloves of 50 × 50 mm^2 stuck to wooden block of 50 mm height. The tested glove materials were pressed and slid against the polymeric materials in form of sheets of 100 × 300 × 5 mm^3. The applied force was 10 N. After sliding, the electrostatic charge generated on the two sliding surfaces was measured. The sliding distance was 0 (contact and separation), 50, 100, 150, 200, 250 and 300 mm. The test rig used in the experiments is shown in Figs. 1, 2. The friction force was measured by the deflection of the load cell. 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 by turning the power screw feeding the base in the direction of motion. The velocity was 2 mm/s. All measurements were performed at 28 ± 2º C and 50 ± 10 % humidity.

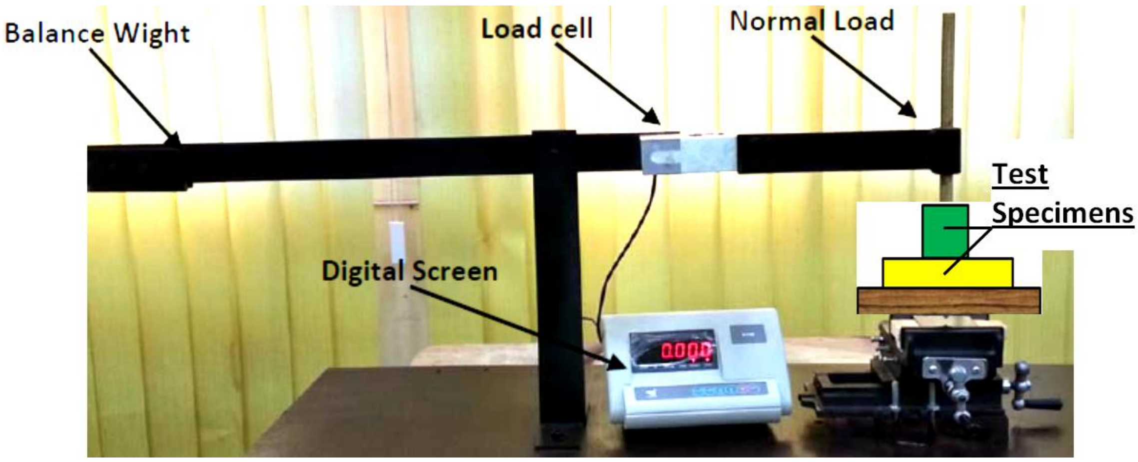

Fig. 1 Details of test rig.

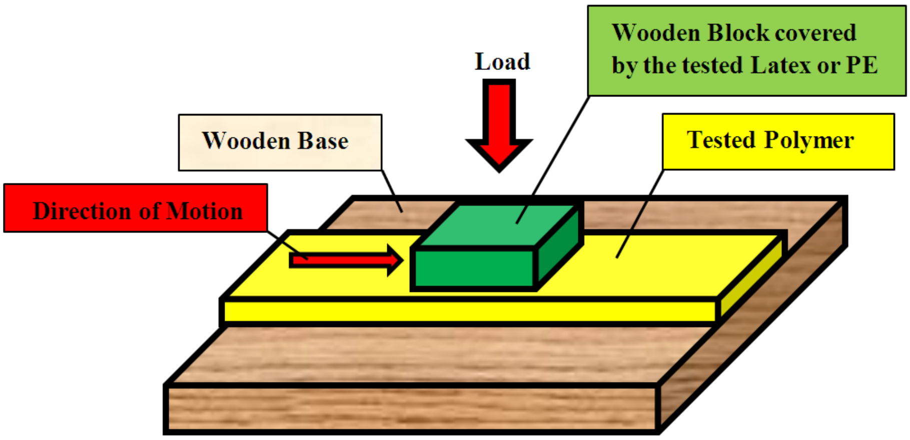

Fig. 2 Schematic drawing of the test procedure.

RESULTS AND DISCUSSION

Electrostatic charge generated on NBR during sliding against PA is shown in Fig. 3. As the sliding distance increases charge increases. The highest value of charge is observed at 300 mm sliding distance. Single layer of NBR showed relatively lower charge (-3900 volts) than that displayed by two layers (-4300). This observation can be interpreted on the fact that the two layers of NBR can form voids which trap the electrostatic charge formed at their internal surfaces, Fig. 4. The application of the mechanical stress on the polymer layers increases the possibility of charge formation due to contact and separation. The assumed charge formation of the internal surfaces is detected by the significant charge increase measured by double layers of the tested polymers. The electrostatic charge gained by PA was 1300 volts after 300 mm distance for two NBR layers, Fig. 5, while single layer showed 408 volts.

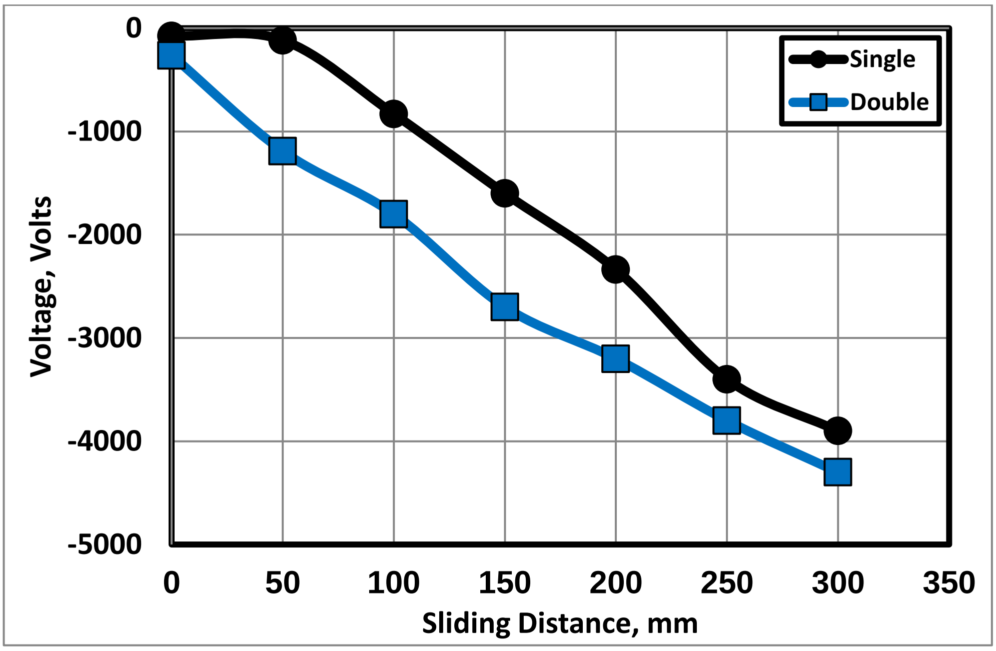

Fig. 3 Electrostatic charge generated on NBR during sliding against PA.

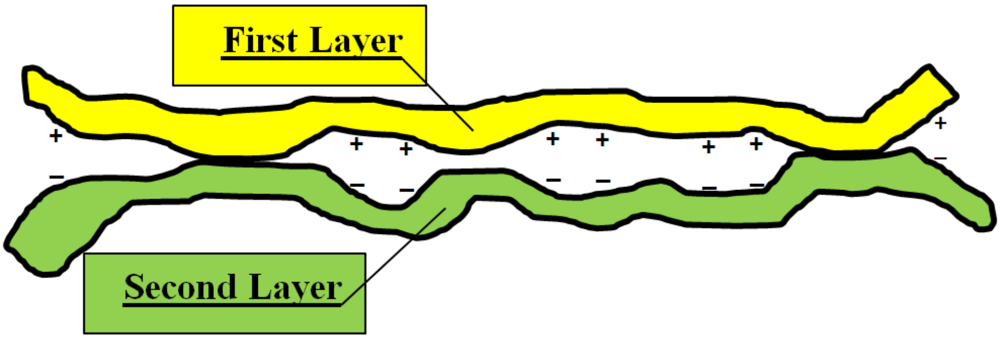

Fig. 4 Schematic representation of the generation of electrostatic charge on the surfaces of the tested polymers.

NBR slid against PP displayed positive charge, Fig. 6, due to their relative position in the triboelectric series, Table 1. Double NBR layers gained positive charge of 3650 volts, while single layer gained only 1000 volts. The advantages of wearing double gloves to reduce the postoperative infections in surgical patients, the number of perforations of the gloves and the risk of contamination. On the other side, double gloving generates excessive electrostatic charge which may increase the intensity of extremely low-frequency electromagnetic fields that measured during surgery. Electrostatic charges cause electromagnetic fields influencing their applications. The electromagnetic fields found in hospital operating rooms can be quite hostile to electronic medical devices. It was indicated that anesthesiologists in operating rooms are exposed to extremely low-frequency electromagnetic field levels that exceed magnetic field intensity of 2 mG recommended by the Swedish Board for Technical Accreditation for production by computer monitors and detected 30 cm from them, [13]. Electrostatic charge generated on PP during sliding against NBR, Fig. 7, approximates to -1200 volts.

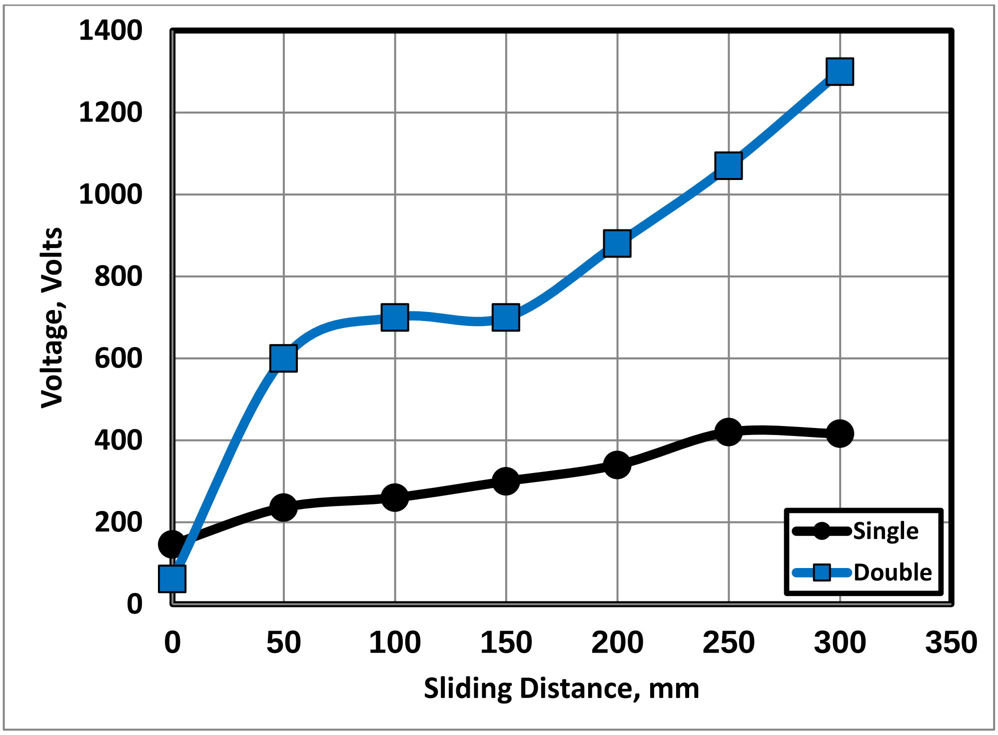

Fig. 5 Electrostatic charge generated on PA during sliding against NBR.

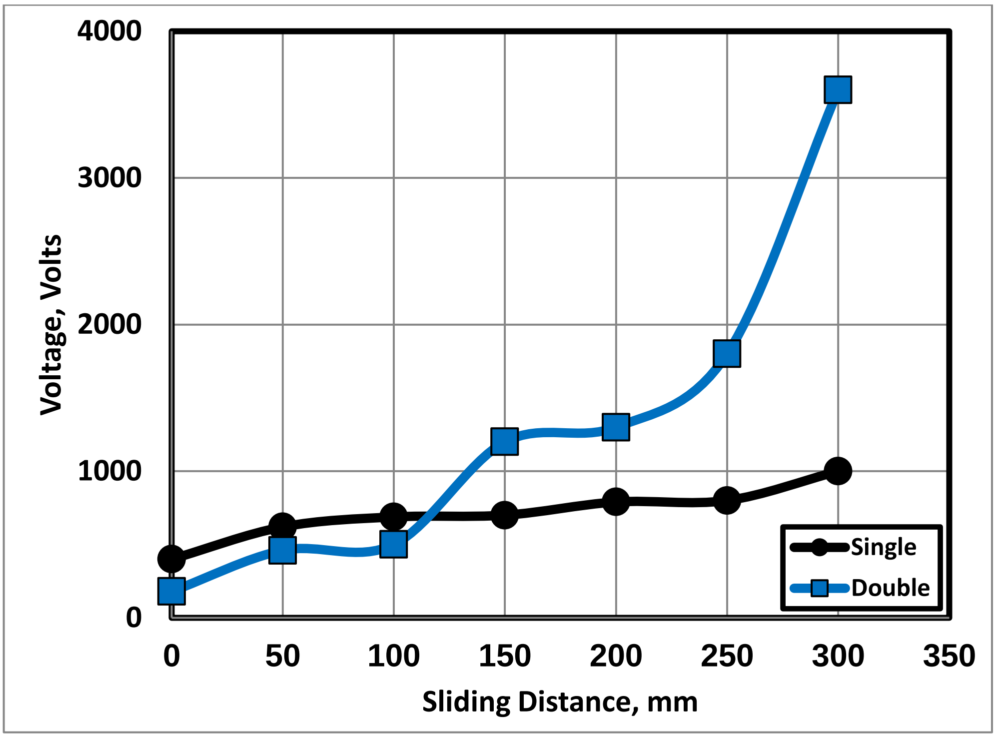

Fig. 6 Electrostatic charge generated on NBR during sliding against PP.

Table 1 Triboelectric series of the tested polymers.

Positive Charge	Polyamide	PA
	Nitrile Butadiene Rubber	NBR
	Polyethylene	PE
	Polypropylene	PP
Negative Charge	Polytetrafluoroethylene	PTFE

Double layers of NBR gained the highest value of charge (11800 volts), Fig. 8, when slid against PTFE, while single layer showed 3100 volts. The disadvantage of using double layer of NBR is confirmed by generating the high value of charge. PTFE slid against NBR gained -5300 volts after 300 mm sliding distance. The relatively high charge is related to the relative positions of both NBR and PTFE in the triboelectric series.

The results of experiments carried out to investigate the generation of electrostatic charge on single and double layers of PE when sliding on PA, PP and PTFE are shown in Figs. 10 - 15. PE slid against PA gained -3900 and -4300 volts for single and double layers respectively. Those values are much higher than that observed for NBR slid against PA. While PA slid against PE gained 1300 volts, Fig. 11. The difference in the value of the charge between single layer and double PE layer was relatively high.

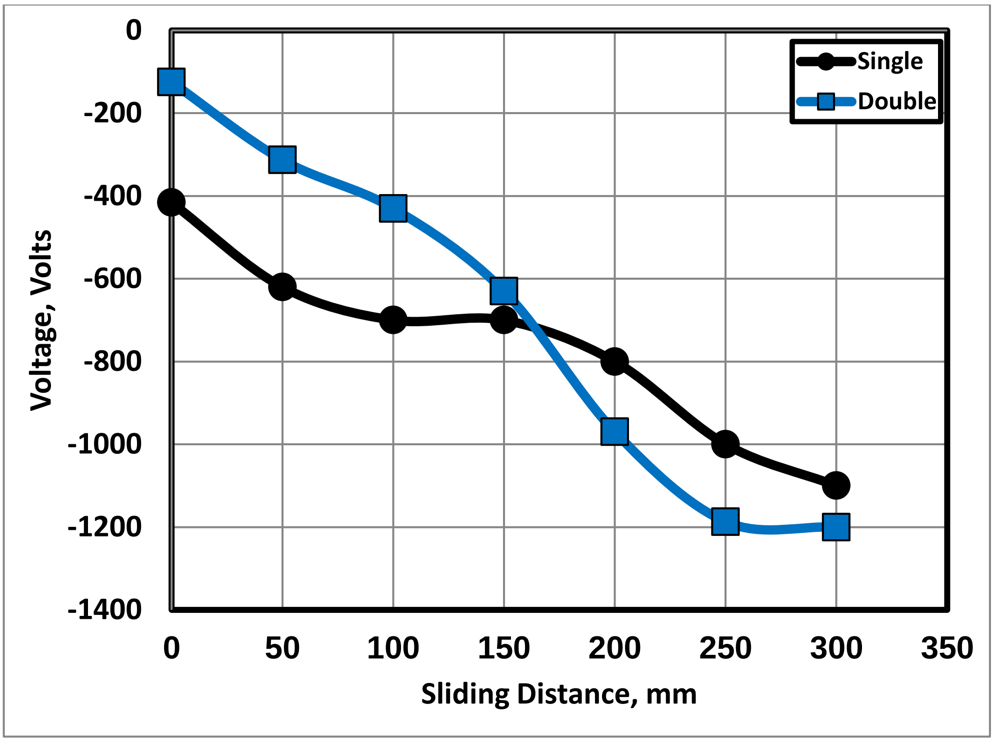

Fig. 7 Electrostatic charge generated on PP during sliding against NBR.

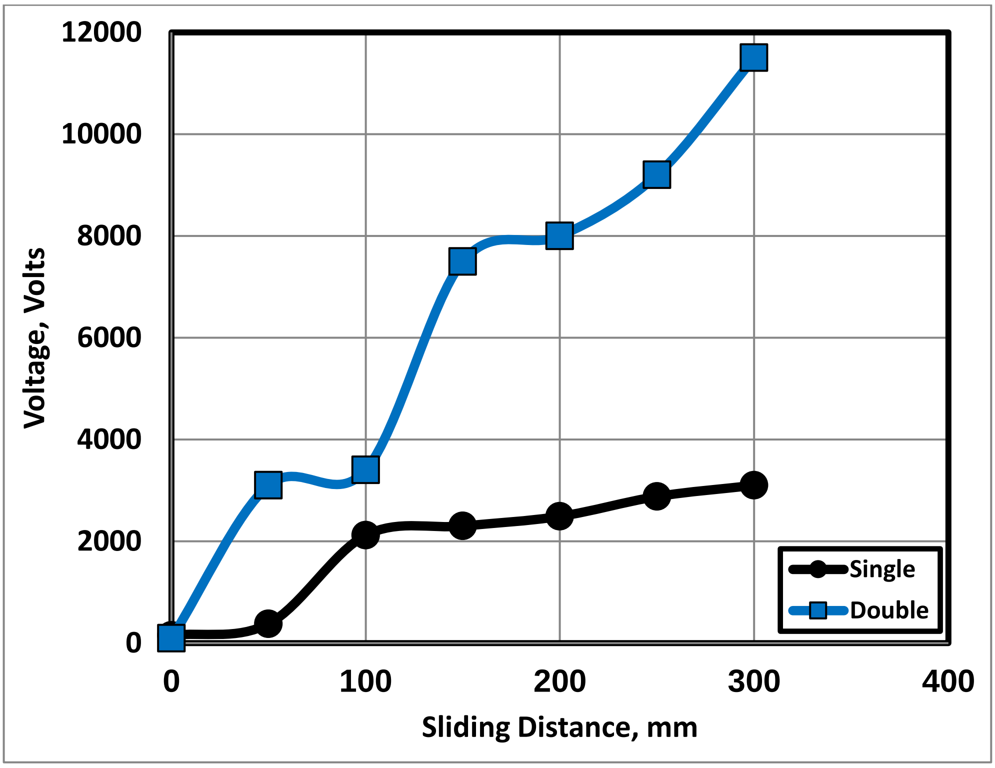

Fig. 8 Electrostatic charge generated on NBR during sliding against PTFE.

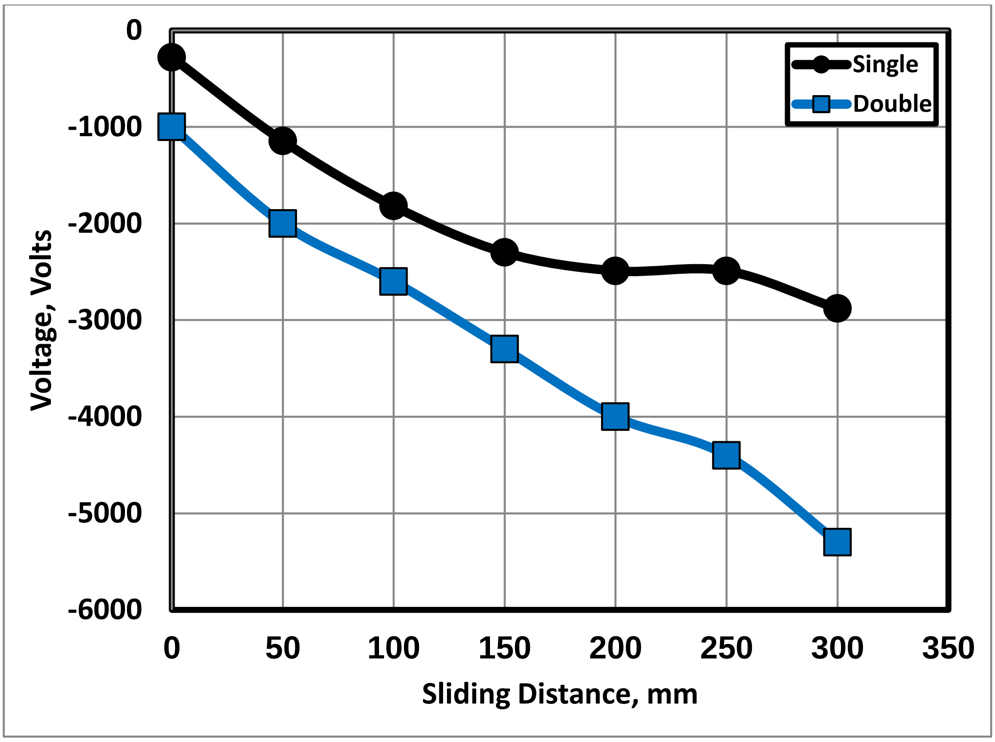

Fig. 9 Electrostatic charge generated on PTFE during sliding against NBR.

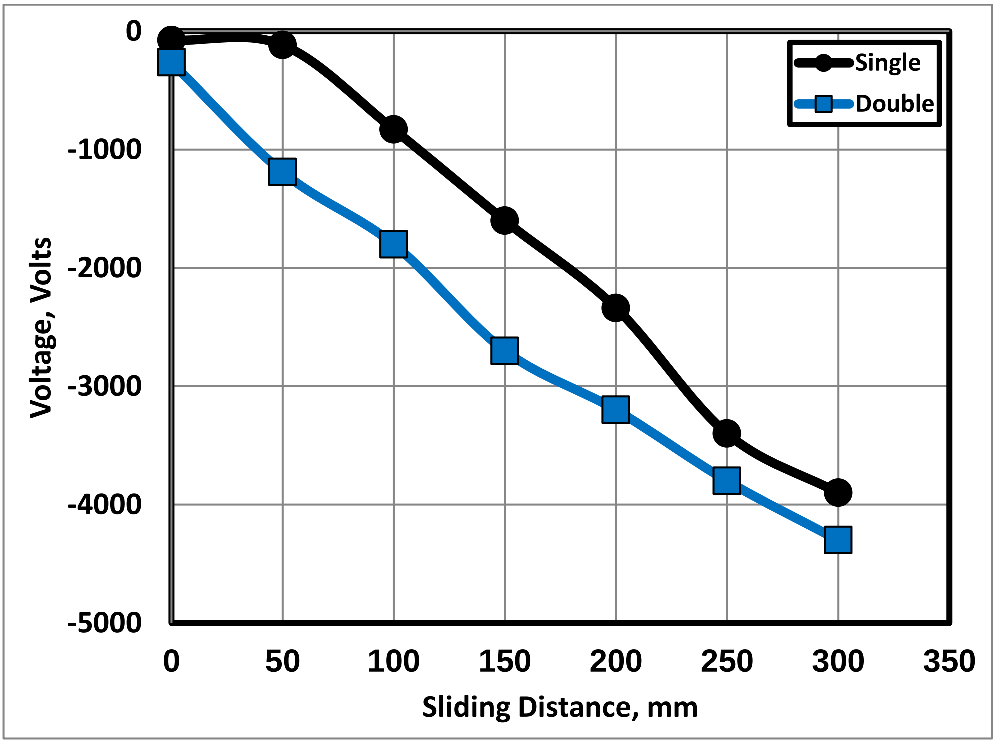

Fig. 10 Electrostatic charge generated on PE during sliding against PA.

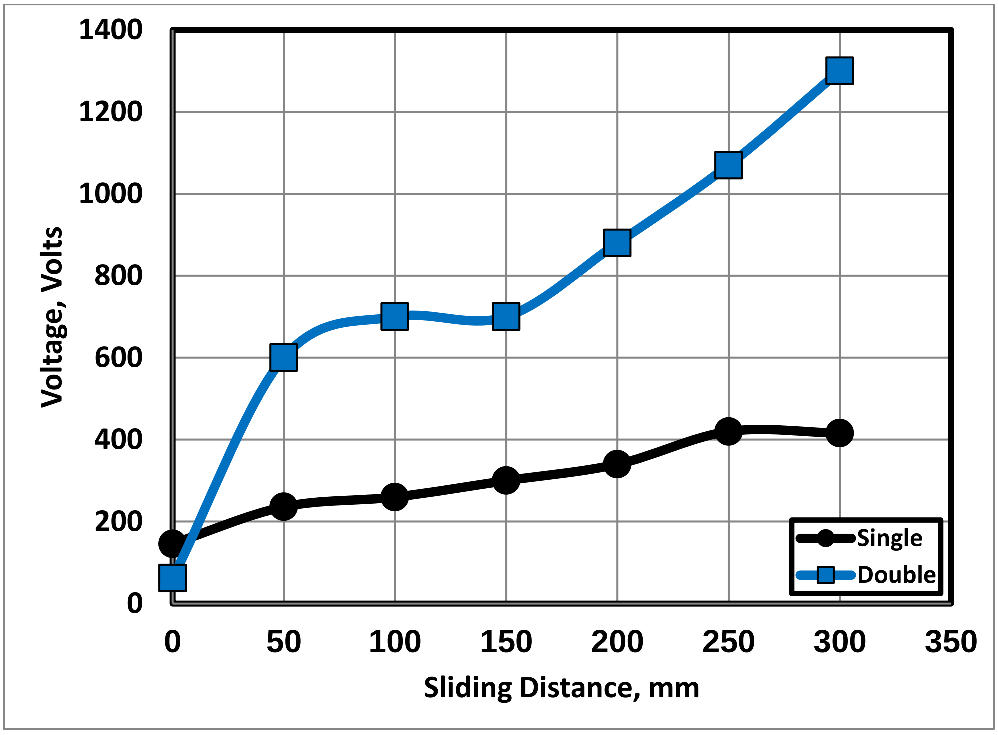

Fig. 11 Electrostatic charge generated on PA during sliding against PE.

Double layer of PE gained 3000 volts when slid against PP for 300 mm, Fig. 12. Contrary to that, single layer PE gained only 400 volts. PP gained lower negative charge than that gained by PE, Fig. 13.

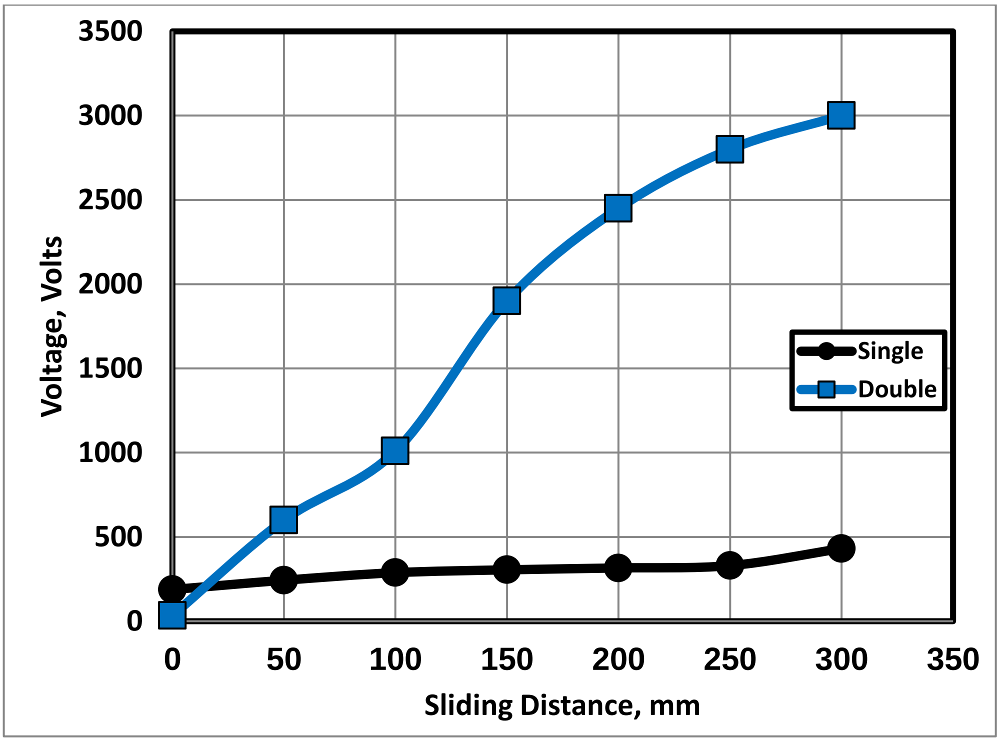

Fig. 12 Electrostatic charge generated on PE during sliding against PP.

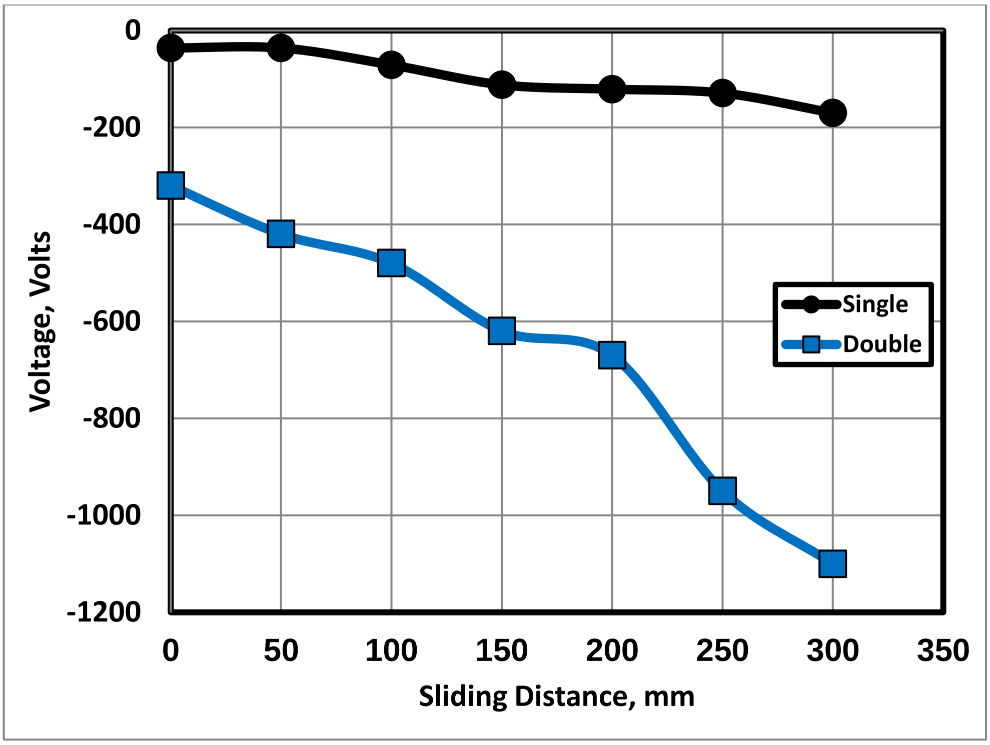

Fig. 13 Electrostatic charge generated on PP during sliding against PE.

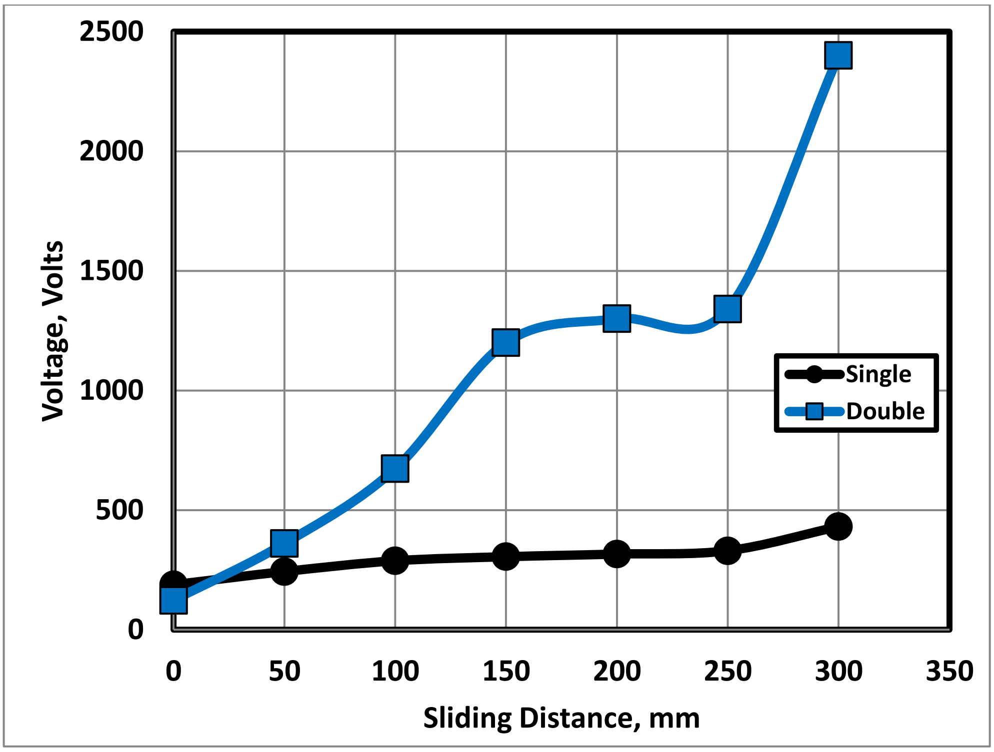

Fig. 14 Electrostatic charge generated on PE during sliding against PTFE.

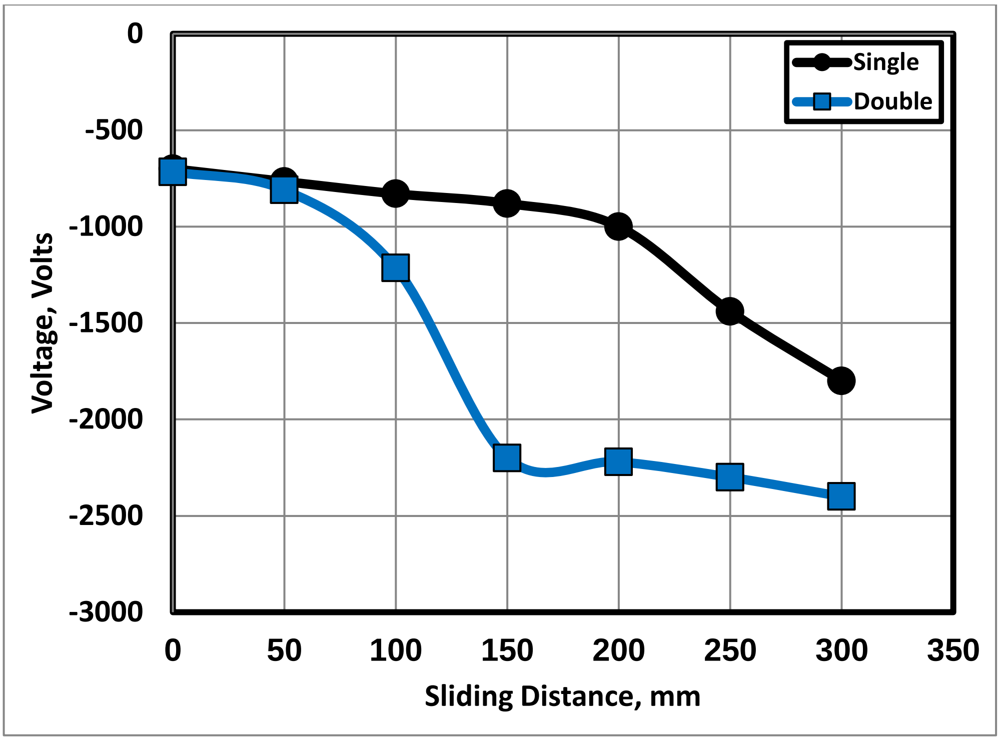

Fig. 15 Electrostatic charge generated on PTFE during sliding against PE.

Electrostatic charge generated on PE during sliding against PTFE showed lower values than that experienced by the sliding of NBR against PTFE, Fig. 14. Double layer of PE displayed 2400 volts, while single layer gained 430 volts. PTFE counterface gained -2400 volts after 300 mm sliding distance against double layer PE, Fig. 15.

CONCLUSIONS

1. When the sliding distance increases, electrostatic charge increases. Double NBR layers gained relatively higher charge than that gained by single layer. NBR slid against PP displayed positive charge due to their relative position in the triboelectric series. This observation can limit the usage of double gloving in surgery. The disadvantage of using double layer of NBR is confirmed by generating high value of charge. The relatively high charge is related to the relative positions of both NBR and PTFE in the triboelectric series.

2. PE slid against PA gained much higher charge than that observed for NBR when slid against PA. The difference in the value of the charge between single layer and double PE layer was relatively high. Double layer of PE gained 3000 volts when slid against PP for 300 mm. Electrostatic charge generated on PE during sliding against PTFE showed lower values than that measured by the sliding of NBR against PTFE. Based on the observations in the present experiments, it can be concluded that the advantages of wearing double gloves to reduce the postoperative infections in surgical patients, the number of perforations of the gloves and the risk of contamination are limited by the fact that double gloving generates excessive electrostatic charge which may increase the intensity of extremely low frequency electromagnetic fields that measured during surgery. Electrostatic charges cause electromagnetic fields influencing their applications. The electromagnetic fields found in hospital operating rooms can be quite hostile to electronic medical devices.

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