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Electric Static Charge Generated from Contact of Surgical Gloves and Covers of the Cloths in Hospitals

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Abstract

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. In the present work, 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 is investigated. 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 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.

Keywords

Electric Static Charge, Contact and Separation, Sliding, Dry, Water Wet, Surgical Gloves, Cloths, Hospitals

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1. Introduction

Several studies have demonstrated critical relationships between electromagnetic fields exposure and various diseases like cancers. Numerous electronic devices have been introduced into operating rooms. The intensity of extremely low-frequency electromagnetic fields was measured during surgery with the extremely low-frequency electromagnetic field strength measurement system at the standing position of anesthesiologists in 18 operating rooms, [1]. 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.

The electric static charge generated from the dry and water wet sliding of propylene shoe against cover of people who are working in hospitals was investigated, [2]. It was found that dry sliding of shoe against cover generated much higher electric static charge measured on the shoe. This observation can confirm the necessity to develop new materials to be applied as glove of low electric static charge. At sliding, the charge value was higher than that recorded for contact and and separation. At water wet contact, the values of friction and electric static charge were lower than that observed for dry contact. It seems that the low values of electric charge were from the ability of water to conduct the charge from the contact surfaces. The electric static charge generated from the

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dry sliding of hair against disposable cap and face mask as well as skin against face mask of people who are working in hospitals was tested, [3]. Relatively high voltage (- 4000 volts) was generated from the sliding of the disposable cap on hair. The electric static charge generated on the disposable cap showed negative and much higher values. Sliding of disposable cap against hair generated much higher charge than that measured in contact and separation. The contact and separation of the mask with hair displayed very high voltage. The charge values were much higher for the mask than that shown for the hair. Electric static charge of face mask generated from its contact and separation with skin displayed much higher values than that observed for skin. This observation can confirm the necessity to develop new materials to be applied as face mask of low electric static charge and the careful selection of the materials used in that application. It is expected that electric field will be formed due to the electric charge formed on sliding surfaces.

Static charge includes potentially dangerous electrical shocks which can cause fires and explosions. It can also cause severe damage to sensitive electronic components. Triboelectric charging is the transfer of electrons which occurs when two materials are in contact and are then separated. One material gains an excess of negative ions and the other an excess of positive ions. The charge generated can be more than 25,000 volts. 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 against each other, [4-6]. The mechanism of charge transfer in tribocharging can be explained by three mechanisms: electron transfer, ion transfer, and material transfer, [7–9]. The metal to metal contact electrification successfully explained by electron transfer mechanism. When two different materials come to contact, electrons transfer happens until their Fermi level equals. Difference in work functions between them is the main driving force, [10]. As for insulators, the electron transfers only happen on the surfaces of insulators, where electrons move from the filled surface of one insulator to the empty surface of the other insulator, [11–13]. Few researchers have drawn up triboelectric series to predict the polarity of the charge that is transferred from one surface to another, [14]. When two kinds of materials contact each other, the upper one in the triboelectric series will get positively charged and the other one will be negatively charged. It is becoming increasingly evident that more than one of these mechanisms may occur simultaneously, [15].

The electrostatic charging of unstrained and strained latex rubber sheets contacted with a series of materials such as polytetrafluoroethylene (PTFE), polyurethane (PU) and stainless steel (SS) was studied, [16]. For SS, strain reduces the frequency of electrical discharges occurring. It was found that material strain can strongly influence triboelectric charging. Besides, straining a material can produce ions, electrons, and radicals that can react to form charged species. Silicon carbide is electrically semiconducting. The friction and wear behaviour of silicon carbide based materials may be influenced by electric potentials applied to the tribological system, [17–20]. Also, it was found that the surface state of SiC ceramics can be influenced by electric potentials.

Triboelectrification and triboluminescence were measured from the sliding or rolling frictional contacts between polymers of PA66, POM, ABS, PET, PP, PVC, PE, and PTFE in various humidity conditions, [21]. Triboluminescence intensity was higher in sliding friction. The saturation charges of all the sliding couples showed their maxima at the humidity from 10 to 30%. It was found that the humidity enhanced charge transfer which resulted in the increase or decrease of electrification, [22]. The contact and separation process leads to the charge transfer between dissimilar materials. When charges are accumulated, they are measured as triboelectrification.

Charge and discharge associated with the rubbing between shoes and carpet are less experienced in summer rather than in winter. It indicates that the charge is suppressed in higher humidity. Experimental data have exemplified this tendency [23-25]. However, other data show that water molecules on the surfaces convey charges in the form of ions to enhance charge separation between two surfaces [26, 27]. These contradictory results require precise measurement of the effect of humidity on charge generation.

It was found that voltage generated by the contact and separation of the tested upholstery materials of car seat covers against the materials of clothes showed great variance according to the type of the materials, [28]. The materials tested showed different trend with increasing load. The contact and separation of the tested against polyamide textiles generated negative voltage, where voltage increased down to minimum then decreased with increasing load. The behaviour can be interpreted on the fact that as the load increased the two rubbed surfaces, charged by free electrons, easily exchanged the electrons of dissimilar charges where the resultant became relatively lower voltage. High density polyethylene displayed relatively lower voltage than cotton and polyamide textiles, while polypropylene textiles displayed relatively higher voltage than that shown for high density polyethylene. The variance of the voltage with load was much pronounced. Remarkable voltage increase was observed for contacting synthetic rubber. This observation can limit the application of synthetic rubber in tailoring clothes. Materials of high static electricity can be avoided and new materials of low static electricity can be recommended.

The wide use of polymer fibers in textiles necessitates to study their electrification when they rubbing other surfaces. The electric static charge generated from the friction of different polymeric textiles sliding against cotton textiles, which used as a reference material, was discussed, [29]. 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. 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 fibers 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, [30]. 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, [31]. Materials can be assessed for risks from static electricity by measurement of charge decay and by measurement of capacitance loading, [32].

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, [33]. 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. 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.

The present study investigate the friction coefficient and electric static charge generated from the dry contact and separation as well as sliding of surgical glove against the cover of the cloths of people who are working in hospitals.

2. Experimental

The present work investigated the measurement of electric static charge generated by the contact and separation as well as dry sliding of latex glove against cover of the cloths of people who are working in hospitals. 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 glove (acrylonitrile butadiene rubber) of 50×50 mm^2 stuck to wooden block of 50 mm height, Fig. 1. The cover material (100×300 mm^2) was adhered to the base supported by two load cells, the first can measure the horizontal force (friction force) and the second can measure the vertical force (normal load), Fig. 2. The cover was pressed by the latex specimen by hand. Friction coefficient was determined by the ratio between the friction force and the normal load. During test, horizontal and vertical load cell connected to two monitors detected normal and friction load respectively. Friction coefficient is the ratio between friction load and normal load. Each test was replicated five times, and the mean value of the friction coefficient was considered. Friction tests were carried out at different load ranging from 0-100 N. The details of the test rig are shown in Fig. 3.

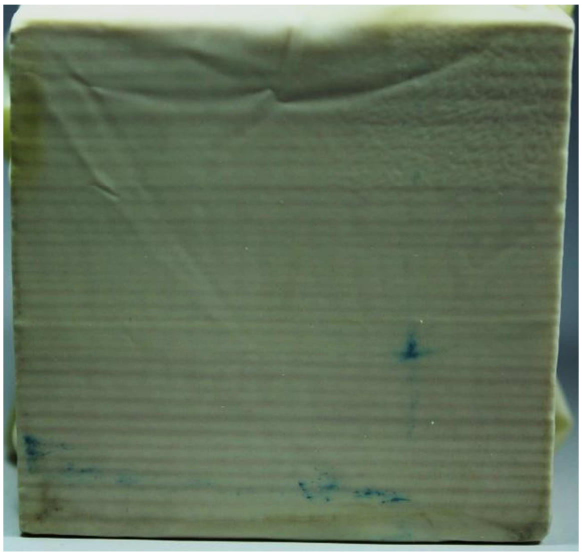

Fig. 1. Test specimen of the latex glove.

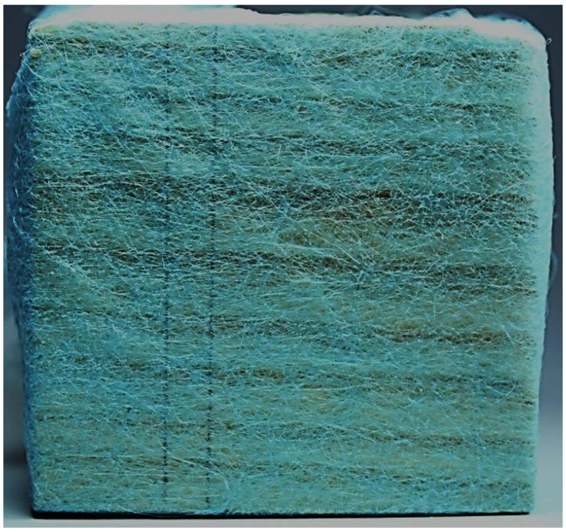

Fig. 2. Test specimen of the cover.

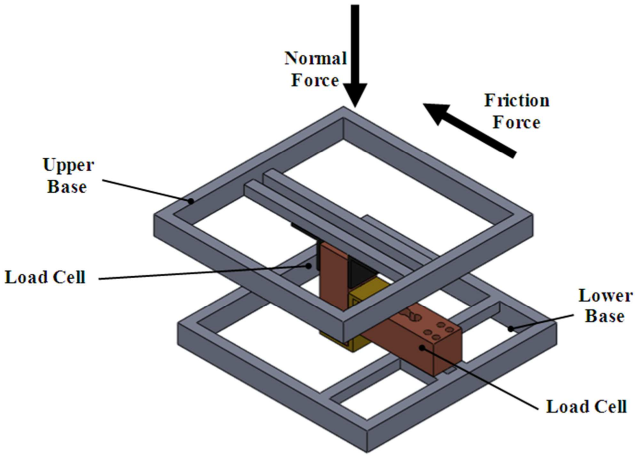

Fig. 3. Arrangement of the test rig.

3. Results and Discussion

The results of the experiments carried out to test the friction coefficient and electric static charge from the dry contact and separation as well as sliding of latex glove against dry cover are shown in Figs. 4–8. Friction coefficient displayed by sliding of latex glove against dry cover, Fig. 4, decreased with decreasing normal load. The lowest friction value was 0.93 at 58 N, while the highest value was 1.25 at normal load of 12 N. As the load increased friction coefficient slightly decreased. The friction values guaranteed the good adhesion of the latex glove and dry cover.

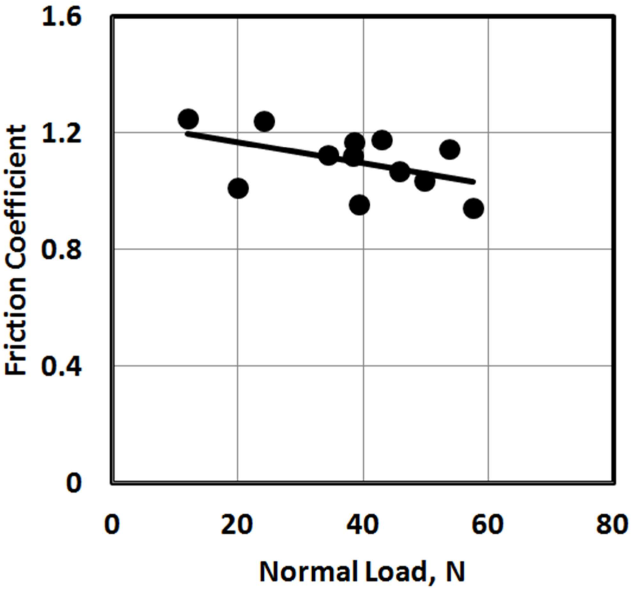

Fig. 4. Friction coefficient displayed by sliding of latex glove against dry cover.

Electric static charge generated on the glove from contact and separation against cover at dry condition is shown in Fig. 5. The values were ranged between 13 and 50 volts distributed on the glove. As the load increased the charge decreased. This behaviour might be attributed to increase of the contact area with increasing load. The electric static charge generated on the cover, Fig. 6, showed negative values ranging from 45 to 178 volts. As the load increased, electric static charge slightly increased. Due to the nature of the electric static charge the scatter in the values measured during experiments was relatively high.

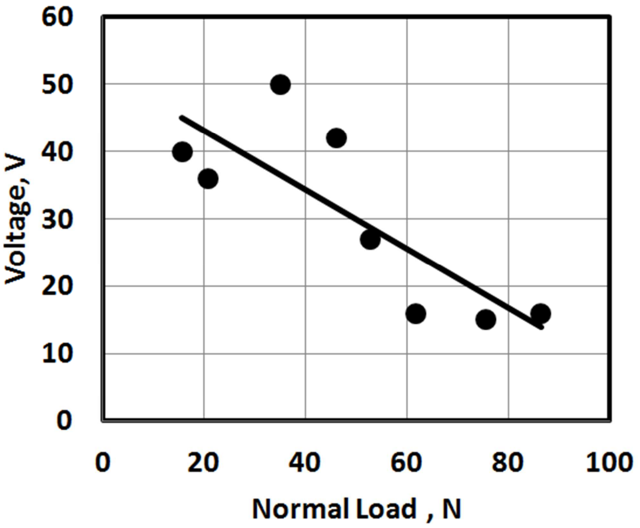

Fig. 5. Electric static charge of latex glove generated from its contact and separation against dry cover.

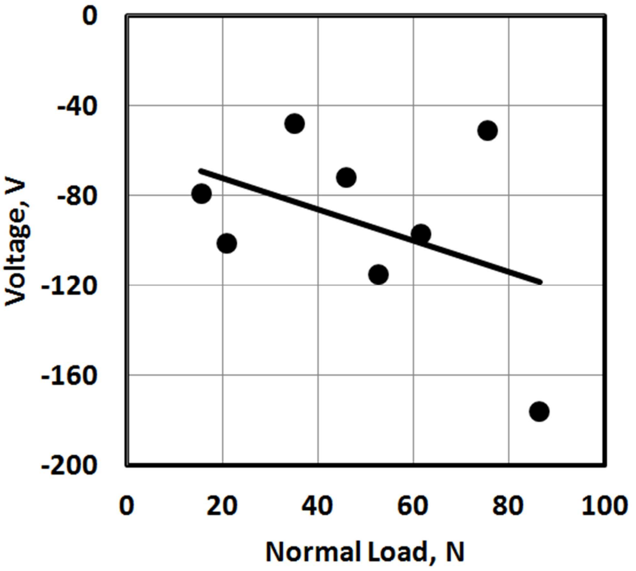

Fig. 6. Electric static charge of cover generated from its contact and separation against dry latex glove.

Sliding of glove against cover at dry condition generated much higher electric static charge than that observed in contact and separation measured on the glove, Fig. 7. The highest voltage reached 250 volts, while the lowest was 42 volts. This observation can confirm the necessity to develop new materials to be used as glove of low electric static charge. As the load increased, the voltage slightly increased. Electric static charge generated on the cover surface recorded very high voltage value of-2600 volts at 67 N, Fig. 8. As the load increased the negative voltage increased. It seems that friction coefficient critically depended on the value of the generated voltage. This behaviour can be explained on the basis that, generation of equal electric static charges on the sliding surfaces of different signs would increase the attractive force between the two surfaces and consequently the adhesion increased leading to friction increase.

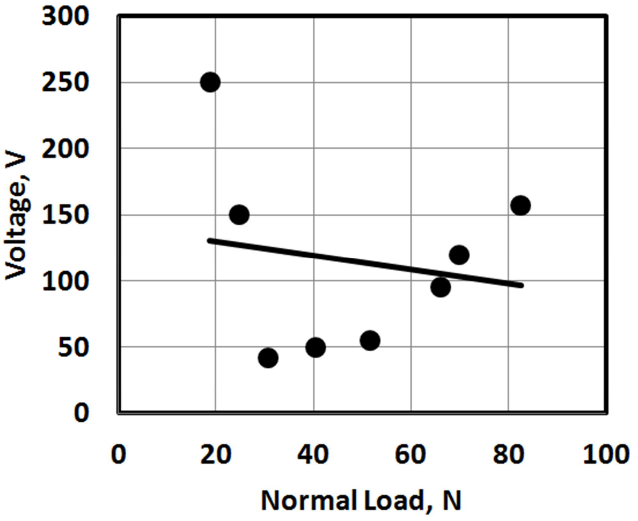

Fig. 7. Electric static charge of latex glove generated from its sliding against dry cover.

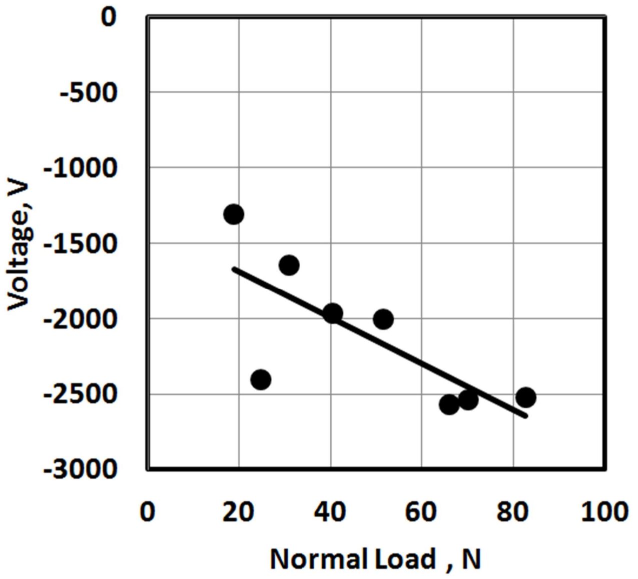

Fig. 8. Electric static charge of cover generated from its sliding against dry latex glove.

It was observed that, at sliding, the values of the charge were higher than that recorded for contact and and separation. Based on this observation it can be concluded that materials of both glove and cover generated very high electric static charge values. When two materials contact each other, the upper one in the triboelectric series will be positively charged and the other one will be negatively charged. As the difference in the rank of the two materials increases the generated voltage increases. It is known that glove (acrylonitrile butadiene rubber) is ranked above the material of the cover (nonwoven polypropylene), so that glove was positively charged and the gap is relatively short in the triboelectric series which decreases the voltage difference. It is therefore necessary to select the materials based on their triboelectric ranking.

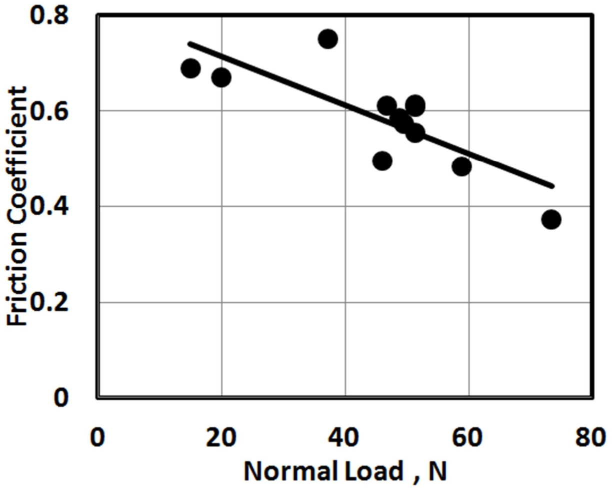

Fig. 9. Friction coefficient displayed by sliding of latex glove against water wet cover.

The results of experiments measuring friction coefficient and electric static charge at water wet contact are illustrated in Figs. 9–13. Friction coefficient is considered as main factor in the evaluation of the contacting materials. Friction coefficient displayed by sliding of glove against cover at water wet condition is shown in Fig. 9. Friction coefficient decreased with increasing the load. The lowest friction value was 0.38, while the maximum value was 0.75. The values of friction were lower than that observed for dry contact.

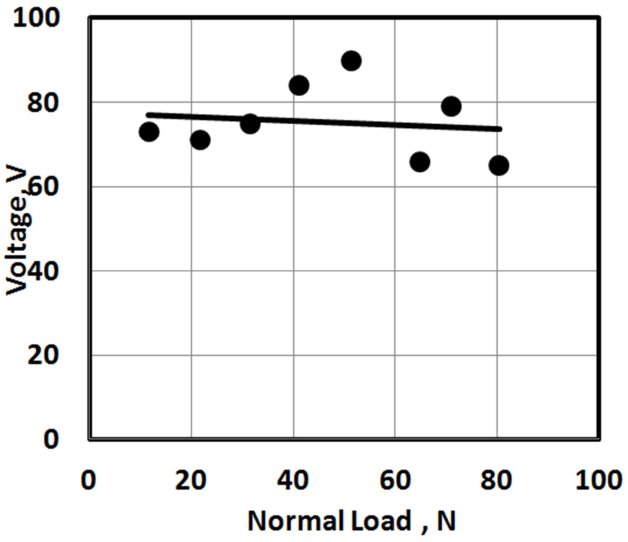

Fig. 10. Electric static charge of latex glove generated from its contact and separation against water wet cover.

Voltage generated on the glove from its contact and separation against cover is shown in over cover, Fig. 11, displayed negative voltage reached-57 volts. The values of electric static charge were approximately similar to that shown for the opposite side (glove). It seems that the low values of charge were from the ability of water to conduct the charge from the contact surfaces. It is recommended to measure the charge simultaneously on the two opposing surfaces.

Voltage generated on sole from its sliding against cover is shown in Fig. 12. The maximum voltage value was 73 volts at 17 N. The electric static charge generated on the cover from its sliding against glove is shown in Fig. 13. The voltage observed was in negative sign with relatively high values.

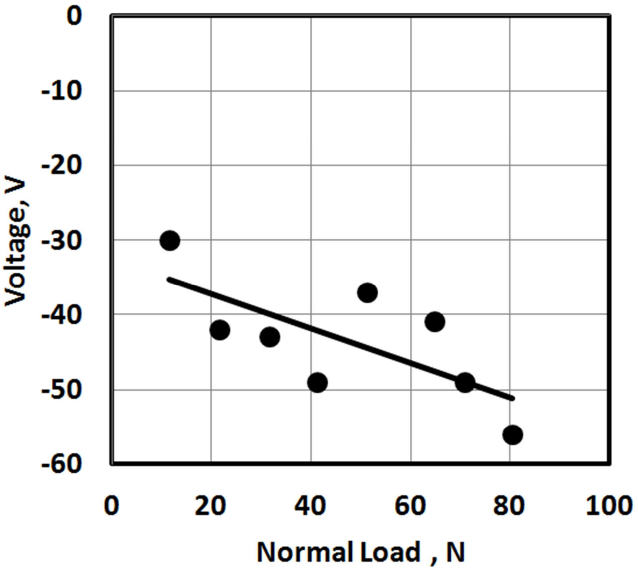

Fig. 11. Electric static charge of cover generated from its contact and separation against water wet latex glove.

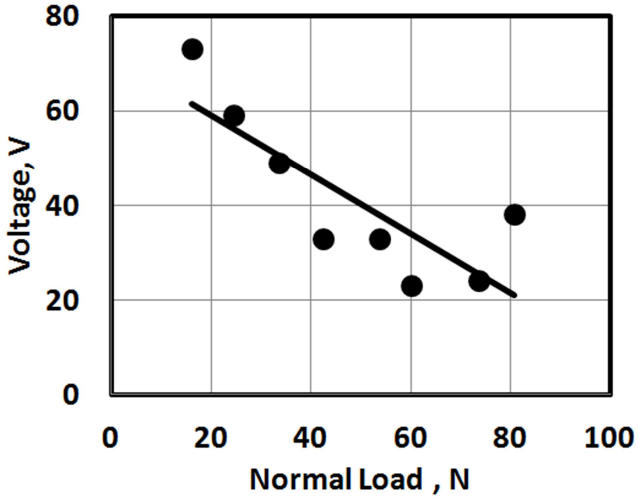

Fig. 12. Electric static charge of latex glove generated from its sliding against water wet cover.

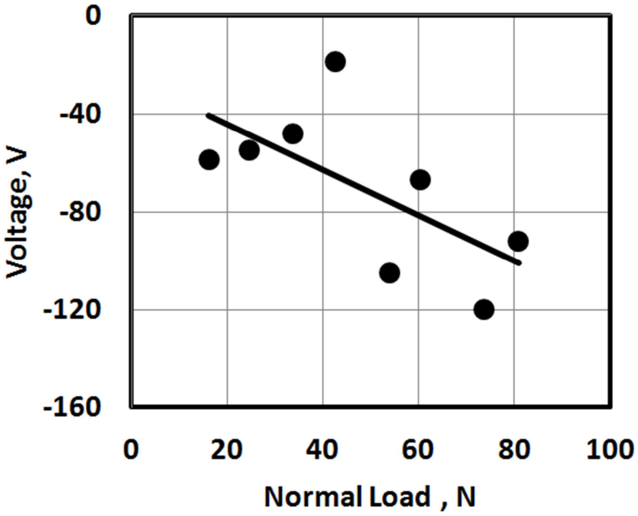

Fig. 13. Electric static charge of cover generated from its sliding against water wet latex glove.

4. Conclusions

1. Friction coefficient displayed by sliding of latex glove against dry cover decreased with decreasing normal load. As the load increased friction coefficient slightly decreased. The friction values guaranteed the good adhesion of the latex glove and dry cover.

2. Electric static charge generated on the dry glove from contact and separation against cover decreased as the load increased showed negative values, while the glove gained positive charge.

3. The sliding of glove against dry cover generated much higher electric static charge than that observed in contact and separation measured on the glove. Electric static charge generated on the cover surface recorded very high voltage value. This observation can confirm the necessity to develop new materials to be applied as glove and cover of low electric static charge.

4. Voltage generated on the glove from its contact and separation against cover displayed negative voltage. The values of electric static charge were approximately similar to that shown for the opposite side (glove). It seems that the low values of charge were from the ability of water to conduct the charge from the contact surfaces.

5. Voltage generated on glove from its sliding against cover was in negative sign with relatively high values.

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