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ELECTRIC STATIC CHARGE GENERATED FROM THE FRICTION OF TEXTILES

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ABSTRACT

The wide use of polymer fibres 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, is discussed in the present work. 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 increasing the displacement up to 300 mm the voltage increased from - 5 V to - 25 V for 100 % polyester specimens The 100% spun polyester showed slight increase of the voltage by increasing displacement. Increase of cotton content decreased the generated voltage. Besides, as the load increased voltage generated from rubbing of 100 % spun polyester specimens increased, while increasing the load had no effect on the 100 % polyester as well as 100 % super max. polyester and the later one displays higher average voltage value compared to the other two polyester specimens.

Mixing polyester with rayon (viscose) showed the same behavior of mixing it with cotton except for 83 % fine polyester and 17 % super rayon which has completely different trend as the voltage decreased by increasing the load. It seems that fine fibres, of the two rubbed surfaces, charged by free electrons easily exchanged the electrons of dissimilar charges, where the resultant indicated relatively lower voltage.

Generally, increasing velocity increased the voltage. 100 % super max. polyester showed higher average voltage values than the other two types of polyester. 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 80 % polyester, 17 % super rayon fabric specimens showed no effect of velocity on voltage that could be attributed to the use of high wet modulus rayon.

KEYWORDS

Cotton, polyester, rayon, textiles, electric static charge, triboelectrification.

INTRODUCTION

The electrostatic charge generated from the friction of polytetrafluoroehylene (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, [1]. 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, [2]. Materials can be assessed for risks from static electricity by measurement of charge decay and by measurement of capacitance loading, [3]. 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, [4]. 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, [5]. 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, [6, 7]. 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, [8]. 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, [9]. 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, [10]. 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.

Little attention has been devoted so far to the electrostatic properties of hair although these properties are very sensitive to the friction between hair and head scarf textiles. Hair has a tendency to develop static charge when rubbed with dissimilar materials like human skin, plastic and textiles. Human hair is a good insulator with an extremely high electrical resistance. Due to this high resistance, charge on hair is not easily dissipated, especially in dry environments. Many macroscale studies have looked at the static charging of human hair, [11 - 13]. Most of these studies include rubbing hair bundles with various materials like plastic combs, teflon, latex balloons, nylon, and metals like gold, stainless steel and aluminum. Hair in these cases is charged by a macroscale triboelectric interaction between the surface and the rubbing element. The kinetics of the charging process and the resulting charge are then measured using modified electrometers.

In the present work, the electric static charge generated from the relative motion between surfaces of different polymeric textiles sliding against cotton textiles will be investigated.

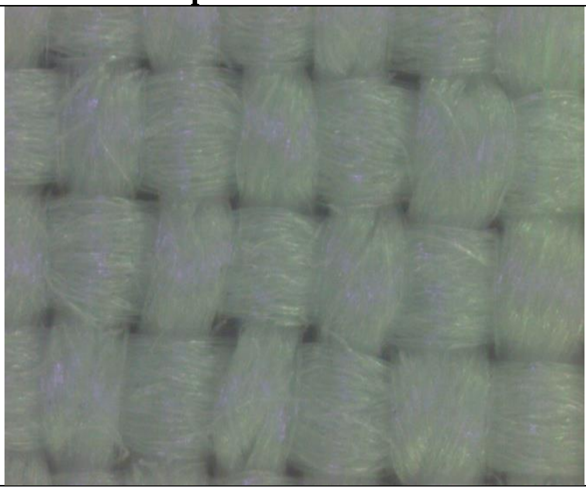
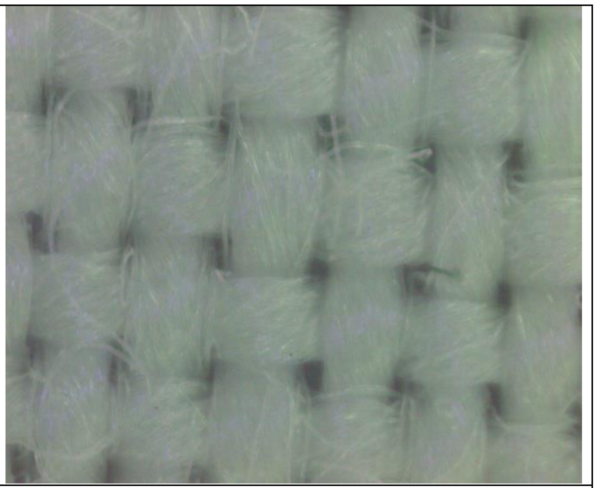
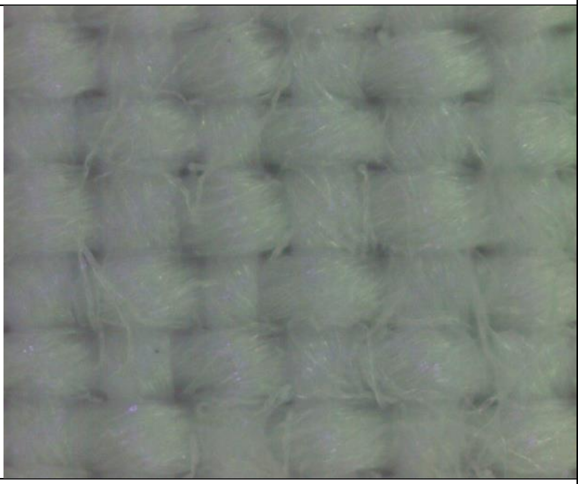
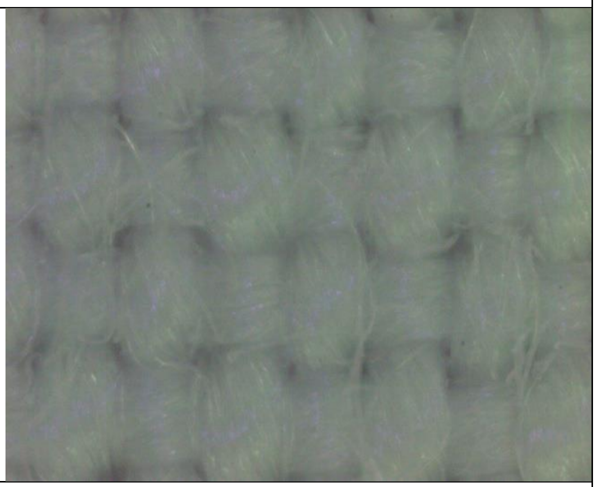
EXPERIMENTAL

The electrostatic fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens, Fig. 1. It measures down to 1/10 volt on a surface, and up to 20 000 volts (20 kV). Readings are normally done with the sensor 25 mm apart from the surface being tested.

Fig. 1 Electrostatic field measuring device.

The specimens, of polymeric textiles, were prepared in strips of 100 mm width and 300 mm length. They were fastened on the surface of wooden plate of 400 × 400 mm^2, Table 1. The cotton textiles were adhered to the wooden block of 50 × 50 mm^2. Tests were carried out at room temperature under 5, 10, 15, 20, 25 and 30 N normal loads. The sliding velocity was 20, 25, 30, 50, 90 and 300 mm/sec. The sliding distance was 50, 100, 150, 200, 250 and 300 mm. Experiments were carried out by sliding the cotton test specimens against the polymeric textiles. The electric static charge was measured by DC voltmeter.

Table 1 Test specimens.

	
100 % super max. polyester.	**100 % polyester.**
	
100 % cotton.	**80 % polyester, 20 % rayon.**

	
50 % cotton, 50 % polyester.	**40 % cotton, 60 % polyester.**

RESULTS AND DISCUSION

Electrostatic charges, measured in voltage, of three different types of polyester fabric specimens rubbing a reference material (cotton) are shown in Fig. 2 as a function of displacement. The 100 % polyester specimens showed that by increasing the displacement up to 300 mm the voltage increased from - 5 V to - 25 V. This behaviour could be attributed to the fact that polyester and cotton are different materials and according to the tribo-electric series, friction between two surfaces causes the object in the upper position of the series to be charged positively (cotton) and that in the lower position to be charged negatively (polyester). It is known that different polarity means attraction. Also, it could be attributed to that the long distance gives higher chance to exchange more charges (electrons) between the two different materials rubbing each other. The 100 % spun polyester showed slight increase of the voltage by increasing displacement.

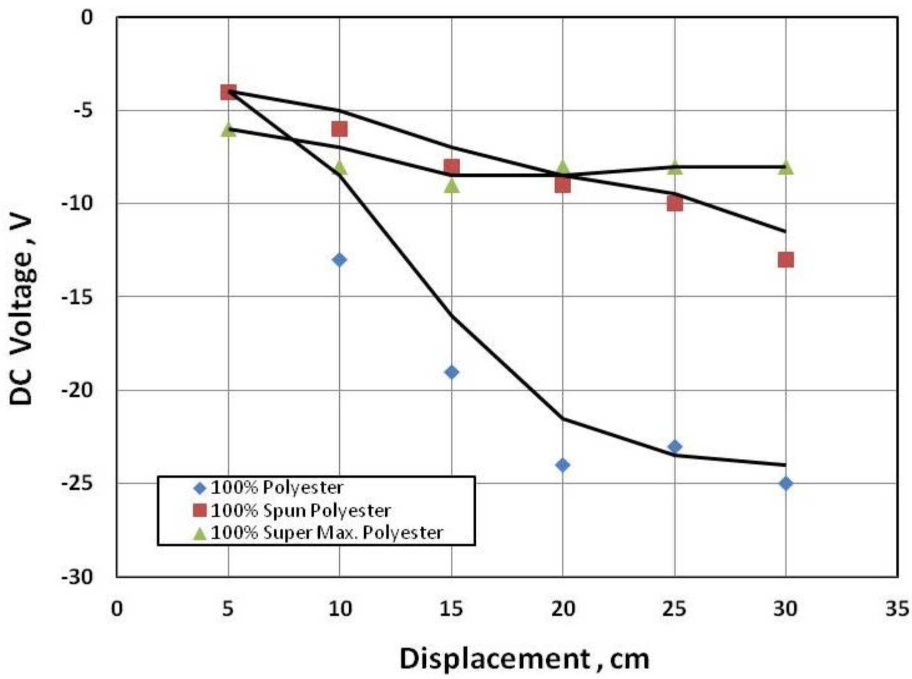


Fig. 2 Voltage generated from electrostatic charges versus displacement of three different types of polyester rubbing cotton.

Figure 3 shows that the increase of cotton content decreased the generated voltage and that may be attributed to the fact that no or small amount of charges will be exchanged if same materials rubs each other. All the tested materials in this experiment were rubbing cotton which was used as a reference material. It also verifies that increasing the distance would increase the voltage. Figure 4 shows that increasing displacement will increase the voltage. At 300 mm displacement specimens containing rayon instead of cotton decreased the value of voltage from -32 V of 60 % polyester and 40 % cotton fabric specimens in Fig. 2 to -17 V for 65 % polyester – 35 % viscose fabric specimens. It can be seen that increasing the load slightly increased voltage generated from rubbing of 100 % spun polyester specimens, while increasing the load has no effect on the 100 % polyester as well as 100 % super max. polyester and the later one displayed higher average voltage value compared to the other two polyester specimens.

Voltage generated from electrostatic charges versus load of four different types of fabrics rubbing cotton is shown in Fig. 5, where increasing the load had insignificant effect on the four different types of fabrics showed in the figure. It is shown that increasing polyester content reduced the average voltage value from -5 V of 100 % cotton specimens to -3 V of 60 % polyester, 40 % cotton specimens.

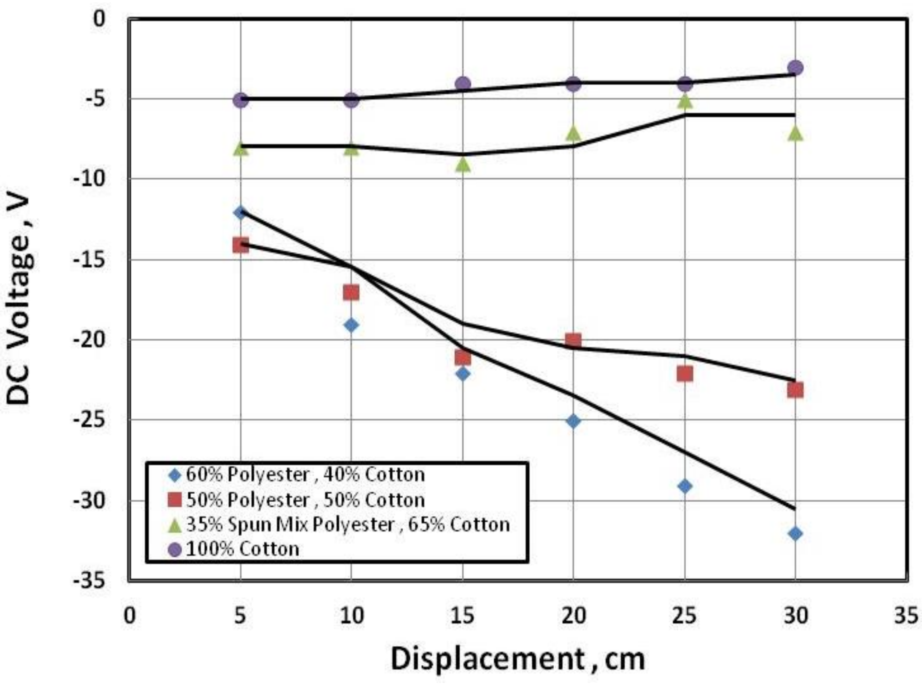


Fig. 3 Voltage generated from electrostatic charges versus displacement of four different types of fabrics rubbing cotton.

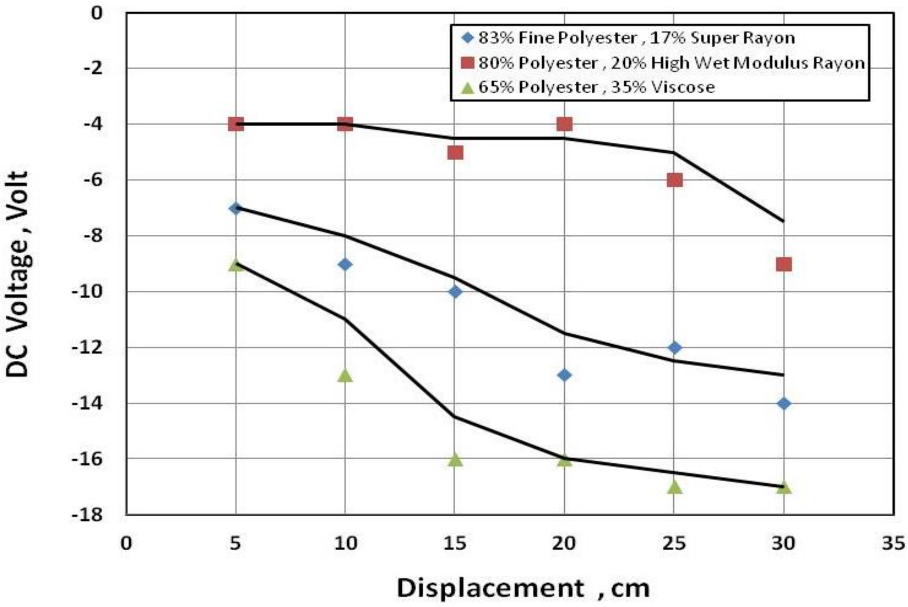


Fig. 4 Voltage generated from electrostatic charges versus displacement of three different types of fabrics rubbing cotton.

Mixing polyester with rayon (viscose) showed the same behavior of mixing it with cotton, Fig. 6, except for textile of 83 % fine polyester and 17 % super rayon which had completely different trend as the voltage decreased by increasing the load. It could be attributed to the use of fine polyester instead of regular one or the use of super rayon since the content percentage of polyester and rayon were nearly the same in polyester high wet modulus rayon fabric specimens and fine polyester, super rayon fabric specimens. It seems that fine fibres, of the two rubbed surfaces, charged by free electrons easily exchanged the electrons of dissimilar charges where the resultant became relatively lower voltage.

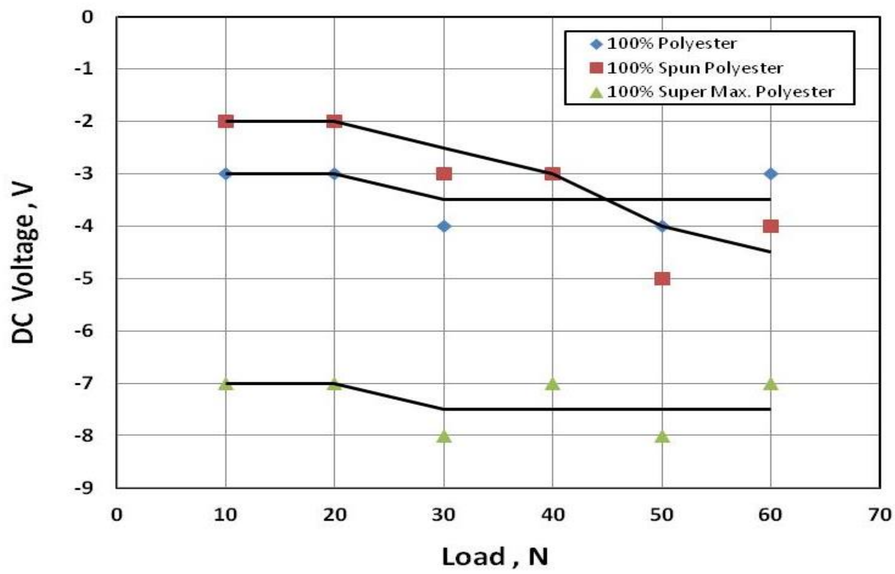


Fig. 4 Voltage generated from electrostatic charges versus load of three different types of polyester rubbing cotton.

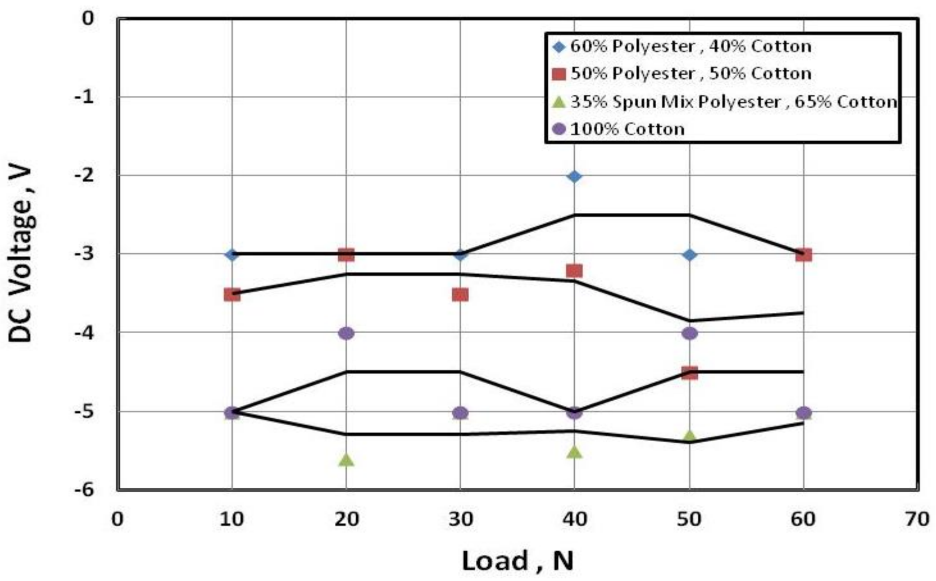


Fig. 5 Voltage generated from electrostatic charges versus load of four different types of fabrics rubbing cotton.

Generally, increasing velocity increases the voltage when the three types of polyester rubbed cotton with variable velocity, Fig. 7. Textile of 100 % super max. polyester showed high average voltage value equal to -20 V as compared to the other two types of polyester which showed approximately an average voltage value equals to -5 V .

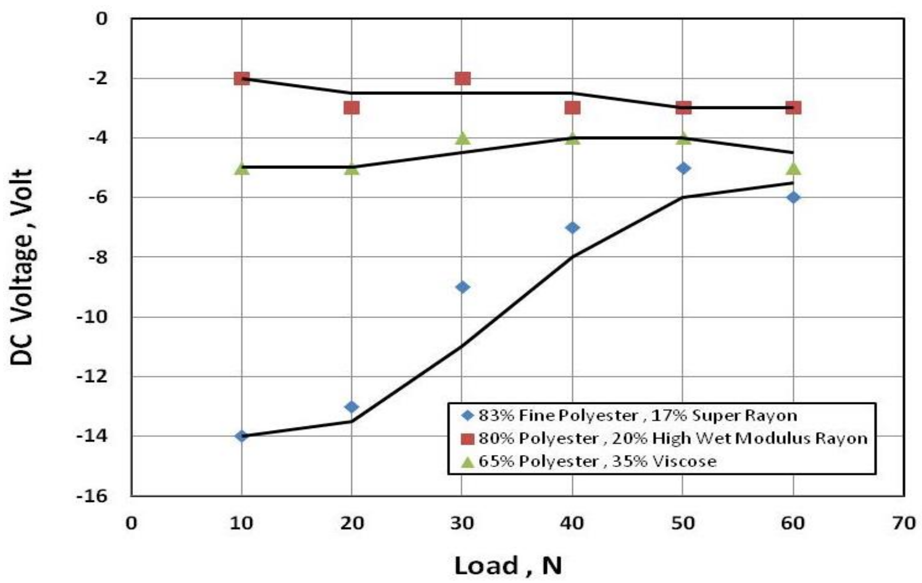


Fig. 6 Voltage generated from electrostatic charges versus load of three different types of fabrics rubbing cotton.

It is clearly seen that 50 % polyester, 50 % cotton fabric specimens, Fig. 8, showed that increasing velocity increased the voltage while increasing polyester content or cotton content decreased the voltage and kept it nearly constant with velocity increase. The voltage increase with increasing velocity might be attributed to the increase of the mobility of the free electrons to one of the rubbed surfaces. The fineness of the fibres much influenced the movement of the free electrons. This was confirmed by the behaviour of 35 % spun polyester and 65 % cotton.

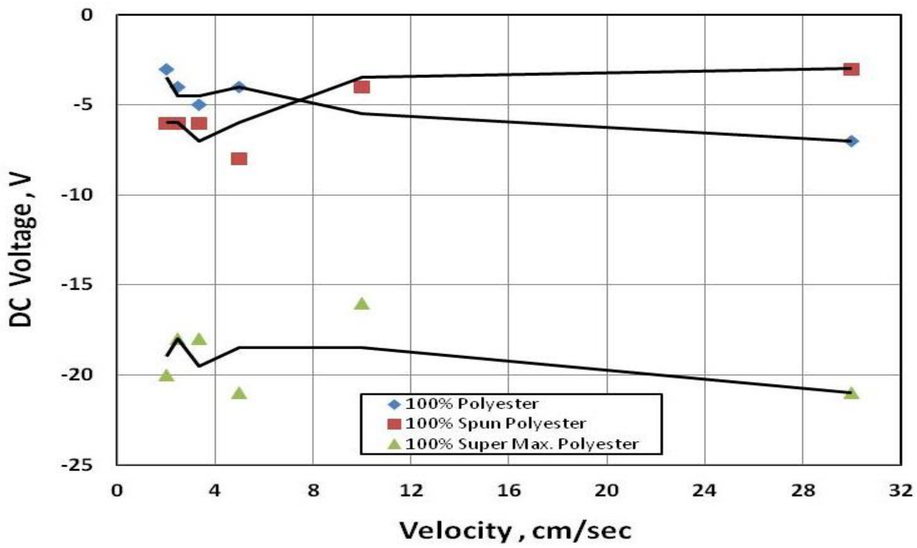


Fig. 7 Voltage generated from electrostatic charges versus velocity of three different types of polyester rubbing cotton.

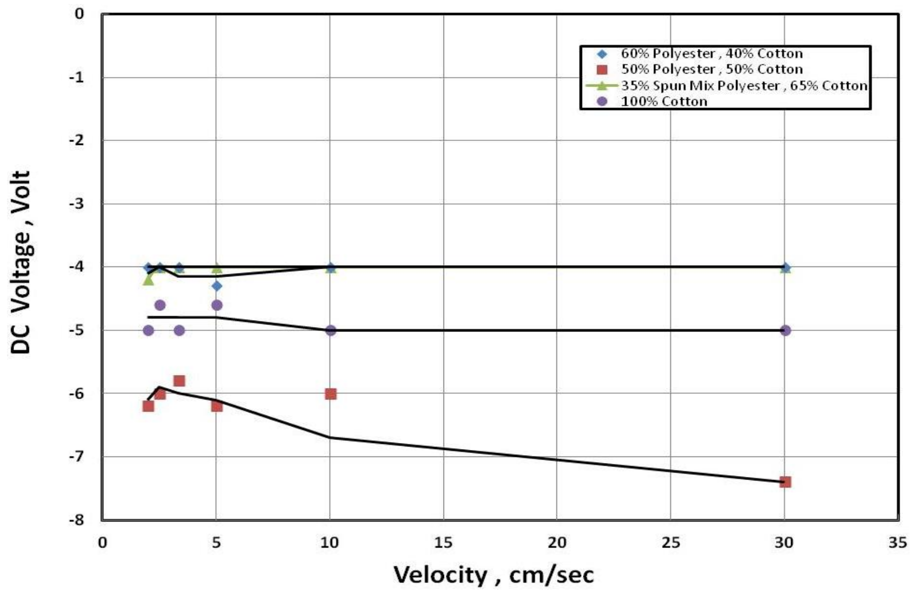


Fig. 8 Voltage generated from electrostatic charges versus velocity of four different types of fabrics rubbing cotton.

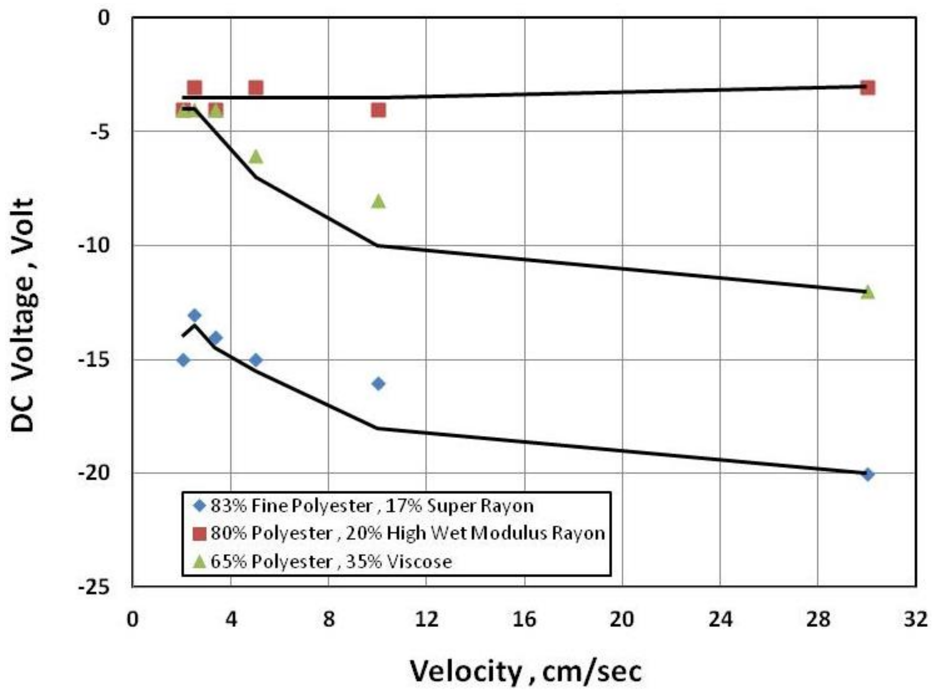


Fig. 9 Voltage generated from electrostatic charges versus velocity of three different types of fabrics rubbing cotton.

Figure. 9 verifies that increasing velocity increased voltage and showed that increasing polyester content and rayon (viscose) increased the value of the voltage. The 80 % polyester and 17 % super rayon fabric specimens showed no effect of velocity on voltage that could be attributed to the use of high wet modulus rayon.

CONCLUSIONS

1. The behavior of electrostatic charges is difficult to be predicted but in general the conducted experiment showed that displacement had a significant effect on the electrostatic charge as displayed by the results which indicated that increasing displacement increased the voltage .
2. Replacing cotton by rayon decreased the value of the charge voltage from -30 V to -16 V due to their close position in the triboelectric series.
3. For mixed polyester/cotton fabrics rubbing cotton the voltage increased when the polyester content increased.
4. Increasing load showed no significant effect, where the effect of high load values needs to be verified.
5. Use of fine polyester and super rayon showed different behavior as the generated voltage decreased by increasing load.
6. Voltage slightly increased when the velocity increased.

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