Friction Coefficient and Triboelectrification of Textiles

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Abstract— The use of polymeric fibers has been extensively increased in the industry of textiles. These materials generate electric static charge that causes serious effects of the health and safety of human beings. Proper selection of textile materials can reduce generation of electric static charge. The present study investigates the effect of blending polyester textiles by cotton and viscose on the friction coefficient and triboelectrification. Static friction coefficient as well electric static charge displayed by polyester textiles of different cotton and viscose contents under dry sliding against wool and polyacrylonitrile textiles are investigated.

Based on the fact that comfort of textiles is measured by the friction coefficient displayed by sliding of textiles against skins or other textiles, it was found that friction coefficient of polyester-cotton blend textiles sliding against wool slightly increased with increasing the cotton content of the tested textile. As the load increases, friction coefficient decreases. Blending polyester by viscose showed slight friction decrease with increasing viscose content. Besides, 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.

Keywords—Friction coefficient, electric static charge, dry, sliding, cotton, viscose, polyester, wool, polyacrylonitrile.

I. INTRODUCTION

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. The use of polymeric fibers has been extensively increased. These materials generate static electricity when they contact and/or rub with other textiles. Electric static discharge can cause problems of health and safety, [1, 2]. Textile materials (textiles, fabrics, upholstery fabrics) accumulate electric charge. Textile materials are composed of fibers and air gaps, [3], and behave like an electric charge accumulating capacitor. Besides, the electrical properties of fabrics or textiles depends on the topography, compactness and atmospheric conditions where the textile products are used. Wearers of textiles are looking for materials generating acceptable electric static charge.

Triboelectric charge generated by woven fabrics like cotton, polyester, nylon and polypropylene materials was investigated, [4]. The charge generated on finish free cotton fabrics was high when compared with other fabrics. On the other side, the charge on cotton fabric decayed very quickly due to the higher conductivity of cotton. The charge decay on polyester, nylon and polypropylene was relatively slower compared to cotton.

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, [5]. 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, [6]. 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, [7]. 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, [8]. Materials can be assessed for risks from static electricity by measurement of charge decay and by measurement of capacitance loading, [9].

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. 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 possibility of having minimum electric static charge generated from the friction between the proposed polymeric composites consisting of polytetrafluoroethylene, (PTFE) and polyamide, (PA) fibres when sliding against cotton textiles was investigated, [11]. The idea depends on the fact that PTFE gains negative electric static charge when sliding against all the other materials, while PA gains positive charge. The control of the content of the materials of the proposed composites is thought to control the value and signal of the generated electric static charge. Experiments were carried out to measure the electric static charge and friction coefficient. Based on the fact that, PTFE gaines negative charge and PA gaines positive charge, the resultant voltage would depend on the combination of both PTFE and PA. This observation confirmed that the intensity of electric static charge depended on the load. Further increase in PA content gave positive voltage. It was observed that, fibre diameter of PA had critical effect on the generated voltage. Voltage generated at sliding was higher than that recorded for contact and and separation. Knowing that in application, contact and separation is accompanied by sliding. Therefore, it can be suggested to use mean values to determine the proper PA content at which zero voltage can be obtained. It is proposed to make further experiments to determine the effect of the fibre diameter of both PA and PTFE on the generated voltage. Besides, microfibres as well as nanofibres should be tested.

The friction coefficient and electric static charge generated from the dry and water wet sliding of surgical gloves and the covers of the cloths of people who are working in hospitals were 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. 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.

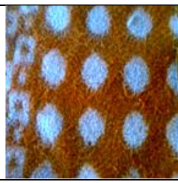
In the present work, the effect of the cotton and viscose contents of polyester textiles on their friction coefficient and triboelectrification when sliding against wool and polyacrylonitrile textiles is discussed. The static friction coefficient electric static charge are investigated.

II. EXPERIMENTAL

The present work investigates the measurement of friction coefficient and electric static charge generated by the sliding of the tested textiles against wool and polyacrylonitrile textiles, Table I. The electrostatic fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electric static charge (electrostatic field) generated on the test specimens. The tested textiles were adhered to the wooden block of 50 × 50 mm2. Tests were carried out at room temperature under varying normal loads using a test rig designed and manufactured for that purpose, Fig. 1. The wool and polyacrylonitrile textiles as well as their blend were placed in a base supported by two load cells, the first can measure the horizontal force (friction force) and the second can measure the vertical one (normal load). Friction coefficient was determined by the ratio between the friction force and the normal load.

During test running, horizontal and vertical load cell connected to two monitors read normal and friction load respectively. Each run was replicated five times, and the mean value of the friction coefficient was considered. Friction test were carried out at different forces (loads) ranging from 0 - 12 N.

TABLE I. TESTED TEXTILES

	
100 wt. % Wool	100 wt. % Polyacrylonitrile
	
50 wt. % Wool + 50 wt. % Polyacrylonitrile	Viscose

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Polyester	Cotton

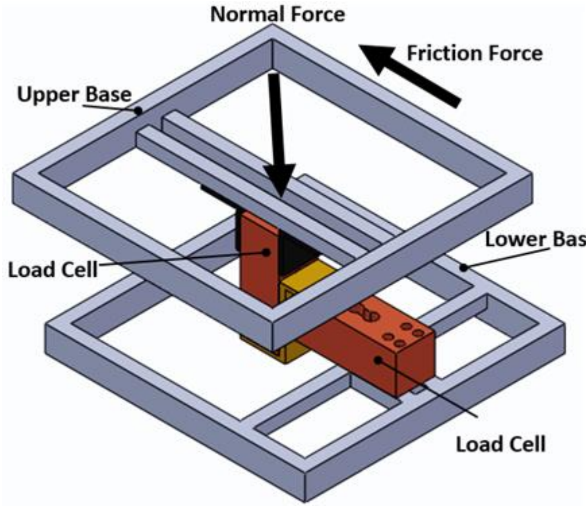
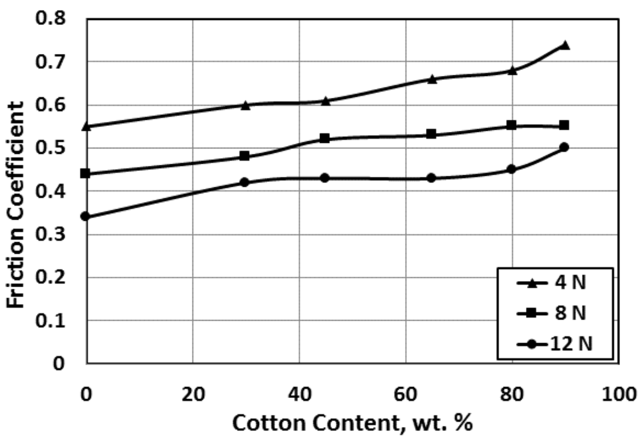


Fig. 1. *Arrangement of the test rig.*

III. RESULTS AND DISCUSSION

Comfort of textiles is the main factor in their specification and evaluation as clothes. The measure of the comfort is the friction coefficient displayed by the sliding against skins or other textiles. As the friction coefficient increased the comfort of the clothes decreased. Tests were carried out at different values of load exerted by hand. In the present work, the results of three values of load of 4, 8 and 12 N are discussed. Friction coefficient displayed by sliding of polyester-cotton blend textiles against wool, Fig. 2, slightly increased with increasing cotton content. As the load increases, friction coefficient decreases. The maximum friction values observed were 0.73, 0.55 and 0.5 for 90 wt. % cotton, while textile of 100 % polyester displayed the lowest friction values of 0.54, 0.43 and 0.33 at load values of 4, 8 and 12 N respectively.



Friction coefficient displayed by sliding of polyester-cotton blend textiles against wool.

Friction coefficient displayed by sliding of polyester-cotton blend textiles against polyacrylonitrile showed slight increase which may be attributed to the fact that cotton displays relatively higher friction than polyester, Fig. 3. Friction coefficient decreased with increasing normal load. Friction values showed relatively lower ones than that observed for sliding against polyacrylonitrile. When the counterface was blend of wool and acrylonitrile, friction coefficient displayed the same trend, Fig. 4, where friction values are relatively lower than that displayed by wool and higher than that shown for polyacrylonitrile. Friction coefficient significantly increased with increasing cotton content, where the highest friction values were displayed by textiles containing 90 wt. % cotton content.

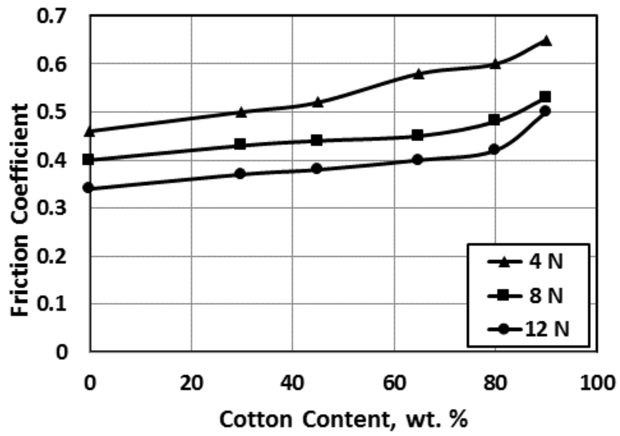


Fig. 2. *Friction coefficient displayed by sliding of polyester-cotton blend textiles against polyacrylonitrile.*

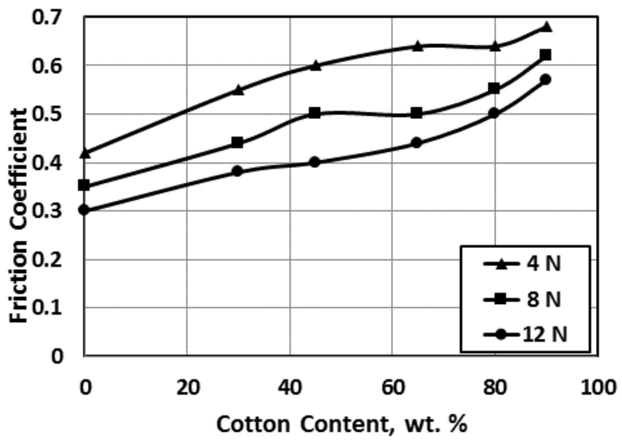


Fig. 3. *Friction coefficient displayed by sliding of polyester-cotton blend textiles against wool-polyacrylonitrile blend.*

The electric static charge of the tested textiles is very sensitive to the friction. They have tendency to develop static charge when rubbed with dissimilar materials like other textiles. Polymeric fibres have good insulation with an extremely high electrical resistance. Due to this high resistance, charge on polymeric textiles is not easily dissipated, especially in dry environments. Electric static charge generated from sliding of polyester-cotton blend textiles against polyacrylonitrile is shown, Fig. 5. Polyester textiles generated high voltage that decreased with increasing normal load. Voltage values were 5200, 4800 and

4000 volts at 4, 8 and 12 N load respectively. Blending polyester by cotton fibres showed drastic charge decrease, where the values were 350, 300 and 250 volts 4, 8 and 12 N load respectively.

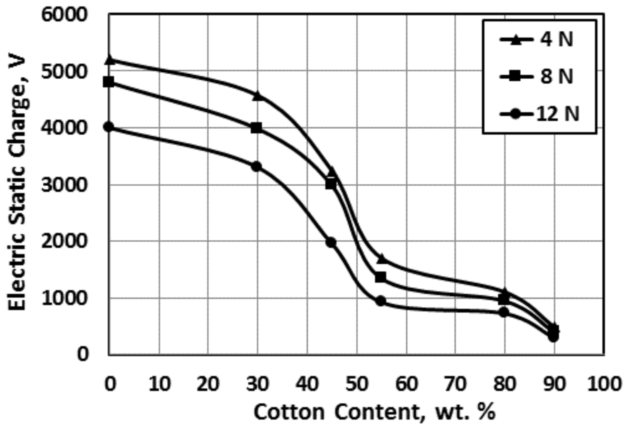


Fig. 4. *Electric static charge generated from sliding of polyester-cotton blend textiles against polyacrylonitrile.*

When wool was the counterface, the generated voltage for polyester displayed very high values reached to 9000 volts then drastically decreased with increasing cotton content, Fig. 6. The triboelectric series of the tested textiles, Table II, can explain the generation of the high value of electric static charge, where the gap between wool and polyester is higher than that indicated for acrylonitrile and polyester. When wool rubs polyester it gains more positive charge because it is near the positive position in the triboelectric series relative to the position of polyester. Polyester gains more negative charge. Because the two materials are far apart from each other in the series, the charge generated will be larger.

TABLE II. TRIBOELECTRIC SERIES OF THE TESTED TEXTILES

Positive Charge	
	Wool
	Viscose
	Cotton
	Polyester
	Polyacrylonitrile
Negative Charge	

Electric static charge generated from sliding of polyester-cotton blend against wool-polyacrylonitrile blend, Fig. 7, showed moderate values relative to that generated in Figs. 5 and 6. As the cotton content increased, voltage drastically decreased. Cotton has a tendency gaining positive (+) charges, while polyester attracts electrons and gains negative (-) charges. Therefore, blending polyester by cotton decreases generation of the electric static charge.

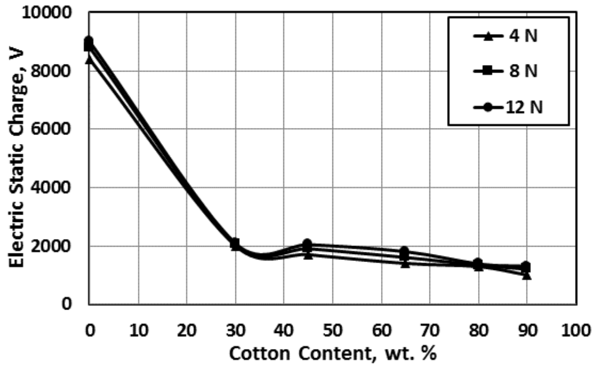


Fig. 5. *Electric static charge generated from sliding of polyester-cotton blend textiles against wool.*

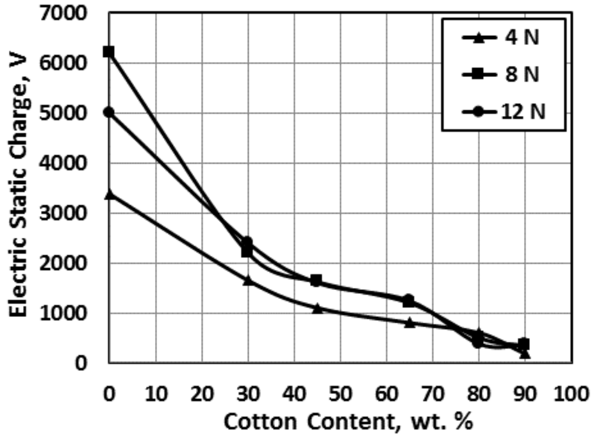


Fig. 6. *Electric static charge generated from sliding of polyester-cotton blend textiles against wool-polyacrylonitrile blend.*

The quality of textiles for certain purposes depends to a large degree on their surface characteristics such as slipperiness and smoothness. The surface characteristics vary with the types of textiles, the weave and the finish. Besides, clothes, home furnishings, surgical gowns and automotive fabrics are touched by the human skin so that friction coefficient is considered one of the important factors that qualify the use of textiles, [15 – 17]. A simple method for specifying the slipperiness or smoothness of a fabric in terms of the coefficient of static friction between two pieces of the same material was described, [18]. Friction coefficient displayed by sliding of polyester-viscose blend textiles against wool, wool-polyacrylonitrile blend and polyacrylonitrile is shown in Figs. 8, 9 and 10 respectively. Slight friction decrease was observed for sliding against wool, Fig. 8. As the load increased, friction coefficient decreased. It seems that, as the load increases the pressure applied on the fibre fringes increases, flattens the fringes and makes their surface smoother. In consequence, friction coefficient decreases, [13]. The second explanation indicated that the fringe behaves more like a sheet of fibres, presenting more uniform area of contact, [14], and leading to the decrease of friction coefficient.

Friction coefficient displayed by sliding of polyester-viscose blend textiles against wool-polyacrylonitrile blend showed more friction decrease with increasing of viscose content, Fig. 10. The lowest friction values

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were 0.24, 0.2 and 0.18 at 4, 8 and 12 N load respectively at 95 wt. % which were lower than that observed for sliding against wool. 100 % polyester displayed lower friction when sliding against wool-polyacrylonitrile blend. Slight increase was detected for sliding against polyacrylonitrile, Fig. 10.

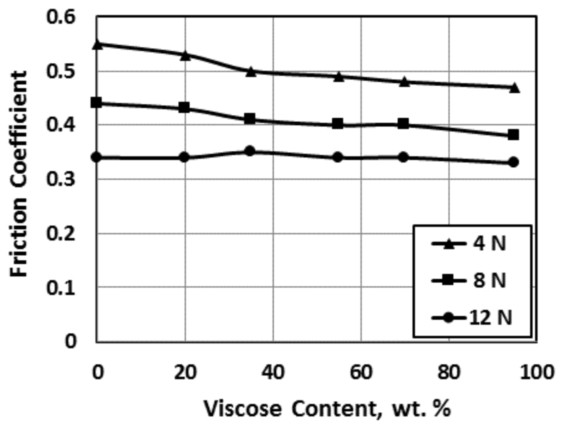

Fig. 7. *Friction coefficient displayed by sliding of polyester-viscose blend textiles against wool.*

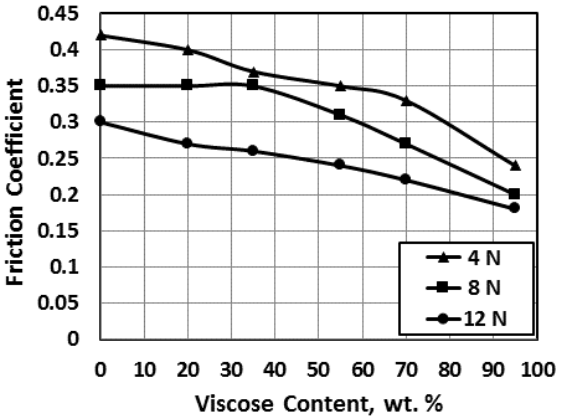

Fig. 8. *Friction coefficient displayed by sliding of polyester-viscose blend textiles against wool-polyacrylonitrile blend.*

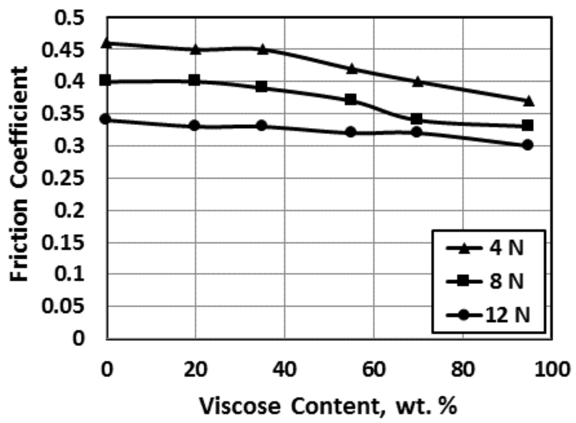

Fig. 9. *Friction coefficient displayed by sliding of polyester-viscose blend textiles against polyacrylonitrile.*

The contact and separation as well as sliding of textiles against each other built up an electric static charge on the textiles when the layers of clothing rub against each other and the human skin. The polymeric textiles in most clothing do not conduct electricity. The risk of electric shock or a spark increases. Electric static charge generated from sliding of polyester-viscose blend textiles against wool is shown in Fig. 11, where blending polyester by viscose caused drastic decrease in the generated electric charge. The same trend was observed for sliding against polyacrylonitrile and wool-polyacrylonitrile blend, Figs. 12 and 13 respectively. It is clearly illustrated that blending polyester by viscose can decrease both the friction coefficient and the generated electric static charge.

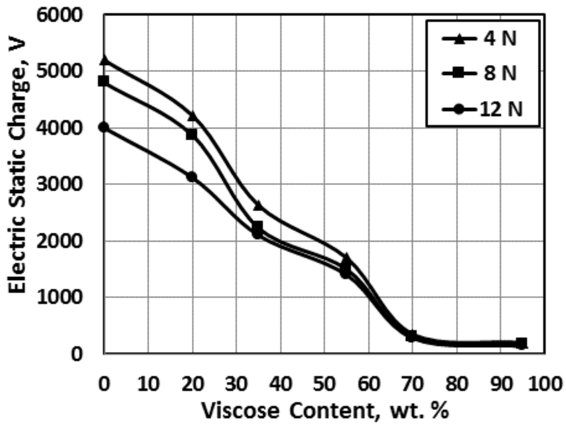

Fig. 10. *Electric static charge generated from sliding of polyester-viscose blend textiles against wool.*

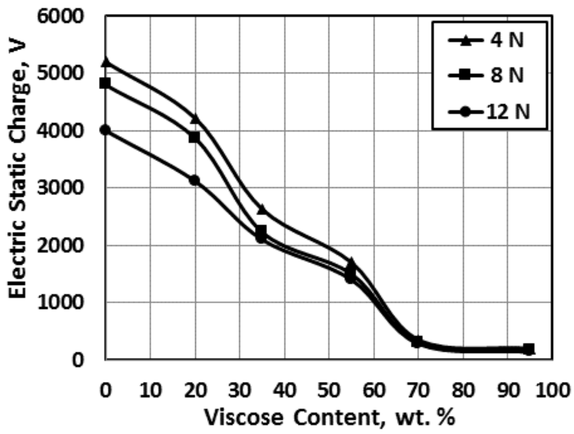

Fig. 11. *Electric static charge generated from sliding of polyester-viscose blend textiles against polyacrylonitrile.*

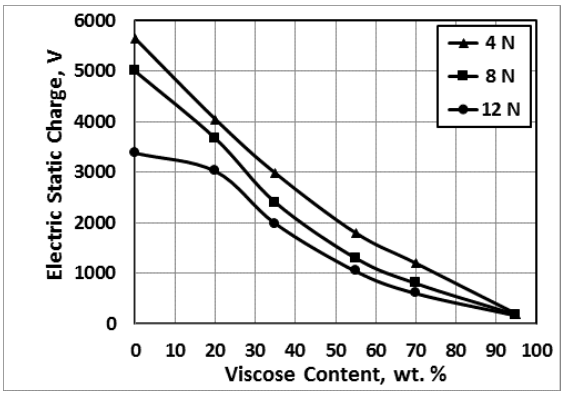

Fig. 12. *Electric static charge generated from sliding of polyester-viscose blend textiles against wool-polyacrylonitrile blend.*

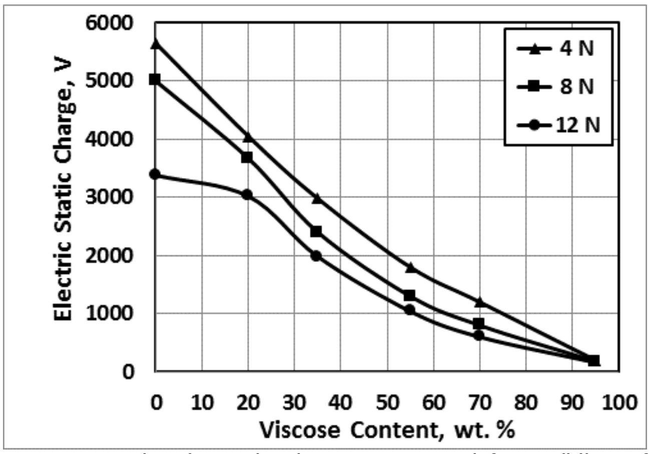

Fig. 13. *Electric static charge generated from sliding of polyester-viscose blend textiles against wool-polyacrylonitrile blend.*

IV. CONCLUSIONS

1. Friction coefficient displayed by sliding of polyester-cotton blend textiles against wool, slightly increased with increasing the cotton content of the tested textile. As the load increases friction coefficient decreases. Sliding against polyacrylonitrile showed lower friction values than that displayed by wool and higher than that shown for polyacrylonitrile.

2. Friction coefficient displayed by sliding of polyester-viscose blend textiles against wool caused slight decrease when sliding against wool, while sliding against wool-polyacrylonitrile blend showed more friction decrease with increasing of viscose content. Slight increase was detected for sliding against polyacrylonitrile.

3. Polyester textiles generated the highest voltage which decreased with increasing normal load. Blending polyester by cotton fibres showed drastic voltage decrease. When wool was the counterface, the generated voltage for polyester displayed the maximum voltage values up to 9000 volts then drastically decreased with increasing cotton content.

4. Blending polyester by viscose caused drastic decrease in the generated electric charge. The same trend was observed for sliding against polyacrylonitrile and wool-polyacrylonitrile blend. It is clearly illustrated that blending polyester by viscose can decrease both the friction coefficient and generated electric static charge.

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