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TRIBOELECTRIFICATION OF POLYMERIC TEXTILES

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ABSTRACT

The present work investigates 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. 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 under varying load.

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 will as nanofibres should be tested.

Comfort of textiles is considered as 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. Friction coefficient drastically decreased with increasing the load and PA content. The lowest friction values were observed at 100 wt. % PA content. 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.

KEYWORDS

Cotton, polytetrafluoroethylene, polyamide, textiles, electric static charge, friction coefficient.

INTRODUCTION

It was found that addition of wool and cotton fibers into polymeric fibres remarkably decreases the electrostatic discharge and consequently the proposed composites will become environmentally safe textile materials. Measurement of static electricity is of critical importance in assessing the proper electric properties of car seat covers and their suitability to be used in application to enhance the safety and stability of the driver. 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, [1, 2]. 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. Remarkable voltage increase was observed for contacting synthetic rubber. This observation can limit the application of synthetic rubber in tailoring clothes.

Another major consideration is the potential for products to produce friction-induced injuries to skin such as blistering, [3, 4]. 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, [5]. 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, [6]. 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, [7]. 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, [8 - 10]. 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 aluminium. 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.

The aim of the present work is to test proposed composites consisting of strings of two materials. The first one is PTFE and the second is polyamide. It is well known that PTFE is negative charged, while polyamide is positive charged. The combination of the two materials is thought to produce composite of minimum electric charge when sliding against cotton.

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. The fibres of PTFE and PA were adhered to the wooden block of 50 × 50 mm^2 in different content. PA fibres were of 0.4, 0.5 and 0.6 mm diameter, while PTFE fibres were of 1.0 mm diameter. The counterface was prepared in cotton textiles of 100 mm width and 300 mm length. They were fastened on the surface of wooden plate of 400 × 400 mm^2.

Fig. 1 Electrostatic field measuring device.

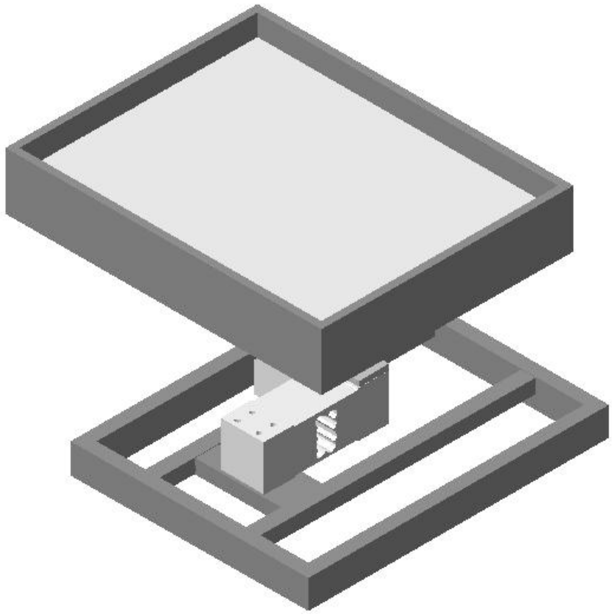

Fig. 2 Arrangement of the test rig.

Tests were carried out at room temperature under varying normal loads. The sliding experiments were carried out at velocity of 20 mm/sec for sliding distance of 200 mm. Experiments were carried out by contact and separation as well as sliding the tested composites against the cotton textiles. The electric static charge was measured by DC voltmeter. The cotton textiles 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 force (normal load). Friction coefficient was determined by the ratio between the friction force and the normal load.

RESULTS AND DISCUSSION

The results of experiments measuring electric static charge and friction coefficient are illustrated in Figs. 3 – 11. Voltage generated from the contact and separation of the proposed polymeric textiles with cotton textile is shown in Fig. 3. The composites of 100 % PTFE displayed the highest negative voltage against cotton. The maximum value were -120, -80 and -40 volts. As PA content, (0.4 mm PA fibre diameter), increased the value of the positive generated voltage increased. 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. The zero voltage was observed at 25, 25 and 17 wt. % PA at 50, 75 and 100 N load respectively. This observation confirmed that, the amount of electric static charge depended on the load. Further increase in PA content gave positive voltage.

The contact and separation of the proposed polymeric textiles with cotton, (0.5 mm PA fibre diameter), is shown in Fig. 4. The zero voltage was noticed at 6 wt. % PA. It seems that as the diameter of the PA fibres increased the generated positive voltage increased. Besides, as the content of PA increased the positive voltage increased up to 200, 180 and 170 volts at 50, 75 and 100 N load respectively.

When the fibre diameter of PA increased to 0.6 mm, the zero voltage was observed at 7, 5 and 3 wt. % PA, Fig. 5. The highest positive voltage value (165, 170 and 270 volts) were observed at 100 wt. % PTFE. The value of PA content at which zero voltage was obtained did not change when the PA fibre diameter increased from 0.5 to 0.6 mm.

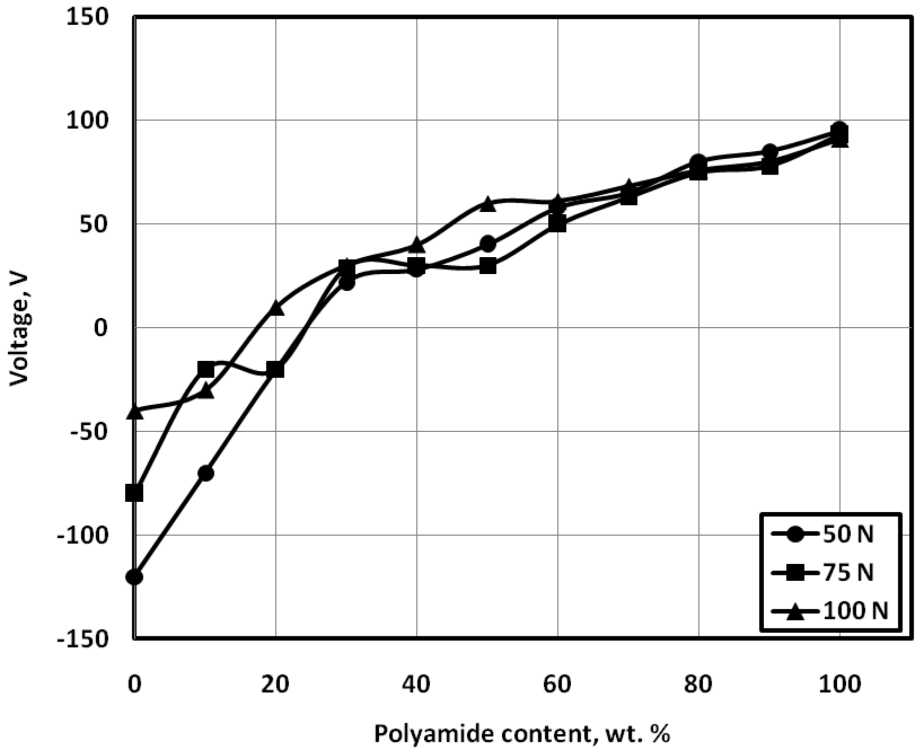

Fig. 3 Voltage generated from the contact and separation of proposed polymeric textile with cotton. (0.4 mm PA fibre diameter).

Voltage generated from the sliding of the proposed polymeric textiles against cotton is shown in Fig. 6. The composites of 100 % PTFE displayed the highest negative voltage against cotton. The maximum value were -380, -310 and -280 volts. As PA content, (0.4 mm PA fibre diameter), increased the generated voltage increased. The zero voltage was observed at 43, 38 and 23 wt. % PA at 50, 75 and 100 N load respectively. It was observed that, at sliding, the PA content was higher than that recorded for contact and and separation. Knowing that in application contact and separation is accompanied by sliding. It can be suggested to use mean values to determine the PA content at which zero voltage can be obtained.

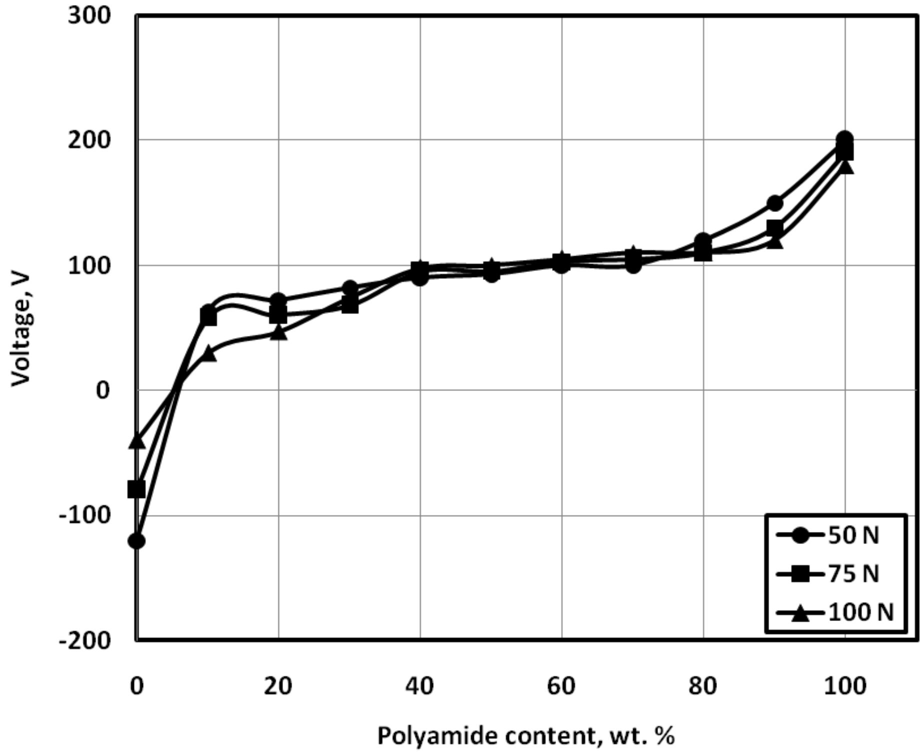

Fig. 4 Voltage generated from the contact and separation of proposed polymeric textile with cotton. (0.5 mm PA fibre diameter).

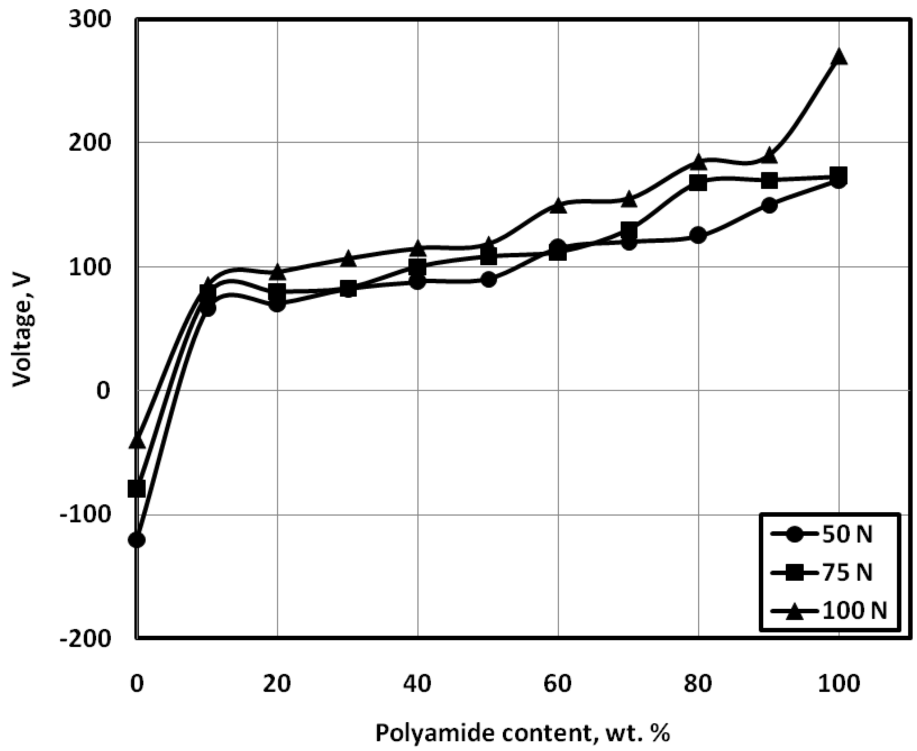

Fig. 5 Voltage generated from the contact and separation of proposed polymeric textile with cotton. (0.6 mm PA fibre diameter).

The sliding of proposed polymeric textile against cotton, (0.5 mm PA fibre diameter), is shown in Fig. 7. The zero voltage was noticed at 26 wt. % PA. It seems that, as the diameter of the PA fibres increased, the generated positive voltage increased. When the content of PA increased, the positive voltage increased up to 280, 240 and 250 volts at 50, 75 and 100 N load respectively.

As the fibre diameter of PA increased to 0.6 mm, the zero voltage was observed at 12, 16 and 17 wt. % PA, Fig. 8. The highest positive values of voltage (450, 690 and 880 volts) were observed at 100 wt. % PTFE. 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 should be tested.

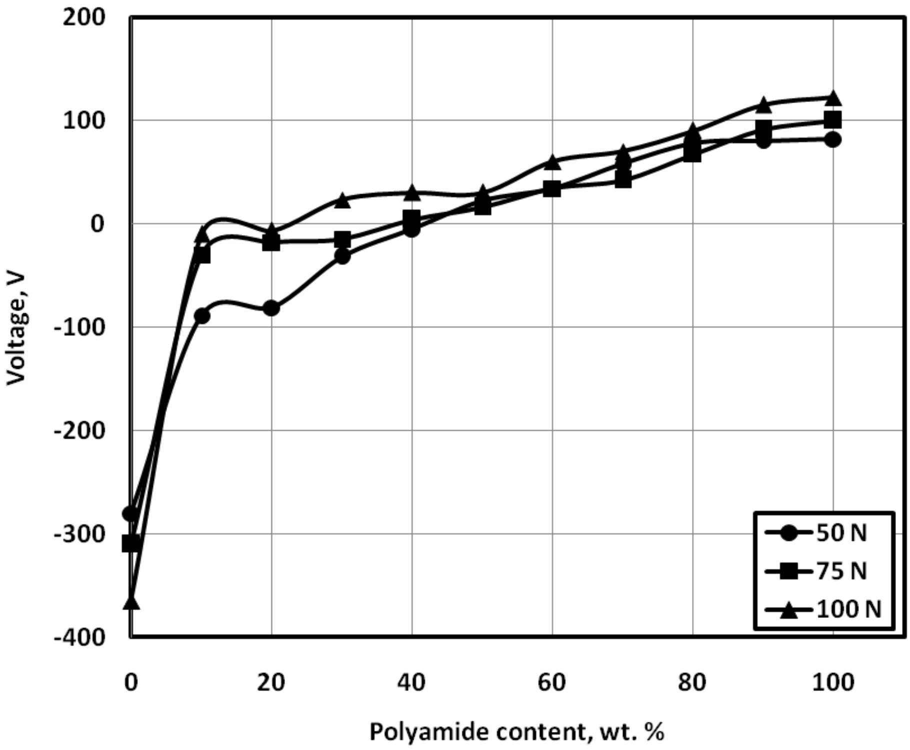

Fig. 6 Voltage generated from the sliding of proposed polymeric textile against cotton. (0.4 mm PA fibre diameter).

Comfort of clothes is considered as main factor in their evaluation as textiles. The measure of the comfort is the friction coefficient displayed between the textiles and skins or other textiles. As the friction coefficient increased, the comfort of the clothes decreased. Friction coefficient displayed by the sliding of the proposed polymeric textile of 0.4 mm PA fibre diameter against cotton is shown in Fig. 9. Friction coefficient drastically decreased with increasing the load and PA content. The lowest friction values were observed at 100 wt. % PA content. 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.

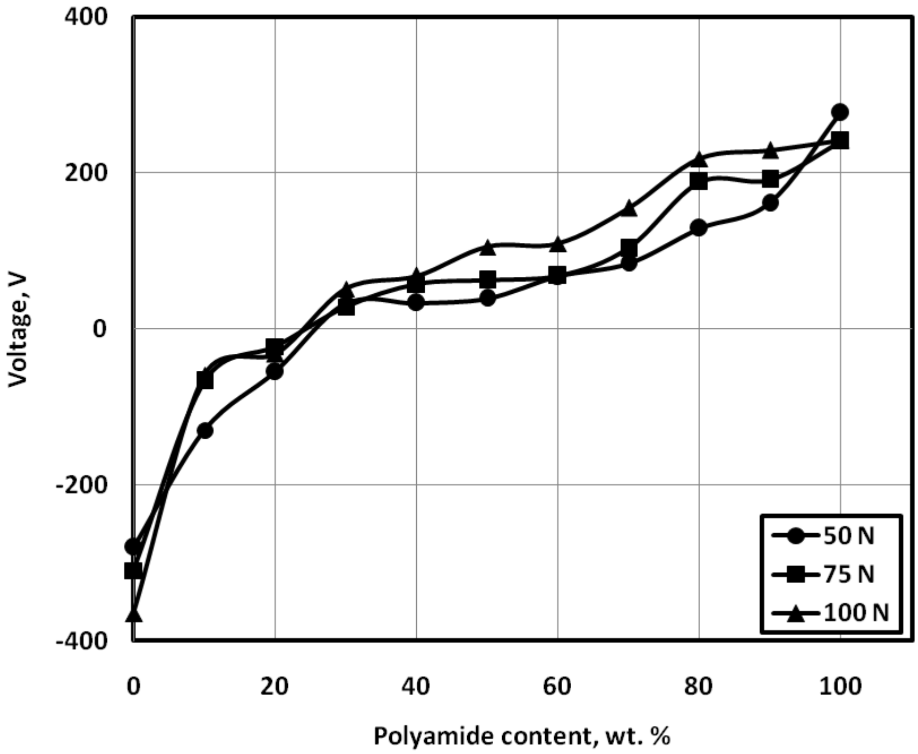

Fig. 7 Voltage generated from the sliding of proposed polymeric textile against cotton. (0.5 mm PA fibre diameter).

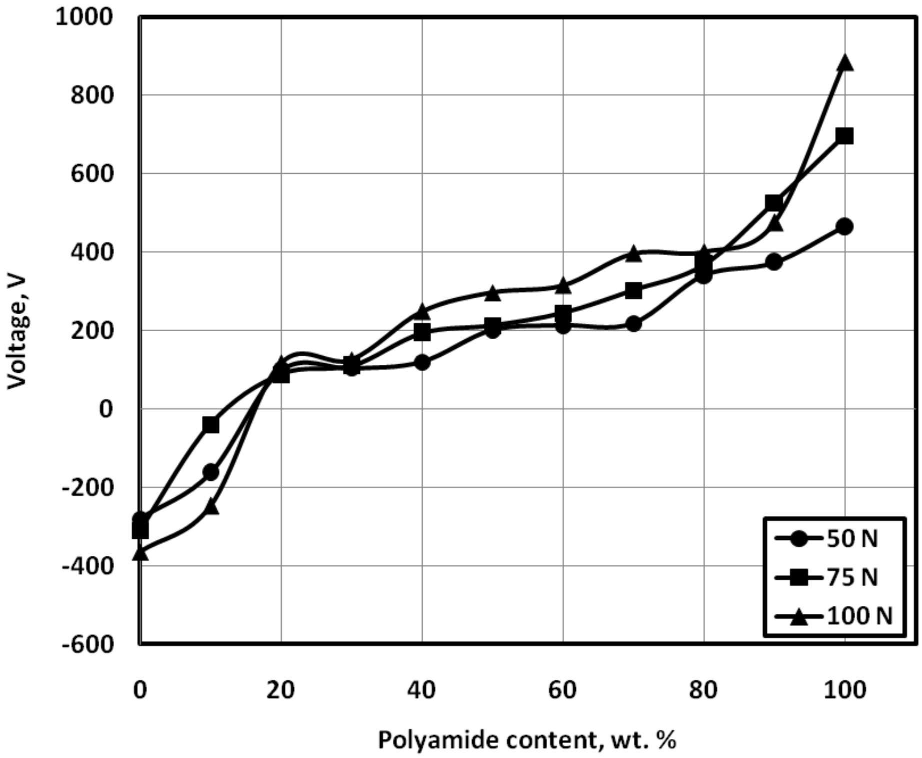

Fig. 8 Voltage generated from the sliding of proposed polymeric textile against cotton. (0.6 mm PA fibre diameter).

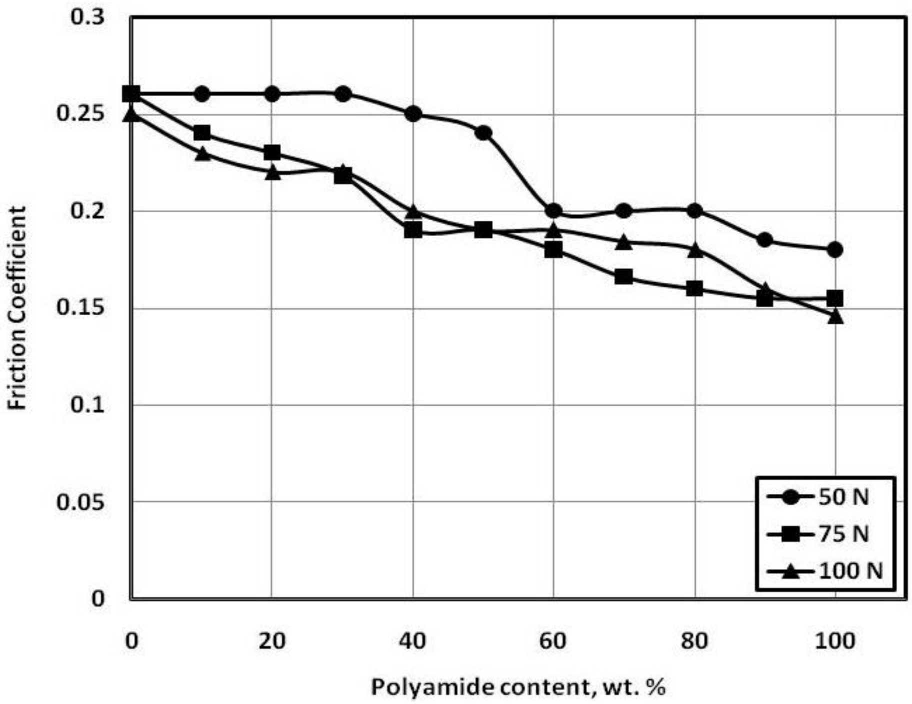

Fig. 9 Friction coefficient displayed by the sliding of proposed polymeric textile against cotton. (0.4 mm PA fibre diameter).

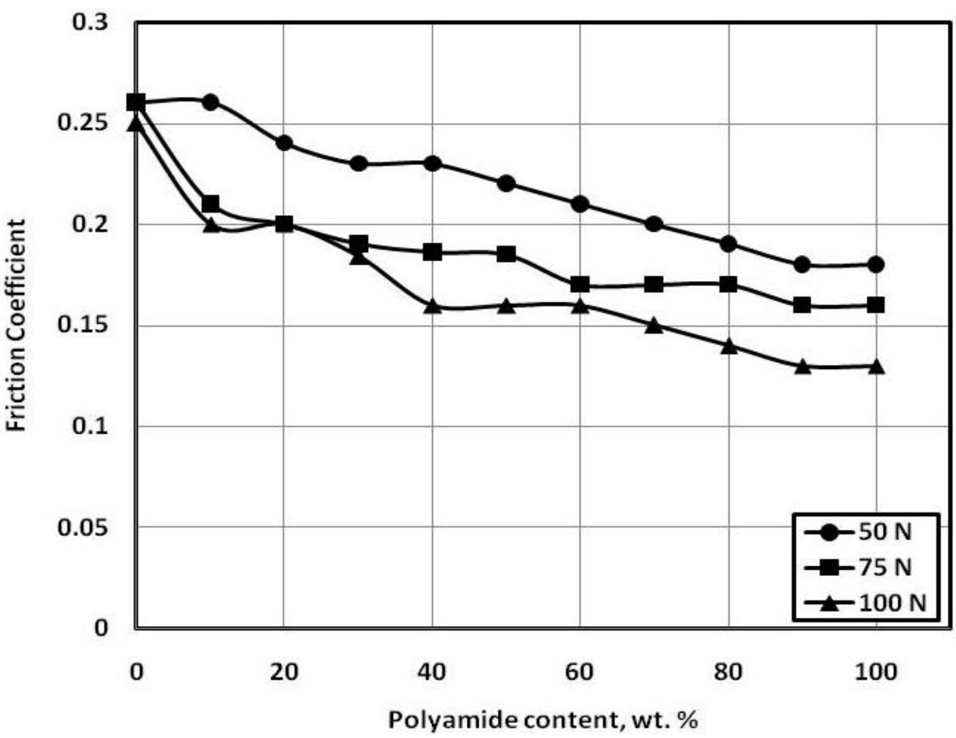

Fig. 10 Friction coefficient displayed by the sliding of proposed polymeric textile against cotton. (0.5 mm PA fibre diameter).

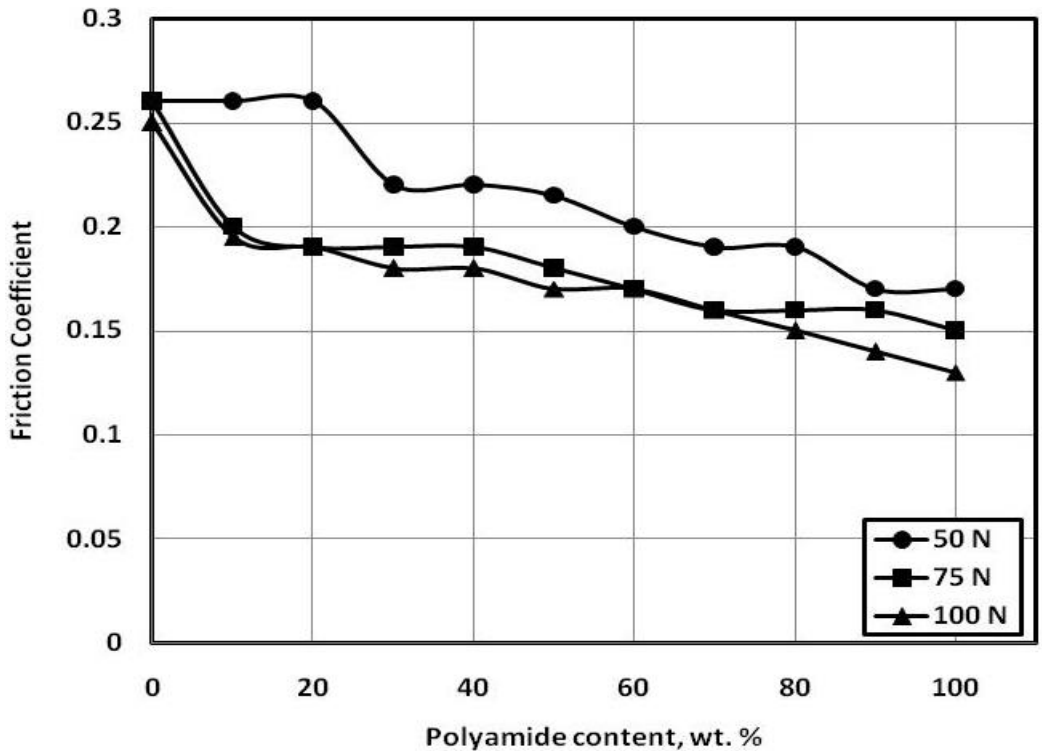

Fig. 11 Friction coefficient displayed by the sliding of proposed polymeric textile against cotton. (0.6 mm PA fibre diameter).

As the PA fibre diameter increased to 0.5 and 0.6 mm, friction coefficient decreased, Figs. 10 and 11, respectively. Although PTFE displayed the lowest friction coefficient when sliding against the majority of the engineering materials, in the present condition, it displayed higher friction than PA when sliding against cotton textiles.

CONCLUSIONS

1. The tested proposed materials of 100 % PTFE displayed the highest negative voltage against cotton. As PA content increased, the generated voltage decreased. The amount of electric static charge depended on the load. As the diameter of the PA fibres increased, the generated positive voltage increased, so that the resultant voltage became positive.

2. Friction coefficient, displayed by the sliding of proposed polymeric textile, drastically decreased with increasing the load and PA content. The lowest friction values were observed at 100 wt. % PA content. As the PA fibre diameter increased to 0.5 and 0.6 mm friction coefficient decreased.

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