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FRICTION COEFFICIENT AND ELECTRIC STATIC CHARGE OF HEAD SCARF TEXTILES

Al-Osaimy A. S., Mohamed M. K. and Ali W. Y.

Faculty of Engineering, Taif University, Al –Taif, Saudi Arabia.

ABSTRACT

In the present work, friction coefficient and electrostatic charge generated from the friction of hair and head scarf of different textiles materials were measured. 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. Ultra surface DC Voltmeter was used to measure the electrostatic charge of the tested textile composites.

The results showed that Asian hair displayed relatively higher friction coefficient than African hair when sliding against polyester head scarf, where friction coefficient decreased with increasing the applied load. Asian hair generated higher voltage than African hair and voltage significantly increased with increasing the applied load. Besides, 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. Asian hair displayed higher friction values than African 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.

Asian hair represented higher friction than African hair for polyester head scarf. 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.

KEYWORDS

Friction coefficient, head scarf, hair, cotton, polyester, nylon, textiles, electric static charge.

INTRODUCTION

The cultural practices such as wearing head scarf have been discussed extensively in academic and popular discourse from the social and religious point of view, [1 – 4]. 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, [5 - 7]. 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.

The manageability and feel of human hair is significantly affected by its surface charge. Previous studies have looked at static charging characteristics of hair on a macroscale. The static charging characteristics of hair were studied on the nanoscale with an atomic force microscopy (AFM), [8, 9]. The charge distribution was characterized by measuring the surface potential of the control area in situ with AFM based Kelvin probe microscopy. The rubbing load was progressively increased, and the effect of this increase on the charge build up was assessed. Virgin, damaged and conditioner treated hair samples were studied for a better understanding of charge build up and dissipation.

Asian, African, and Caucasoid humans are often distinguished by their straight, curly, and wavy hair features, respectively. Understanding the mechanism of the curly pattern of hair is a fundamental issue in anthropology, [10 - 13], and in physiology, for example helping detect various hair diseases and exploring possible therapeutic. The fundamental mechanical properties of human hair including Young's modulus and hardness have been investigated, [14 - 23], owing to the composite-like microstructure. The electrostatic properties and the wetting behaviour of the human hair surface at the nanometric scale have been investigated by using atomic force microscopy (AFM), [24]. Surface potential imaging was used to determine the electrostatic.

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, [25]. 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, [26]. Materials can be assessed for risks from static electricity by measurement of charge decay and by measurement of capacitance loading, [27]. 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, [28]. 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, [29]. 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, [30, 31]. 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, [32]. When isolated, all textiles were capable of causing ignitions regardless of the anti-static strategy employed.

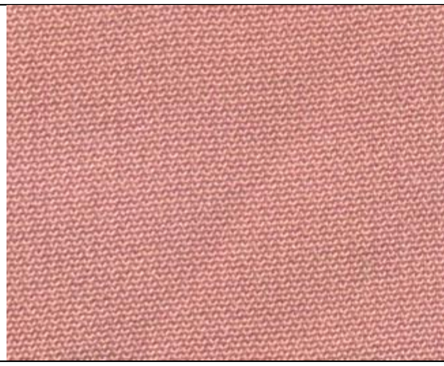
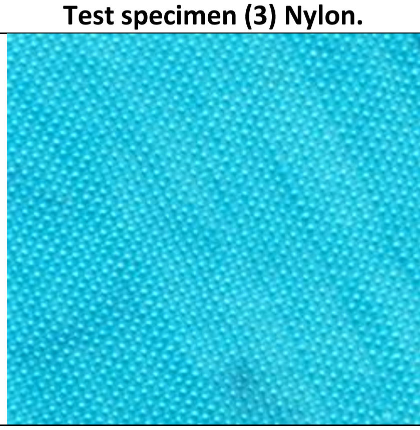
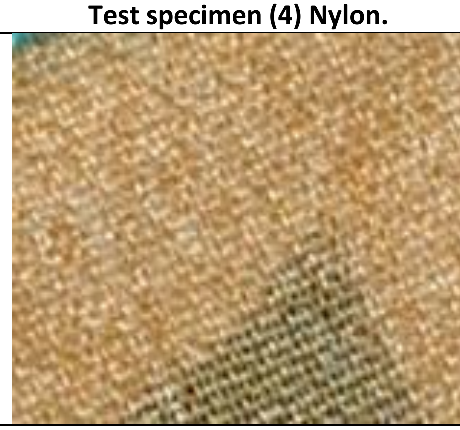
In the present work, the friction and electric static charge generated from the relative motion between head scarf of different materials and hair will be investigated.

EXPERIMENTAL

Electrostatic charge effects occur when an excess of either positive or negative charge becomes confined in a small volume, isolated from charges of the opposite polarity. Because of mutual repulsion, the charges try to escape. As a result, the charges may move or redistribute themselves, sometimes rapidly, such as with a spark. This redistribution usually causes problems. 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.

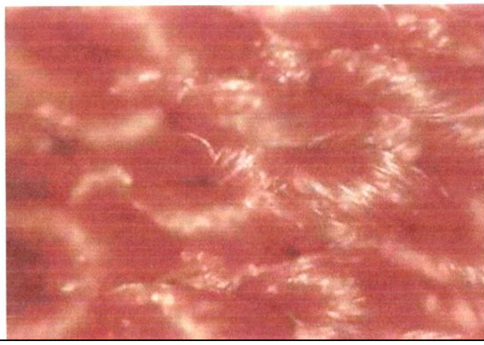
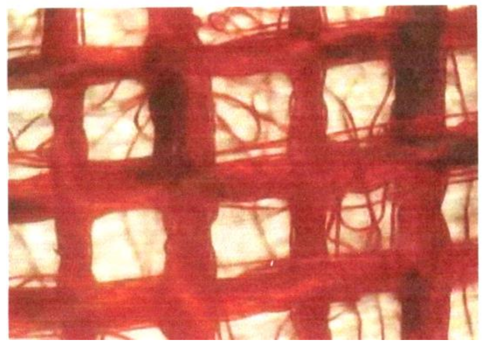
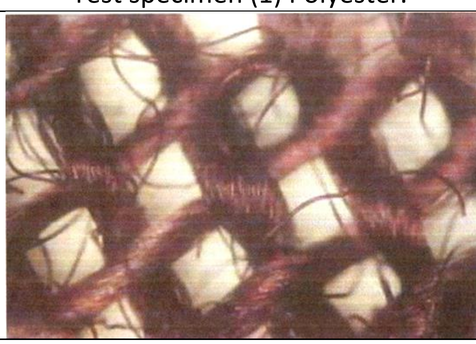
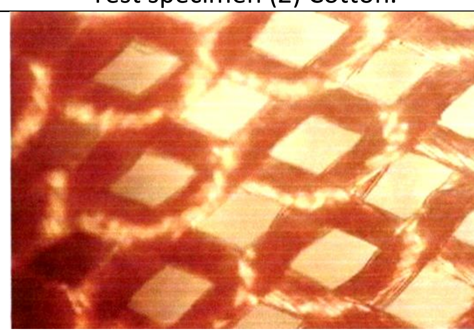
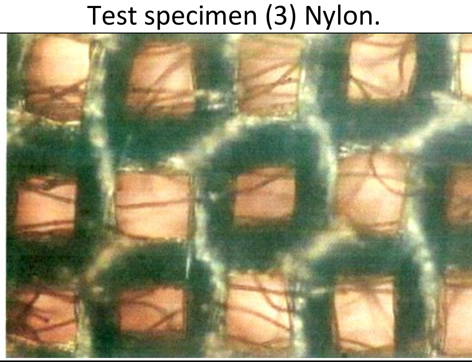
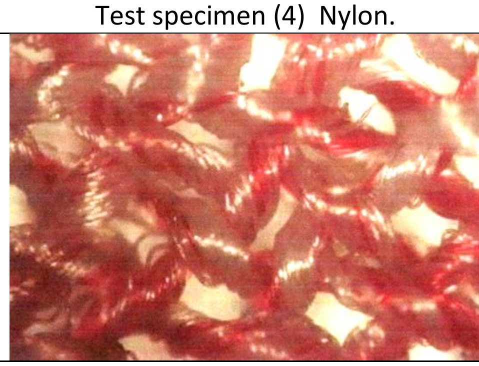
Fig. 1 Electrostatic field measuring device.

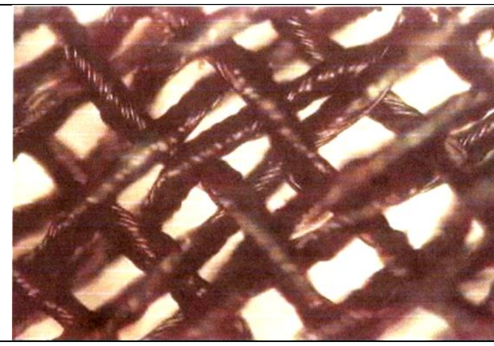
Tabel 1 Head scarf textiles used as test specimens.

	
Test specimen (1) Polyester.	**Test specimen (2) Cotton.**
	
Test specimen (3) Nylon.	**Test specimen (4) Nylon.**
	
Test specimen (5) Polyester.	**Test specimen (6) Polyester.**

	
Test specimen (7) Nylon.	**Test specimen (8) Nylon.**

Table 2 Weaves of the tested head scarf textiles.

	
Test specimen (1) Polyester.	Test specimen (2) Cotton.
	
Test specimen (3) Nylon.	Test specimen (4) Nylon.
	
Test specimen (5) Polyester .	Test specimen (6) Polyester.

	
Test specimen (7) Nylon.	Test specimen (8) Nylon.

The specimens, of head scarf, were prepared and arranged for the tests and measurements in the surface of a wooden block of 20 × 20 × 10 mm. Test specimens consisted of one cotton, three polyester and four nylon textile specimens, Tables 1, 2. Tests were carried out at room temperature under 2, 4, 6, 8, 10 and 12 N normal loads. The test specimens were sliding against African and Asian hair. Experiments were carried out by sliding the test specimens against the hair. Textiles of head scarf gained negative electrostatic charges, while hair gained positive charge. This charge was measured by DC voltmeter.

RESULTS AND DISCUSSION

Friction coefficient generated from the sliding of the polyester head scarf (1) against hair is shown in Fig. 2. Asian hair displayed relatively higher friction coefficient than African hair. Generally, friction coefficient decreased with increasing applied load. The values of friction coefficient displayed by Asian hair were lower than 0.2 for the range of loads applied. The possibility of scarf slip increased for the African hair. Voltage generated from the sliding of head scarf (1) against hair is illustrated in Fig. 3, where Asian hair generated higher voltage than African hair. The maximum voltage generated was 2600 volts at 12 N applied loads for Asian hair, where voltage significantly increased with increasing applied load.

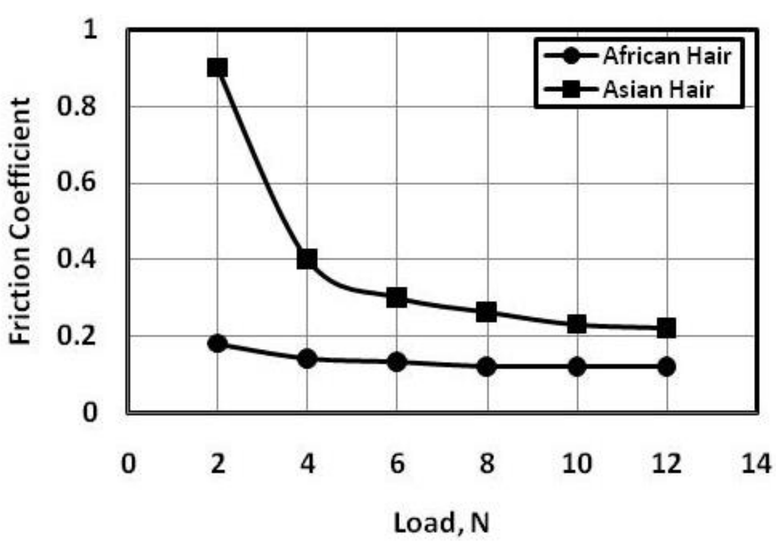


Fig. 2 Friction coefficient generated from the sliding of polyester head scarf (1) against human hair.

Friction coefficient generated from the sliding of the cotton head scarf (2) against hair displayed higher values than that showed by polyester head scarf (1). The difference in friction between African and Asian hair was insignificant, Fig. 4. At light loads friction value reached 1.45 and 1.55 for Asian and African hair respectively. African hair displayed relatively higher voltage than that measured for Asian hair, Fig. 5. This behaviour might be attributed to the fact that African hair, however, exhibits a characteristic tightly curled structure so that when sliding against the fibrous cotton textiles a relatively high amount of electric static charge generated. Besides, Asian hair has higher ultimate strength and strain to failure than African hair. African hair showed very low mechanical properties in terms of modulus, yield point and strain to failure, [9]. The lowered mechanical properties of African hair are thought to partly arise from the higher stresses it encounters during normal combing and detangling due to its characteristic curly structure.

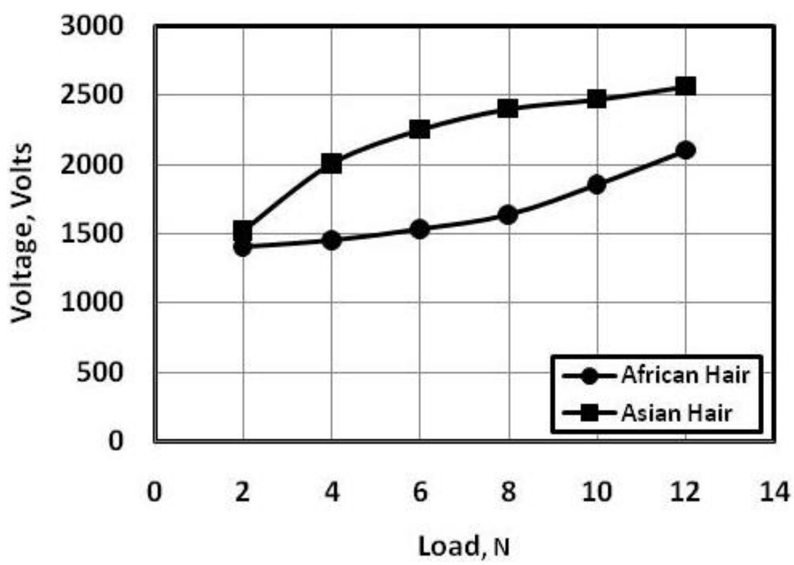


Fig. 3 Voltage generated from the sliding of head scarf (1) against human hair.

The nylon head scarf when sliding against hair showed relatively lower friction coefficient than that observed for polyester and cotton scarf, Fig. 6. Asian hair displayed higher friction values than African hair, where friction values decreased with increasing applied load. Electric static charge measured in voltage represented relatively lower values, Fig. 7. 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 compared to the gap between hair and cotton as well as hair and polyester. It is commonly known that as the gap increases the amount of electric static charge increased. It is expected that electric static charge generated from the friction of human hair and polyester will be higher followed by that generated from hair and cotton as well as nylon.

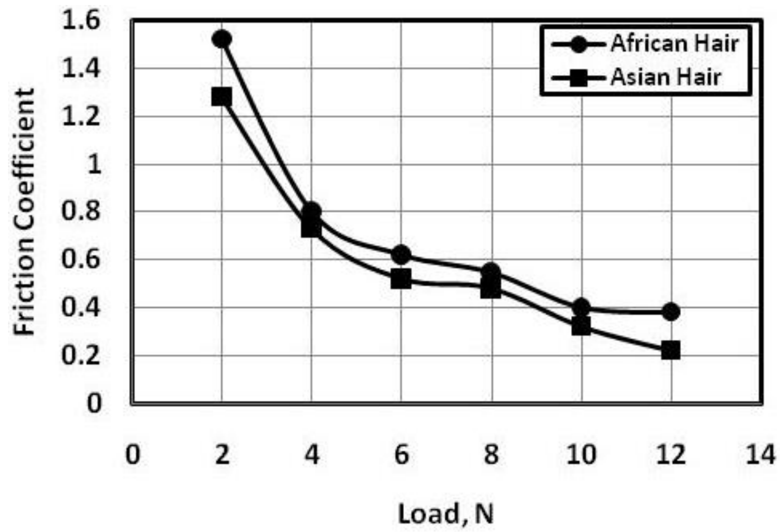


Fig. 4 Friction coefficient generated from the sliding of cotton head scarf (2) against human hair.

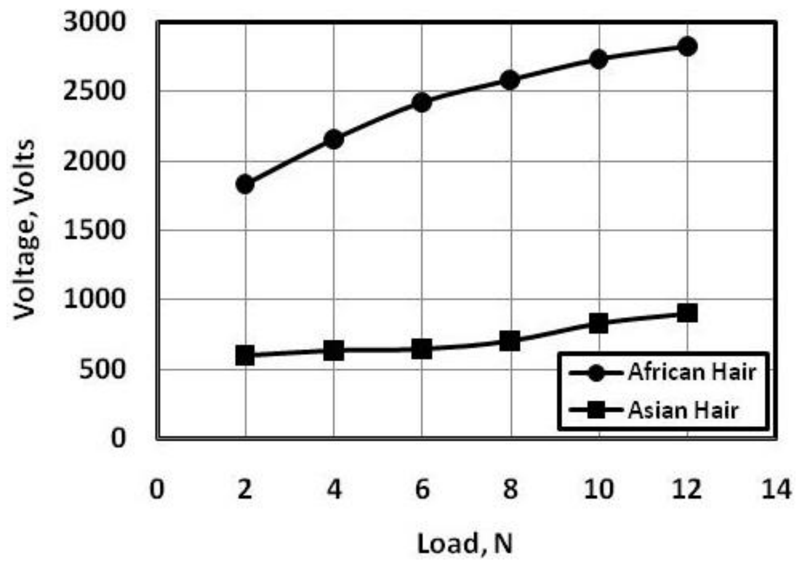


Fig. 5 Voltage generated from the sliding of cotton head scarf (2) against human hair.

Friction coefficient generated from the sliding of nylon head scarf (4) against hair is shown in Fig. 8. African hair showed higher friction coefficient than Asian hair. Asian hair is stronger and thicker than African hair and has a predominantly circular cross-section. African hair is generally more liable to damage and breakage, has a highly elliptical cross-section. Asian hair is generally very straight along its axis, while African hair exhibits a characteristic tightly curled structure due to the hair follicle shape. It seems that the curled structure is responsible for the friction increase. As expected, voltage generated from the sliding of nylon head scarf (4) against hair displayed lower values than the previously tested head scarves, Fig. 9. The highest voltage (1050 volts) was recorded for Asian hair at 12 N load.

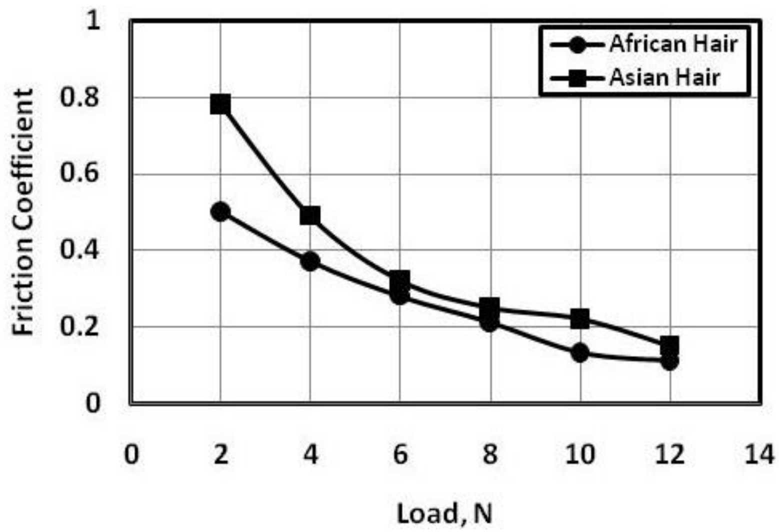


Fig. 6 Friction coefficient generated from the sliding of nylon head scarf (3) against human hair.

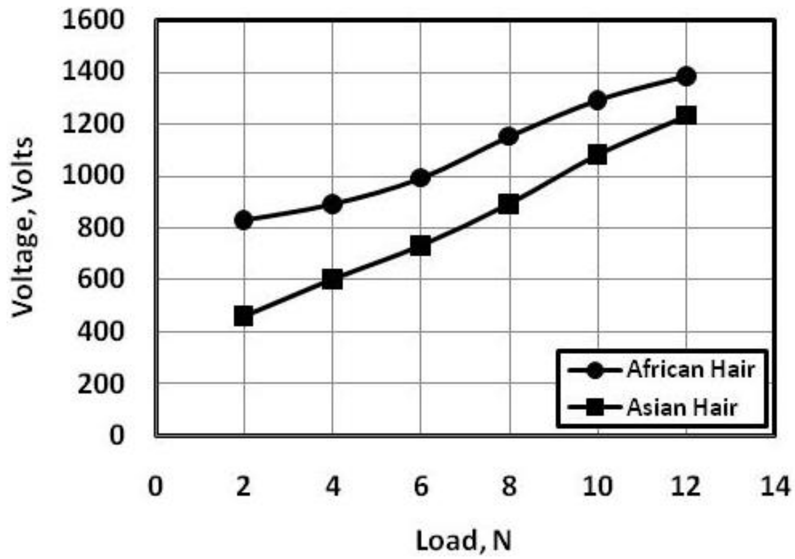


Fig. 7 Voltage generated from the sliding of nylon head scarf (3) against human hair.

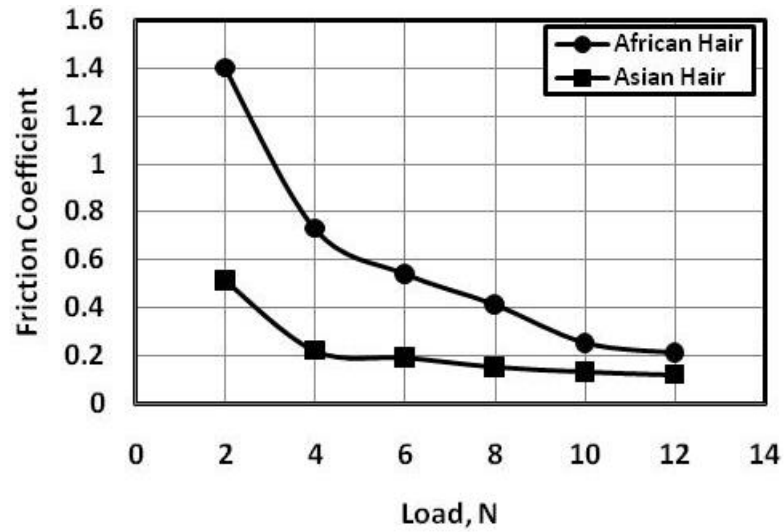


Fig. 8 Friction coefficient generated from the sliding of nylon head scarf (4) against human hair.

Polyester head scarf (5) displayed relatively low friction values, Fig. 10. Asian hair represented higher friction than African hair. The minimum friction value was 0.2 for African hair at 12 N load. Generally, at higher loads, the difference in friction values was insignificant. African hair displayed relatively higher voltage, generated from electric static charge, than Asian hair. The maximum voltage value was 3350 volts at 12 N load, Fig. 11. African hair showed relatively lower voltage, where its value reached 1000 Volts at 12 N load.

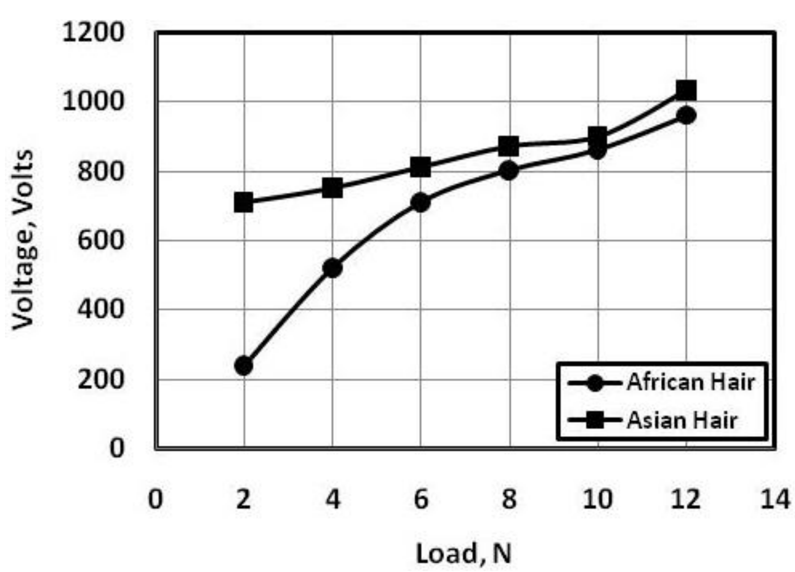


Fig. 9 Voltage generated from the sliding of nylon head scarf (4) against human hair.

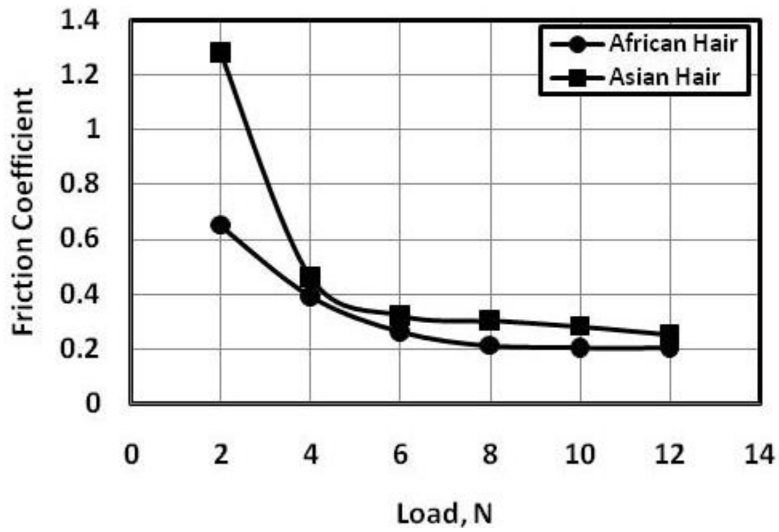


Fig. 10 Friction coefficient generated from the sliding of polyester head scarf (5) against human hair.

Friction coefficient generated from the sliding of polyester head scarf (6) against human hair is illustrated in Fig. 12. Asian hair showed lower friction than African hair. The lowest friction value was 0.1 at 12 N load. The voltage generated showed its maximum value (2600 volts) at 12 N load for African hair, Fig. 13. The relative difference in the voltage values observed for test specimens (5) & (6) may be attributed to the difference in the weaves form.

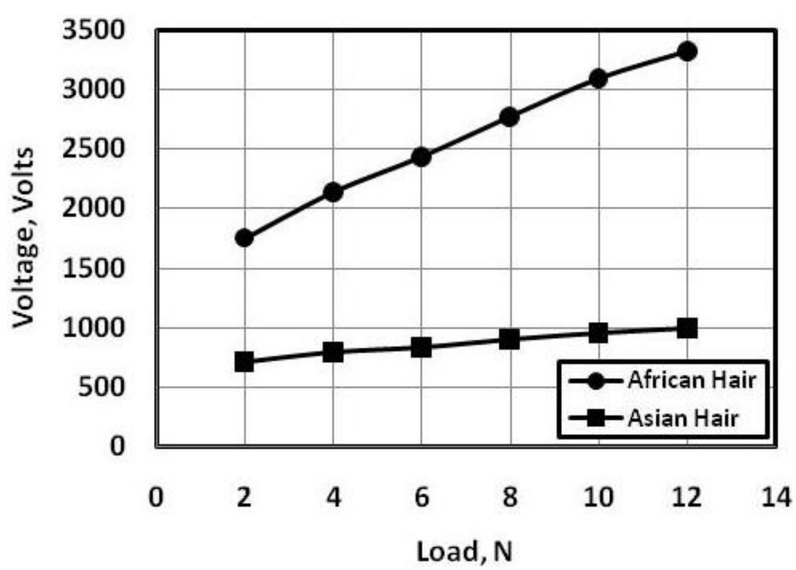


Fig. 11 Voltage generated from the sliding of polyester head scarf (5) against human hair.

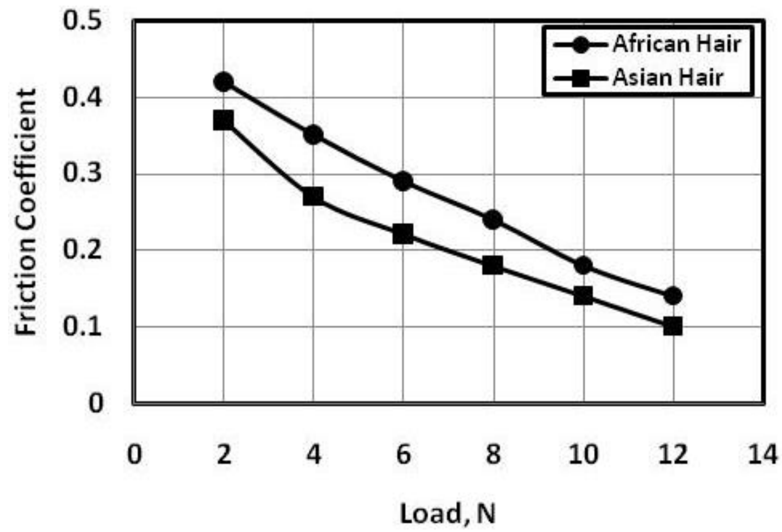


Fig. 12 Friction coefficient generated from the sliding of polyester head scarf (6) against human hair.

Nylon head scarf (7) slid against human hair showed higher friction coefficient for African hair than Asian hair, Fig. 14. Nylon displayed relatively higher friction coefficient than polyester when slid against human hair, while cotton proposed the highest friction coefficient especially at lower loads. Voltage generated from the sliding of nylon head scarf (7) against hair showed an increasing trend with increasing applied load, Fig. 15. The maximum voltage measured (2400 volts) was recorded for African hair at 12 N load.

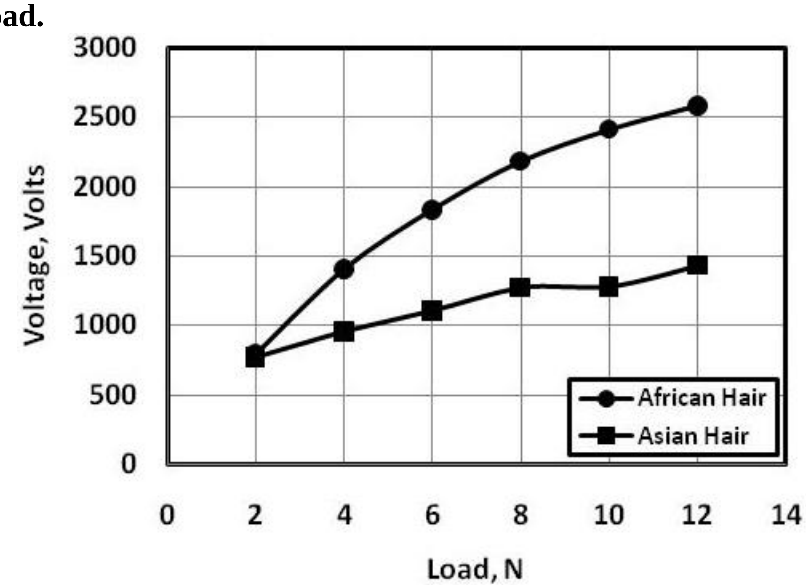


Fig. 13 Voltage generated from the sliding of polyester head scarf (6) against human hair.

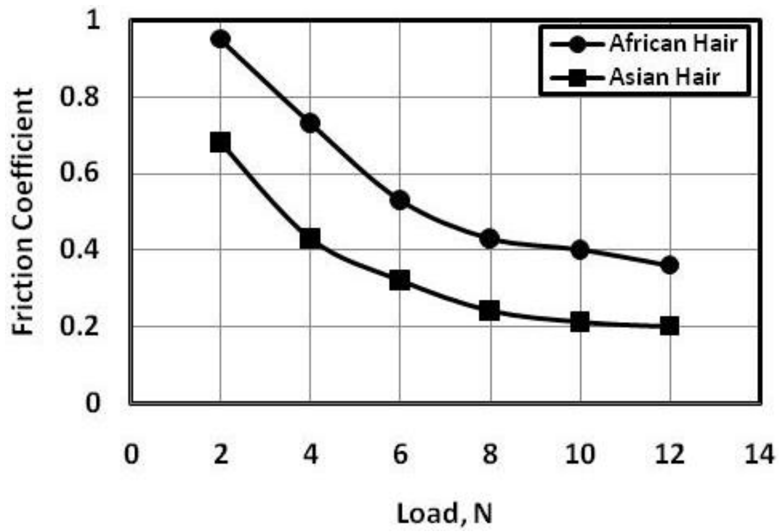


Fig. 14 Friction coefficient generated from the sliding of nylon head scarf (7) against human hair.

Nylon head scarf (8) showed slight decrease in friction coefficient compared to scarf (7), Fig. 16. The decrease might be from the difference in the weave form although the both two textiles are made of nylon. Significant decrease in the voltage generated from the sliding of nylon head scarf (8), Fig. 17, against human hair was observed compared to behaviour of nylon scarf (7).

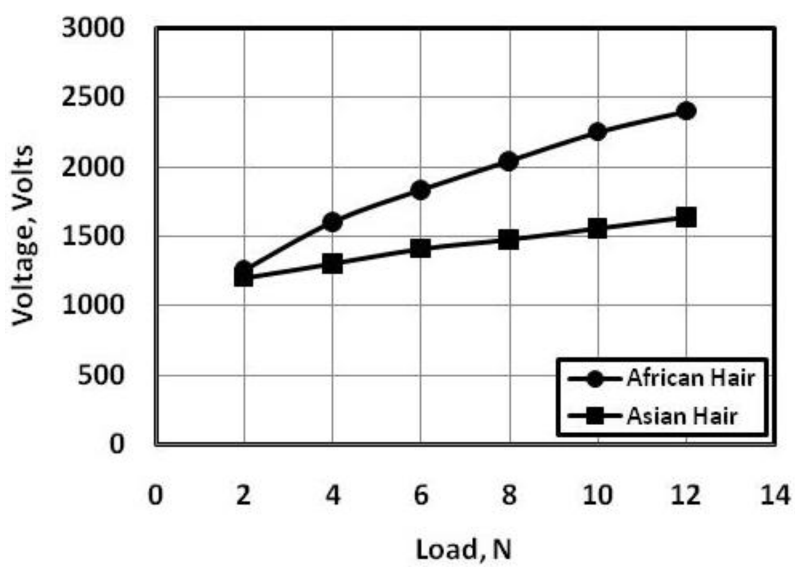


Fig. 15 Voltage generated from the sliding of nylon head scarf (7) against human hair.

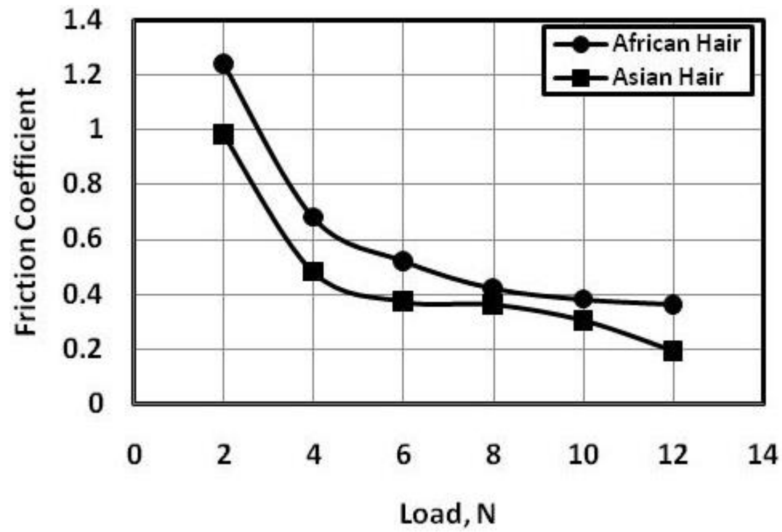


Fig. 16 Friction coefficient generated from the sliding of nylon head scarf (8) against human hair.

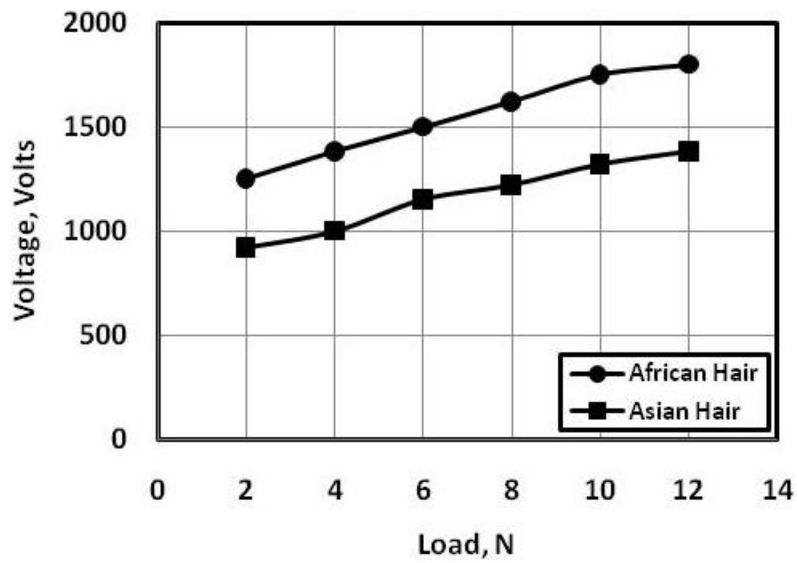


Fig. 17 Voltage generated from the sliding of nylon head scarf (8) against human hair.

CONCLUSIONS

Within the limitations of the present work the following conclusions can be withdrawn:

1. Polyester textiles head scarf generated the highest voltage when slid against hair followed by cotton then nylon.

2. Cotton displayed the highest friction coefficient followed by nylon and polyester.

3. Cotton head scarf displayed higher friction when slid against African hair more than Asian hair. Besides, voltage generated was higher for African hair.

4. Nylon showed higher friction coefficient and voltage for African hair than Asian hair.

5. Polyester showed similar friction and voltage generated for both African and Asian hair.

6. The weaves form has significant effect on friction coefficient and voltage generated.

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