International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2000-000X
Vol. 2 Issue 7, July – 2018, Pages: 25-33

A Study on the Electrostatic Charge Generated From the Friction of Wig Cap Textiles against Human Skin and Hair

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Abstract— *Chemotherapy is one of the most powerful cancer treatment methods however hair fall is one of its side effects. Women usually wear artificial wigs to compensate for hair falling and to enhance their appearance. The friction between the internal wig cap textile and the women head skin and hair generates an electrostatic charge, which can increase cancer or decrease the effectiveness of treatment. The objective of this study is to develop a new cap textile in which it can decrease the slippage between the artificial wig and the woman head and, therefore decrease electrostatic charge generation. Decreasing slippage depends on the friction coefficient of the textile when sliding against woman head skin and hair. Tests were carried out using human skin and four types of hair namely, African hair, Asian hair, and two types of commercial artificial hair, sliding against textiles. Six types of textiles were utilized; cotton, chiffon, acrylic, dantel, and two types of polyester, low and high-density fibers. Results indicated that polyester 2, of denser fibers, has relatively the highest friction coefficient against the skin and all types of hair. Besides, the electrostatic charge generated on its surface was relatively high and reached 615 volts. Chiffon fabrics followed polyester 2 in term of generating electric charges (539 volts). The generated electrostatic charge on the surface of the other four textiles varies from 24.5 to 248 volts with a friction coefficient relatively lower than that displayed by polyester 2. Based on the results, a new textile is proposed which composed of cotton, acrylic and high-density polyester with the same ratio. Results showed that the proposed textile has approximately the same friction coefficient of polyester 2 with a generated electrostatic charge did not exceed 25 volts.*

Keywords—Artificial Wig; Electrostatic charge; Tribological Performance

1. INTRODUCTION

The malignant tumor in the brain, brain cancer, is one of the most significant issues which causes a disproportionate level of mortality and morbidity among a wide range of people (1). The standard brain cancer treatments are the whole brain radiation therapy and surgery focusing on symptom palliation. Chemotherapy for brain cancer treatment is limited due to presumed lack of effectiveness because of the blood-brain barrier. However, researchers tried to prove the importance of chemotherapy compared to whole-brain radiation therapy (2). Researchers proved that chemotherapy is the best treatment for Cancer, nevertheless it has some disadvantages or side effects like hearing loss, bone tissue death, vomiting, decreased white and red cells, hair fall and anemia (3).

Although chemotherapy is able to shrink cancer or slow down its growth, exposure to some uncontrolled external circumstances may increase cancer growth. A study proved that the size of diseased cells exposed to uncontrolled electrostatic fields for two weeks was increased threefold, the percentage of abnormal chromosomes, compared to cells under controlled fields (4). Gray et al. (5) studied the acceleration of cancer growth among groups of diseased mice subjected to electrostatic fields. They were able to generate uncontrolled electrostatic charges on two mice groups by rubbing the mice under a polyester carpet. On the other hand, another group rubbed under a carpet surface (to be subjected to equivalent mechanical forces), although, the carpet was modified with an antistatic agent to decrease the generation of static charge. A final group of mice was not rubbed against any surface to prevent the generation of the electrostatic field permanently. Results showed that within 13 days the average of tumor growth in the two groups that were rubbed against the polyester carpet was more than twice larger than the two groups exposed to the minimal electrostatic field.

People are usually exposed to different sources of electrostatic fields during normal activity (6). These fields are generated due to the rubbing of two materials (or when materials are in contact then disconnected). This commonly occurs when clothes rub together or with another surface like upholstery. Department of Defense Handbook 263 documents presented some standard measurements of electrostatic charges developed by different normal activities. 20 feet of walk over a carpet at 10-20% and 65-90% humidity can develop 35,000 volts and 1,500 volts, respectively (7). Electrostatic charges are usually very near to people bodies, the fields we are exposed from them can be dangerous. For instance, rubbing of polyester blouse over a nylon bra can generate a thousand volts on the fabric surfaces (5).

Temporary hair-loss is one of the most popular side effects of using chemotherapy cancer therapy as mentioned before (8). Diseased women and girls usually wear artificial wigs in order to compensate for hair falling and to enhance their appearance. The conventional method of fabricating wigs is to attach the artificial hair to the outer surface of a cap-shaped frame made of textile fabric (9). Insufficient attention has been dedicated to the generated electrostatic charge from the friction between hair/skin and the wig cap made of textile fabric. Human hair is able to generate an electrostatic charge when rubbed against different materials such as plastic, textiles and human skin. According to the high insulation of the human hair and the high resistivity for electricity, the generated charge is not easily dissipated particularly in dry circumstances (10).

Researchers studied rubbing hair bundles against different materials like Teflon, plastic combs, nylon, latex balloons, and metals like stainless steel, gold, and aluminum. Then, charge due to the interaction between surfaces was measured using different electrometers in order to study the charging of human hair (11-12). Indira et al. (13) claimed that electrostatic charge generated on the hair could affect the feel and manageability of human hair significantly. They studied the characteristics of static charging on the nanoscale using AFM. They tried to increase the rubbing load in order to evaluate its effect on the generated electrostatic charge. They found that increasing rubbing loads did not affect the potential difference. Dupres et al. (14) investigated the wetting behavior and the electrostatic properties of human hair surface using atomic force microscopy. The electrostatic characteristics were evaluated by surface potential imaging.

The electrostatic charge is generated due to the friction between two materials as mentioned before. Ibrahim et al. (15) investigated the electrostatic charge generated by the friction of PTFE textile, merged with 50% different types of textile fibers, and car padding textile. They found that adding of cotton, nylon and wool decreased the electrostatic charge dramatically. Mahmoud et al. (16) studied the effect of adding viscose and cotton content to polyester textiles sliding against polyacrylonitrile and wool textiles on the electrostatic charge and friction coefficient. They found that polyester textile developed the highest electrostatic charge and adding cotton fibers decreased the electrostatic charge dramatically.

In this work, a study on the effect of using different types of textiles, as a wig cap-shaped frame, on the friction coefficient and the generated electrostatic charge when sliding against four types of hair and skin. Proper choice of the textile-type can decrease the generation of electrostatic charge which can affect the safety of the cancer treatment process. Textile with high friction coefficient can decrease the electrostatic charge (16), and this could be attributed to the decrease of slipping between the artificial wig and the human head.

2. Experimental

The current work investigates the friction coefficient and the electrostatic charge of sliding skin and different types of hair against various types of textiles. After the beginning of chemotherapy of cancer, hair starts to fall, and women begin to wear artificial wigs. Figure 1 illustrates the artificial wig and its structure. In this case, friction occurs between the cap-shaped frame textile and the natural hair of women. Where, women natural hair can be classified into two types, African hair and Asian hair (17). In advanced stages of treatment, hair falls completely, and the friction becomes between the cap textile and skin. Moreover, the artificial hair attached to the cap sways during the movement of women which causes rubbing between the artificial hair and the cap textile and therefore electrostatic fields are generated. Consequently, experiments were carried out using four types of hair, African hair, Asian hair and two types of artificial hair with different diameter besides the skin. According to the natural hair, the clipped fibers from the scalp were donated by individual women. Table 1 lists the microscopic results for the hair fibers diameters of different ethnic origins and artificial ones. For each hair the diameter was measured 20 times and the mean value was calculated.

On the other hand, six types of common used textiles were used in this investigation namely, acrylic, cotton, dantel, chiffon, polyester high-density stitch (Poly.1) and polyester low-density stitch (Poly.2). Based on the initial results, a new textile has been developed which consists of three different yarns with the same ratio, acrylic, cotton, and polyester with high fibers density. Table 2 illustrates the different types of textiles used in the current study, and the developed textile is shown in Fig. 2.

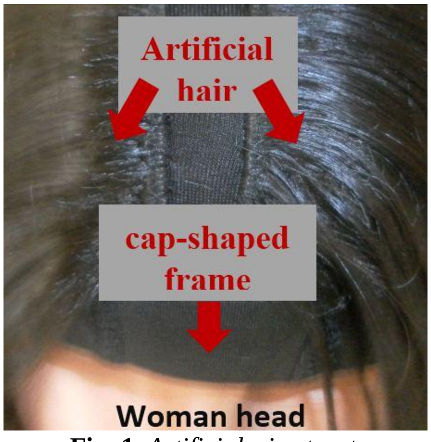
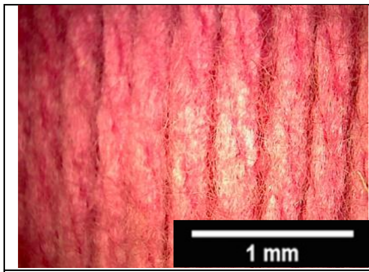
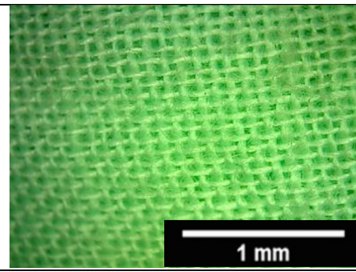
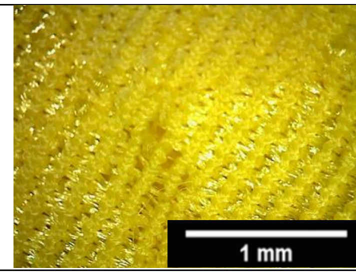
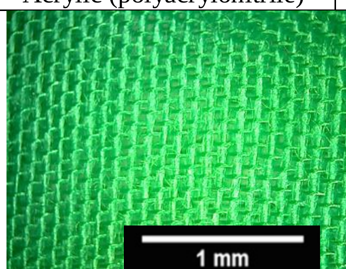
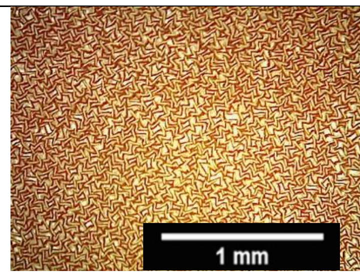
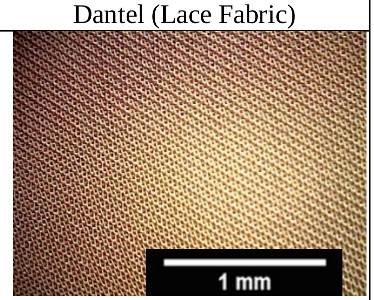


Fig. 1. *Artificial wig structure.*

Table 1: Diameter of different types of hair.

Hair Type	Range (µm)	Mean (µm)
African hair	58.31 - 82.28	69.79
Asian hair	67.21 - 88.65	77.43
Artificial 1	65.12 - 65.51	65.26
Artificial 2	109.31 - 109.65	109.43

Table 2: Tested textiles.

		
Acrylic (polyacrylonitrile)	100% Cotton	Dantel (Lace Fabric)
		
Chiffon (30% Cotton, 70% Nylon)	100% polyester low-density stitch (Poly.1)	100% polyester high-density stitch (Poly.2)

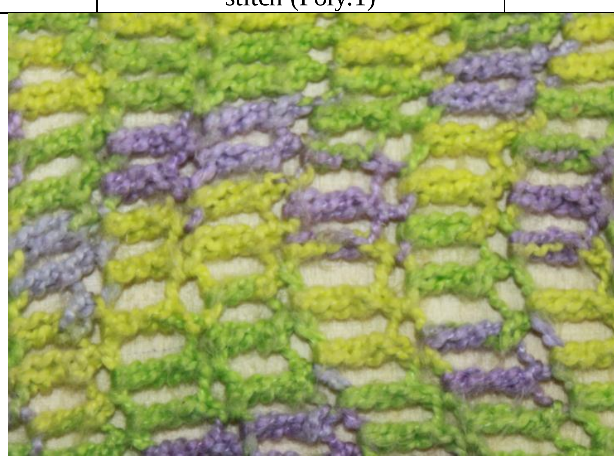


Fig. 2. Textile composed of acrylic, cotton, and polyester.

The test rig was designed and manufactured for measuring the friction coefficient, as shown in Fig. 3. It basically consists of two incorporated load cells and a plate to hold the textile. The textile was assembled on the plate of the test rig, and the load was applied on the textile on the normal direction. The hair was adhered to a block of wood 50 ×50 × 50 mm3 and tests were carried out at room temperature 27 oC and humedity 50 %. Once the experiment starts, the researcher sought to slide the hair slowly as he can, in order to identify clear static friction coefficient. In other words, the wig is usually fixed on the women head, and the relative movement between the wig cap and the head is very slow. Once the hair starts to move on the textile surface, the normal force and the friction force are recorded, and the friction coefficient values were calculated. Once the test starts equal electrostatic charges are generated on the contact surfaces with different signs, and that occurs in real between the woman head and the artificial wig as shown in Fig. 3. The electrostatic charge (voltage) was measured using ULTRA STABLE SURFACE DC VOLTMETER. The device measuring range varies from 1/10 volt on a surface, and up to 20 000 volts (20 kV). Readings are usually recorded when the sensor is 25 mm far from the surface is being tested. The average of friction coefficient and electrostatic charge were recorded after minimum ten attempts to ensure the measurement repeatability. According to the skin experiment in vivo, researcher sought to slide the back of his hand, between the wrist and before figures, against the textile to insure constant contact area during all skin experiments.

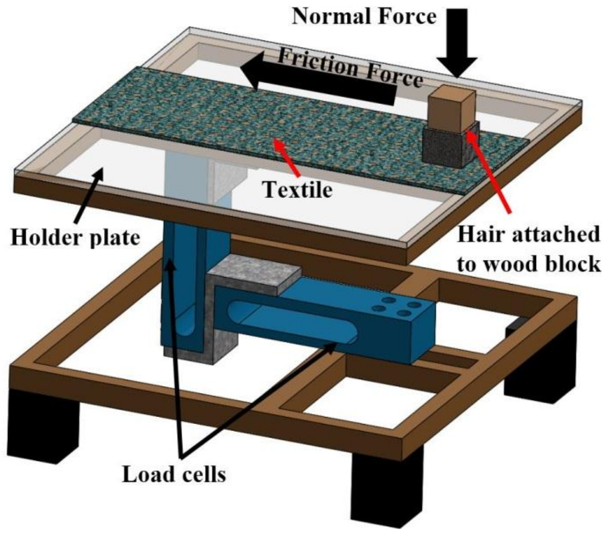


Fig. 3. Test Rig.

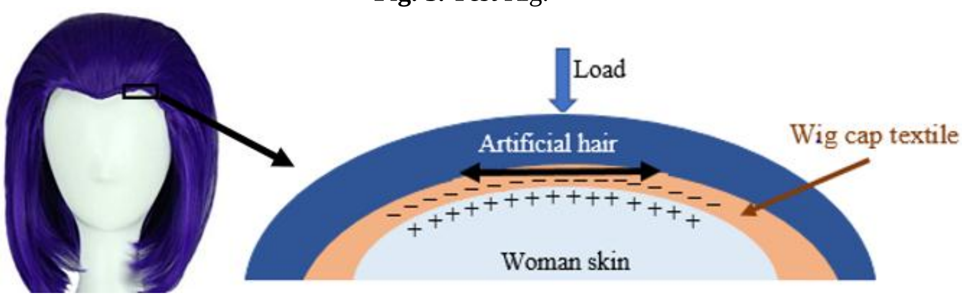


Fig. 4. Generation of electrostatic charge on the sliding surfaces (skin and textile).

3. RESULTS AND DISCUSSION

Electrostatic charge is usually generated when two materials are in contact and then separated as well as sliding. During the use of an artificial wig, the electrostatic charge is generated due to the slippage of the internal wig cap against the woman head skin or hair. Based on the friction coefficient between the wig cap and the woman head skin or cap, the slipping process may be occurred, decreased or not happened. In this study, the normal and friction forces were measured and recorded during the slipping of different hair samples against different seven textiles, and the friction coefficient was calculated. Tests were conducted ten times for each textile, and then the average friction coefficient and the standard error were calculated.

Figure 5 and 6 illustrate the friction coefficient and the corresponding electrostatic charge of an African hair sample slips against seven textiles, respectively. It is clearly seen that Polyester 2, of high-density stitch, has the highest friction coefficient compared to the other six textiles. Moreover, the electrostatic charge generated on its surface was the highest value. That could be attributed to the stitch density of the polyester type. As shown in table 2, the density of poly 2 fibers is very high, and each fiber is charged during the experiment in which the movement of electrons to the air or the ground became obstructed. The density and fineness of textile fibers much affect the free electron movement [18]. This result could be clarified when compared to the electrostatic charge generated on the surface of Poly. 1, polyester low-density stitch. Increasing the density of fibers increases the generated electrostatic charge. Although the friction coefficient of Poly. 2 is very high, it is very dangerous to be used as wig cap material due to the high electrostatic charge.

On the other hand, the proposed textile which consists of acrylic, cotton, and polyester could achieve a high friction coefficient with very low electrostatic charge. As mentioned before, the proposed textile was developed based on the initial results of the other textiles. The proposed textile was developed from cotton and acrylic, that have a very low electrostatic charge, combined with a high-density polyester to achieve high friction coefficient. The proposed textile was designed in which large gaps between stitches which allows free electrons to move to air, as shown in Fig. 2. Dantel, cotton, acrylic and poly 1 have approximately the same friction coefficient, and electrostatic charge except the dantel have a relatively high value of ESC. Chiffon has the lowest friction coefficient and has a high electrostatic charge reached about 205 volts.

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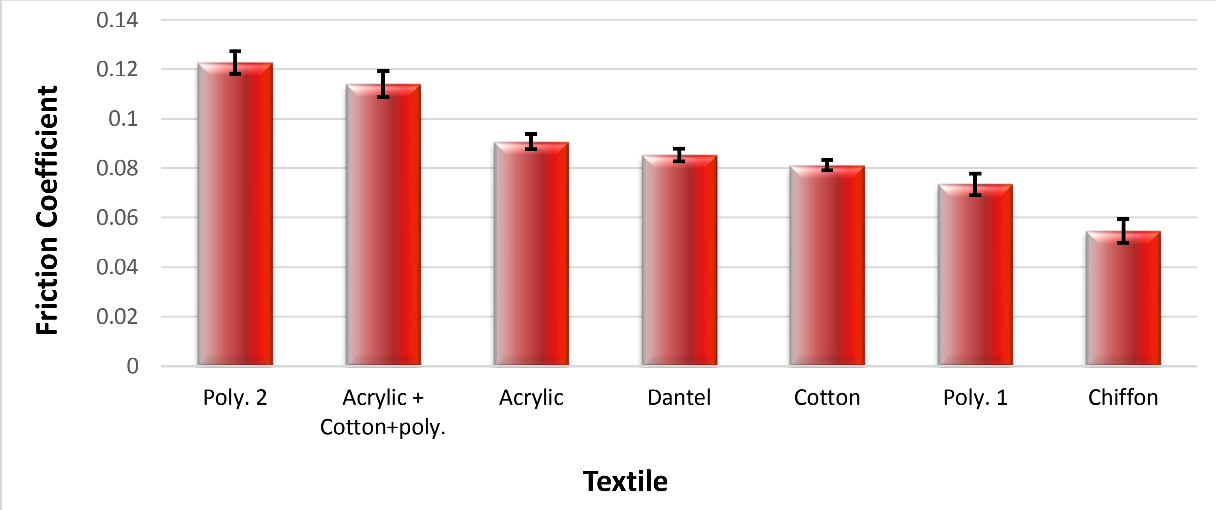

Fig. 5. Friction coefficient of African hair with different types of textiles.

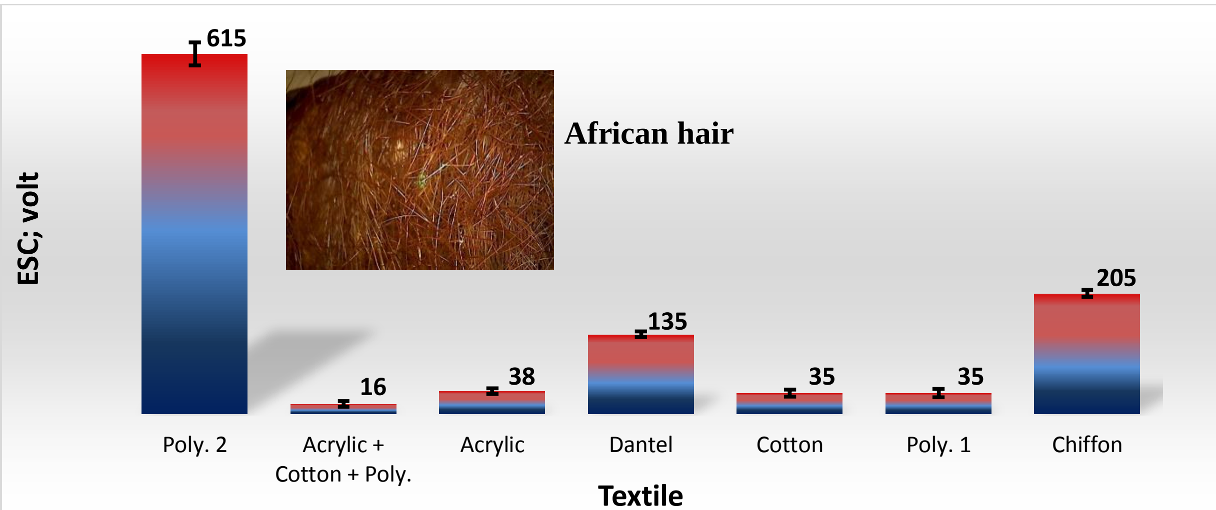

Fig. 6. ESC generated from sliding of African hair against different types of textiles.

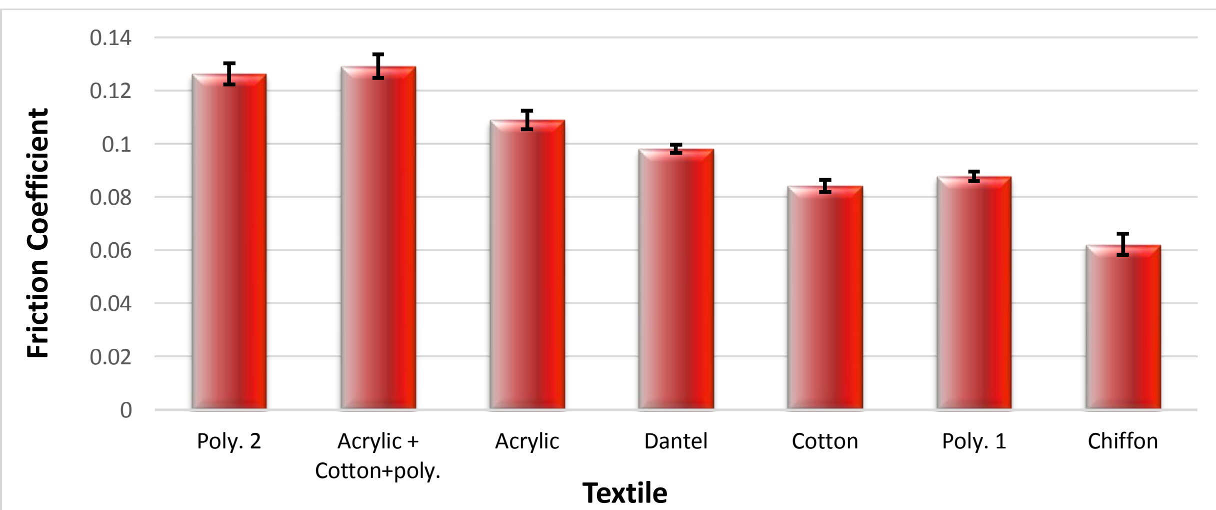

Fig. 7. Friction coefficient of Asian hair with different types of textiles.

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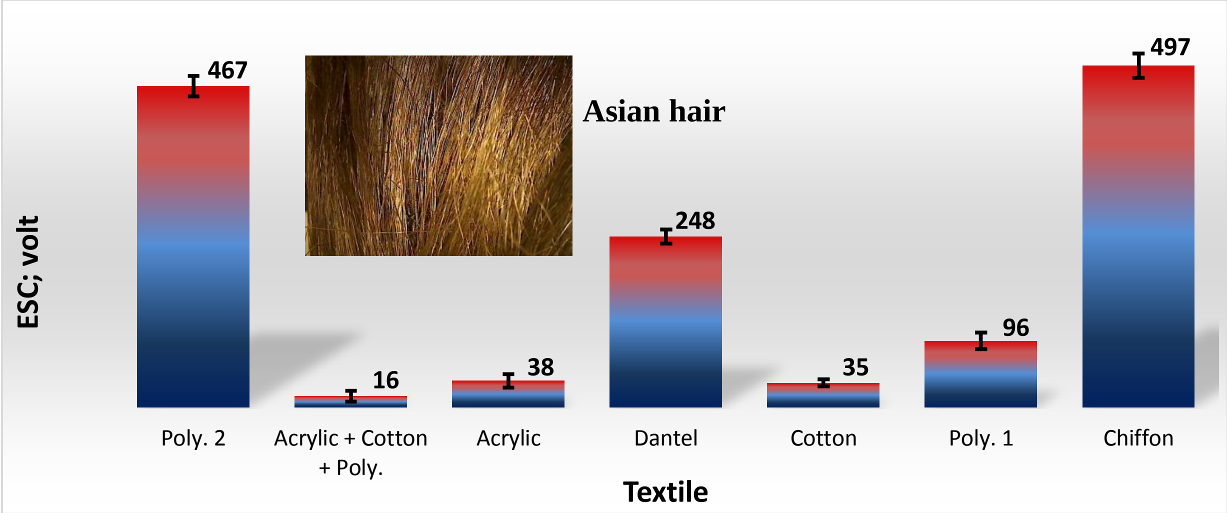

Fig. 8. ESC generated from sliding of Asian hair against different types of textiles.

Friction coefficient and the resultant electrostatic charge of slipping an Asian hair sample against the same seven textiles are shown in Fig. 7 & 8. It is obviously clear that the proposed textile could achieve the highest friction coefficient with a very low electrostatic charge when rubbed with Asian hair compared to other textiles. According to the other textiles, results showed a great agreement with the African hair results.

The same experiments were repeated in case of skin, artificial hair one and artificial hair two rubbed against the seven textiles. Figures 9, 11 and 13 illustrate the friction coefficient skin, artificial hair one and artificial hair two rubbed against the seven textiles, respectively. Figures 10, 12 and 14 show the resulting electrostatic charge of skin, artificial hair one and two rubbed against the textiles, respectively.

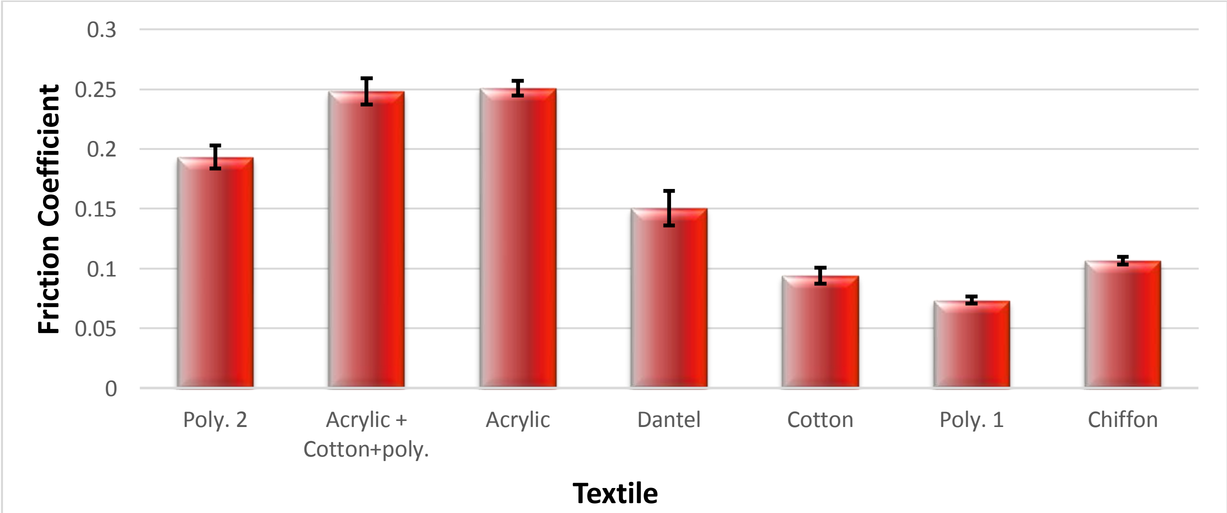

Fig. 9. Friction coefficient of skin with different types of textiles.

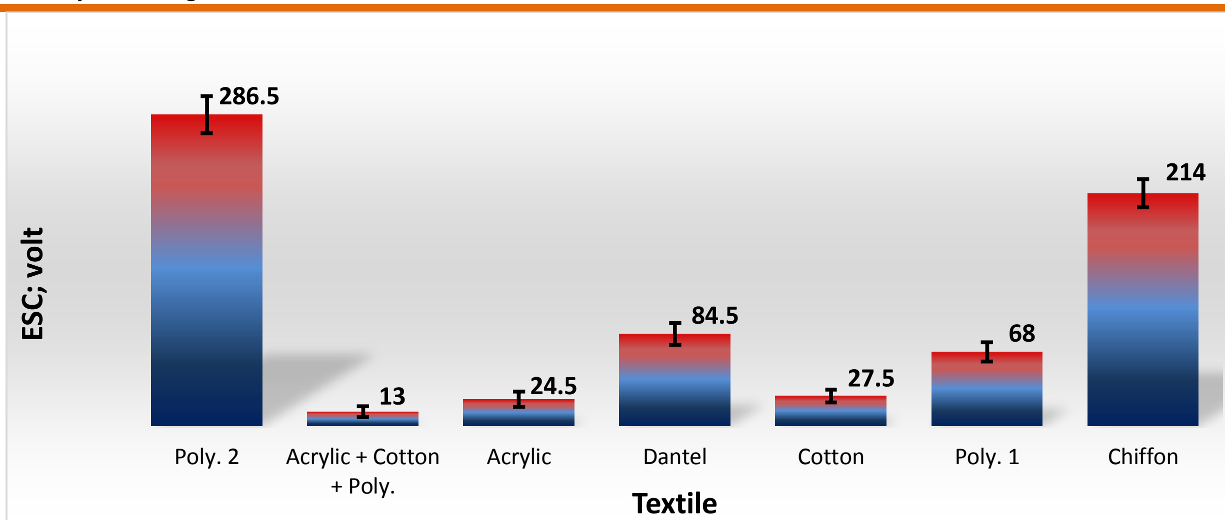

Fig. 10. ESC generated from sliding of skin against different types of textiles.

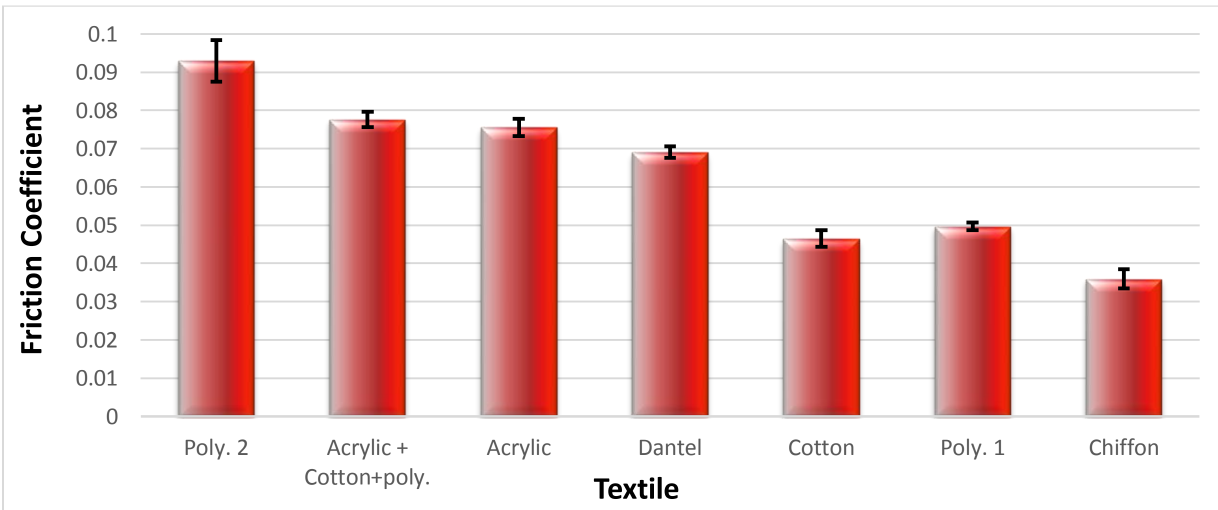

Fig. 11. Friction coefficient of artificial hair one with different types of textiles.

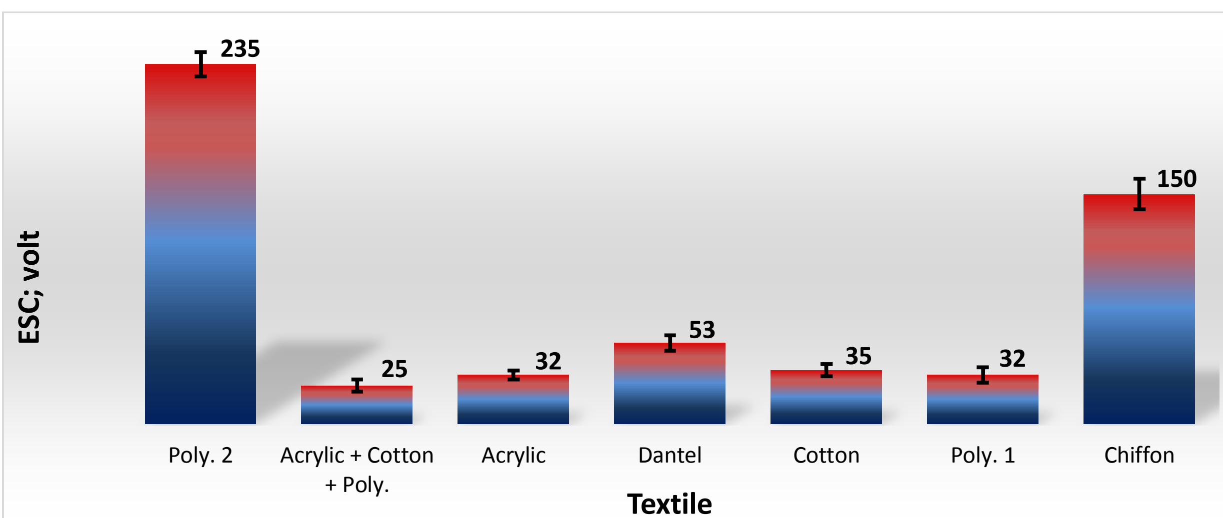

Fig. 12. ESC generated from sliding of artificial hair one against different types of textiles.

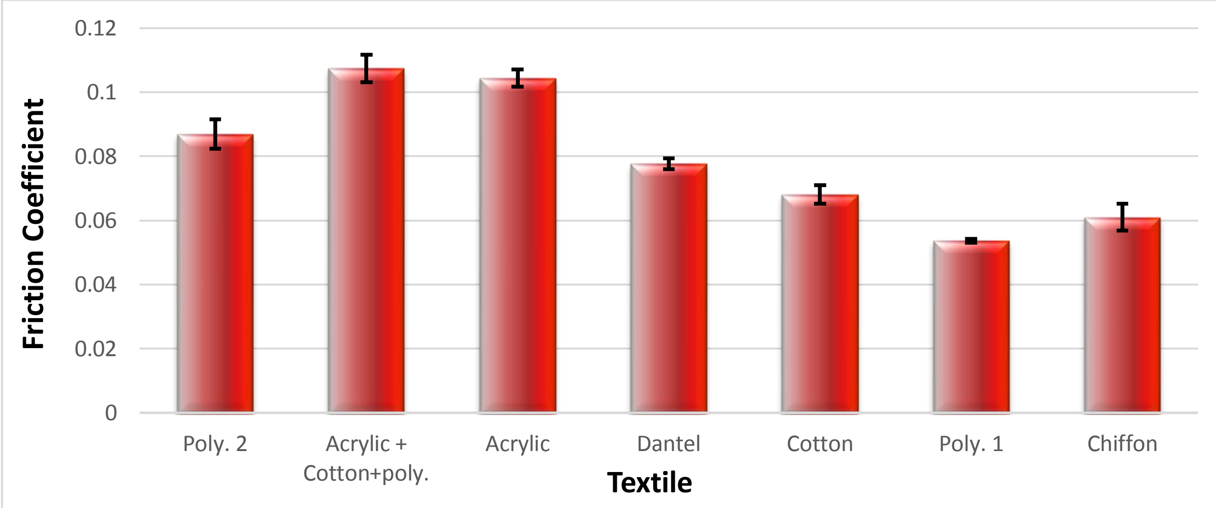

Fig. 13. Friction coefficient of artificial hair two with different types of textiles.

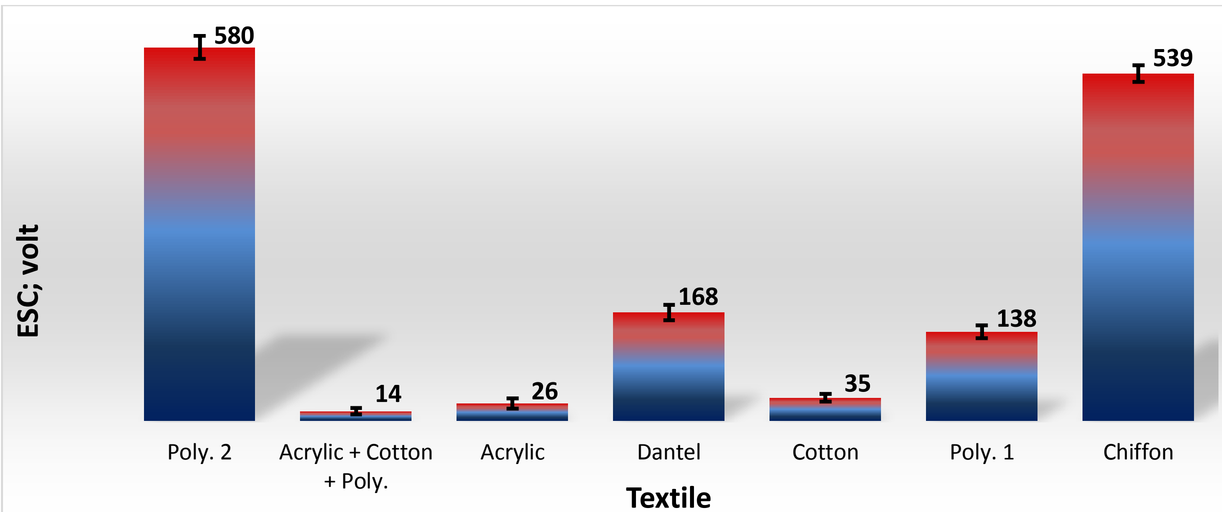

Fig. 14. ESC generated from sliding of artificial hair two against different types of textiles.

As shown in the above figure, the poly 2 usually have a large friction coefficient when rubbed against skin, artificial hair one and artificial hair but it generates the largest electrostatic charge compared to other textiles followed by chiffon. Cotton, acrylic, poly 1and dantel usually have very close friction coefficient and resultant electrostatic charge. The proposed textile, cotton + acrylic + poly, has succeeded to achieve a relatively high friction coefficient and generates the lowest electrostatic charge in all cases. The success of this composition could be attributed to the large stitch which allows electrostatic charge to discharge into the air. Furthermore, the selection of three textiles that have initially high and moderate friction coefficient against hair and skin helped to obtain an acceptable friction coefficient compared to other textiles.

4. Conclusions

This paper presents a study of the friction coefficient and the electrostatic charge generated from the slippage of the artificial wig cap against women head skin and hair. Experiments were conducted using different samples of natural and synthetic hair, namely African hair, Asian hair, artificial one and two, besides the skin. Hair samples were rubbed against six types of commercial and usable textiles, cotton, chiffon, dantel, acrylic, poly 1 and poly 2. Based on the results a new textile is developed in which it consists of cotton, acrylic, and polyester with high-density fibers with the same ratio. Results showed that polyester with high density could allow relatively high friction coefficient compared to other textiles, but the resultant electrostatic charge was relatively very high for all types of hair and skin. The weaves and stitch form has a significant effect on the friction coefficient and the generated voltage, and this was obviously shown in the results of poly 1 with low fibers density. Results of chiffon fabric usually gave a relatively low friction coefficient and a relatively high electrostatic voltage. Cotton, acrylic, and dantel gave a moderate friction coefficient, against different typed of hair and skin, and a relatively low voltage compared to other textiles. Eventually, the proposed textile, cotton + acrylic + poly, was able to give a relatively high friction coefficient and generates the lowest electrostatic charge in all cases.

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