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Uwe Reischl
Boise State University

Budimir Mijovic
University of Zagreb

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Assessment of Electrostatic Potential Resulting from Friction between Fabric Samples made of Natural and Synthetic Fibers

Uwe Reischl[1*], Budimir Mijovic[2]

[1]*Boise State University, Boise, Idaho, USA*
[2]*University of Zagreb, Zagreb, CROATIA*

Corresponding author's email: ureischl@boisestate.edu

Abstract

Synthetic fibers are known to be a major source of electrostatic potential occurring on clothing. The electrical properties of fibers are determined by their chemical composition and polymer structure. Environmental factors such as humidity, temperature, and friction intensity can influence these properties. Due to the insulative characteristics of most fabrics, fibers are able to keep their charge for relatively long periods. This can result in clothing to cling to each other, attract dust, and create discharge shocks. To reduce these issues, suggestions have been proposed to mix garment layers made of natural fibers with garment layers made of synthetic fibers. The purpose of this study was to identify combinations of commercially available natural and synthetic fabrics that may result in reduced electrostatic build-up. Sixteen combinations of four fabric types were evaluated under controlled laboratory conditions. The fabric samples included 100% Polyester, 100% Nylon, 100% wool and 100% cotton. All combinations were evaluated using the same friction test protocol. The results showed that wool and cotton both exhibited the lowest electrostatic charge build-up while the polyester sample created the highest electrostatic charge build-up, even when paired with fabric samples of cotton and wool. The results suggest that layering synthetic fabrics with fabrics made of natural fibers will not significantly reduce the electrostatic potential created by the friction with synthetic fibers.

Keywords: Triboelectric Effect; Electrostatic Potential; Synthetic Fibers; Natural Fibers

1. Background

1.1 Static Electricity

Static electricity is generated when different materials rub against each together. Under static conditions, the atoms within a material are neutral as negatively charged electrons are being balanced by the positively charged protons. However, when one of the atoms comes in contact with another atom through friction, electrons are attracted to the nucleus of the other atom. Some of the electrons may be removed altogether through this friction. The material which loses the electrons then becomes positively charged while the other material will become negatively charged. Fabrics used in clothing are known to differ significantly in their propensity to lose such electrons due to friction [1].

1.2 Textile Materials

In general, textile materials used for clothing are poor conductors of electricity. Clothing layers will develop an opposite charge as they rub against each other. When the layers are separated, one will retain its positive charge and the other a negative charge, resulting in static cling. Charged clothing can also induce a charge on the entire human body [2].

1.3 Triboelectric Charging

The electrostatic charge created by friction between two materials is called "triboelectric charging". The amount of charge created by the triboelectric effect depends on the area of contact between two materials, the moisture in the material, the water vapor pressure in the air, the molecular structure of the materials, the friction intensity imposed on the two materials, and other factors [3, 4]. Once a charge is created, it becomes an electrostatically charged material. This charge may be transferred to another material resulting in an electrostatic discharge event.

Virtually all materials, including water and air, can be triboelectrically charged. How much charge is being generated, where that charge goes, and how quickly, depends on a material's physical, chemical, and electrical conductive characteristics.

1.4 Laboratory Tests

Research in triboelectric charging has relied on three main measurements approaches:

1) Measurement of fabric surface resistivity
2) Measurement of electrical capacitance
3) Measurement of electrostatic potential

With the availability of new instrumentation, it is now possible to accurately measure the electrostatic potential resulting from friction between different materials including textiles. This measurement method was chosen for the current study.

1.5 Research Objective

The objective of this study was to determine whether combining textiles made of natural fibers with textiles made of synthetic fibers can reduce the electrostatic charge build-up on clothing since natural fibers are known to exhibit a lower propensity for electrostatic charge build-up than synthetic fibers.

2. Methods and Procedures

2.1 Triboelectric Generator

A friction generator was constructed consisting of a non-conductive support frame, a 9cm diameter variable-speed rotating cylinder (rotor), and a 77g fabric tension weight. A True-RMS Multimeter was used to record the electrostatic potential generated by the fabric materials exposed to the friction caused by the rotating cylinder. The negative terminal of the Multimeter was placed on the rotor while the positive terminal was attached to the fabric sample. The design of the triboelectric friction generator is illustrated in Fig.1.

2.2 Fabric Samples

Four types of fabric material were evaluated including 100% Cotton, 100% Wool, 100% Polyester and 100% Nylon. Samples were obtained from clothing worn previously. Fabric structural specifications such as yarn count, yarn density and weave density could not be examined. Two sets of each were made. The dimensions were 6 cm in width and 42 cm in length. While one sample was mounted onto the rotating cylinder, the other was suspended vertically toughing the rotating cylinder at a constant pressure. The geometry and dimensions of the fabric samples are illustrated in Fig.2.

2.3 Test Protocol

All fabric samples were exposed to the same friction level created by the rotating cylinder (rotor). 20 rotations during a 15-second period were used for each test. Fabric pressure on the rotor was created by a 77 gram weight attached to the bottom of the fabric sample. Each combination was tested five times and the average value calculated. Laboratory air temperature was maintained at 24^{0}C with a relative humidity of 20%

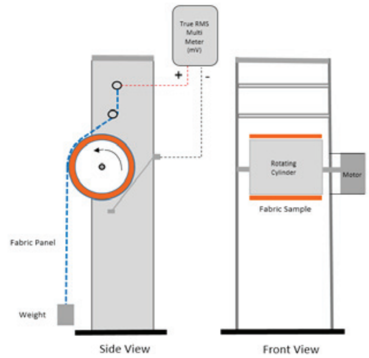

Fig.1 Triboelectric generator used in assessing friction induced electrostatic charge on fabric samples

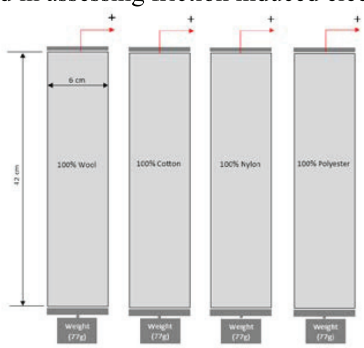

Fig.2 Geometry of fabric samples used in the tests. Two samples of each were made. One was mounted onto the rotor and the other was suspended externally as illustrated in Fig.1

2.4 Fabric Combinations

Sixteen combinations of fabric pairs were evaluated including Nylon, Polyester, Wool and Cotton. The combinations are illustrated in Table 1.

Table 1. Combination of fabric sample pairs tested

Rotor Mounted Fabric Sample	Suspended Fabric Sample
Nylon	Nylon
Nylon	Polyester
Nylon	Wool
Nylon	Cotton
Polyester	Polyester
Polyester	Nylon
Polyester	Wool
Polyester	Cotton
Wool	Wool
Wool	Nylon
Wool	Polyester
Wool	Cotton
Cotton	Cotton
Cotton	Nylon
Cotton	Polyester
Cotton	Wool

3. Results

Table 2 summarizes the electrostatic charge build-up observed for the sixteen fabric sample combinations exposed to the controlled triboelectric charging. The table lists separately the fabric samples mounted onto the rotating cylinder and the fabric samples contacting the rotor externally.

Table 3 summarizes the average electrostatic charge observed for the Wool and Cotton fabric samples interacting with other Wool and Cotton samples, with Nylon and other Polyester fabric samples.

Table 4 provides a statistical comparison between synthetic fabrics and natural fabrics in the reduction of the electrostatic charge build-up. The reductions are relative to the electrostatic build-up exhibited by the synthetic fabric combinations.

Table 2. Summary of electrostatic charge observed for sixteen fabric combinations

	Fabric Panel	Fabric Panel	Fabric Panel	Fabric Panel
Rotor Mounted	100% Wool	100% Cotton	100% Nylon	100% Polyester
100% Wool	200 mV (SD=22)	125 mV (SD=18)	230 mV (SD=24)	180 mV (SD=17)
100% Cotton	60 mV (SD=7)	20 mV (SD=8)	80 mV (SD=6)	55 mV (SD=5)
100% Nylon	100 mV (SD=20)	100 mV (SD=20)	80 mV (SD=11)	100 mV (SD=15)
100% Polyester	240 mV (SD=16)	200 mV (SD=20)	270 mV (SD=23)	200 mV (SD-22)

Table 3. Summary of average electrostatic charge build-up observed for fabric combinations tested.

Fabric Sample Combination	Electrostatic Build-up
Wool/Cotton + Wool/Cotton	101 mV (SD=78)
Wool/Cotton + Nylon/Polyester	145 mV (SD=72)
Nylon/Polyester + Nylon/Polyester	152 mV (SD=88)

Table 4. Statistical comparisons of electrostatic charge reductions observed for all combinations of fabric samples tested.

Fabric Comparison	Reduction in Electrostatic Static Buildup	Statistical Significance
Natural vs. Synthetic	$\Delta = 51$mV	$p<0.05$
Natural / Synthetic vs. Synthetic	$\Delta = 7$ mV	$p<0.05$

4. Discussion

Differences between the electrostatic charge build-up observed for the natural fiber textiles and synthetic fiber textiles were seen. Higher electrostatic levels were observed when a fabric sample was mounted onto the triboelectric rotor in comparison to the fabric sample when it was placed externally, touching the rotor. Although the length of both fabric samples was the same, i.e., 42 cm, the contact area between the external fabric sample and the rotor was different, i.e., 7 cm. While the fabric sample mounted on the rotor was exposed a total of 28 cm for each rotation, the surface contact area for the external fabric panel remained at 7 cm. This may explain the differences in electrostatic charge build-up observed between the two panel locations. However, averaging the two values together provided an overall value as summarized in Table 3.

In this study, the electrostatic potentials were documented for natural/natural fiber pair, the natural/synthetic fiber pair, and the synthetic/synthetic fiber pairs separately. While the natural/natural pair exhibited a substantial lower electrostatic charge than the synthetic/synthetic pair, the difference between the natural/synthetic pair and the natural/natural pair was only 14%. The results of this study, therefore, suggest that combining fabrics made of synthetic fibers with fabrics made of natural fibers may not be able to eliminate or substantially reduce the electrostatic potential created by this combination of textiles.

5. Limitations

The fabric samples evaluated in these experiments were obtained from previously worn clothing and may have been impacted by their previous use. Furthermore, the structural fiber characteristics such as yarn count, weave type and weave density could not be determined. However, such variables may have influenced their electrostatic characteristics. Controlling such variables in the future will allow a more precise differentiation of a fabric sample's propensity to create an electrostatic charge due to friction with other fabric samples.

6. Conclusions

Combining natural textiles with synthetic textiles has shown to reduce electrostatic charge build-up by approximately 14%. Although this reduction appears "small", it can contribute to an overall reduction of fabric cling when combined with other methods such as antistatic surface agents and methods of integrating metallic or highly conductive fibers into fabrics [4, 5]. To date, these alternative approaches have been successful in lowering the electrostatic charge on garments. However, future preferences for natural fibers in clothing may reduce the demand for anti-static chemicals and use of conductive Nano-materials.

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