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Electrostatic Properties of Clothing Fabrics Suitable for Different End-Uses

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Abstract
The static electricity properties of textile products are very important, especially when clothing comfort is the main subject. In this study, four sets of clothing fabrics containing 33 systematic and 18 non-systematic woven fabrics in total were used in order to examine the electrostatic charging properties. A testing mechanism which provides static electricity by the triboelectrification method was manufactured, and electrostatic voltage values occurring on the fabric samples were measured by an electrostatic voltmeter simultaneously with the testing mechanism. The repeatability of the results was checked by using polyester and cotton systematic woven fabrics. After this stage, the effects of fabric structural parameters and the rubbing period on electrostatic charging properties were evaluated. Moreover, non -systematic commercial woven fabrics were also tested in the study. In the last section of the experimental part, the best clothing and lining fabric combinations were revealed according to the lowest static electricity results.

Key words: *clothing fabrics, static electricity, electrostatic properties, clothing comfort.*

Introduction

Electrostatic charging is a fact that we can see at any period in our daily life. The human body can be charged by static electricity while walking on a carpet, rising from an armchair, or removing clothes. When a person charged with static electricity touches a metal object, an electrostatic discharge occurs, and there may be a spark at the moment of contact [1, 2]. This electrostatic discharge may be unpleasant for people because of the physical reactions of the body at different levels of charging, which are given in BS EN 7506-1 [3]. According to the values in the related standard, if the equivalent body voltage is 3.6 kV, it is a perceptible reaction level for the human body. Any value higher than 3.6 causes some problems, such as a definite sensation at 11.5 kV or an unpleasant shock at 26.5 kV.

The static electricity that occurs on textile products during usage mostly ensues as a result of rubbing. The clinging of clothes on the body or the feeling of crawling because of static electricity causes people to feel uncomfortable [4]. The most often and disturbing electrostatic discharge problem occurs while putting on or taking off clothes, which may cause painful and restless effects. Also, there are physiological effects of electrostatic charging on the human body.

There are many factors affecting electrostatic properties, the most important of which are the material type, the moisture content of the test material, the relative humidity and temperature of the environment, and the number of repetitions of the rubbing movement. Besides these, external factors can greatly change the electrostatic propensity of textiles [4]. Various researches have been made on the static electrification of textile products and the factors affecting static electrification. In recent years, these researches have focused specifically on the static electrification of protective clothes where new conducting fibres are used [6].

Schemer et al. determined that an increase in the amount of moisture in the environment decreases the level of electrostatic charging by the rubbing of upholstery fabric and concluded that pattern fabric, which has higher electrostatic charge levels, causes more static electrification during confection protection [6]. Zhao investigated the effect of rubbing material on the static electrification of textile materials [4]. Osei-Ntiri, (1992) examined the electrostatic effects of protective clothes used in the petrochemical industry and pointed out that protective clothes with antistatic fibre cause less electrostatic voltage. In another study, the effects of abrasion and washing on electrostatic characteristics were investigated using fabrics made of conducting fibre [6]. It was mentioned that the electrostatic charging tendency decreases as the number of conducting fibres in the fabric structure increases and that the static electrification characteristics of fabrics with conducting fibre are affected negatively by abrasion and washing [7, 8]. Anderson et al. (2008) examined the effect of upholstery fabric used in car seats on the electrostatic charging of the human body and determined that the electrostatic voltage amount caused by polyester upholstery fabric with conductive fibre is smaller compared to any polyester fabrics. In recent years, the electromagnetic shielding effect of textiles consisting of conductive yarn has been generally investigated by an increasing number of researches on e-textiles or wearable electronic textiles. Varnaitė-Žuravliova (2013) measured electrostatic characteristics such as surface and vertical resistances to examine shielding properties [9]. Žilinskas et al. (2013) described a non-contact way for electrostatic property measurement based on affecting some textile materials by ions with a positive or negative charge [10]. Mahmoud and Ibrahim (2016) investigated the effect of blending polyester textiles with cotton and viscose on the friction coefficient and triboelectrification [11]. Smalwood (2018) explained that static electricity nuisance shocks have become prevalent since floor covering and shoe sole materials have been increasingly made from highly insulating materials, such as polymers [12].

The static electricity properties of textile products are very important, especially when clothing comfort and clothing fabric are the main subjects. Although there are a number of studies on this topic, new researches are still needed examining different types of fabrics from different points of view. From this perspective, a wide range of systematic and non-systematic fabrics were tested in the current study, and the disturbing limit was evaluated when these fabrics were used as clothing. Thus, a testing mechanism creating electrostatic charging by the rubbing effect was manufactured. The repeatability of the mechanism was statistically verified before the measurements. After this stage, the effects of fabric structural parameters and the rubbing period on the electrostatic charging properties were evaluated. In the last section of the experimental part, the best clothing-lining fabric combinations are revealed according to the lowest static electricity test results.

Material and method

A testing mechanism that creates electrostatic charging by the rubbing effect was manufactured and used during all the experiments. The design methodology of this testing mechanism is to consider which fabrics cause the maximum electrostatic voltage by rubbing and will also cause the maximum electrostatic effect on the human body. Thus, the present study consists of four main parts: production of the testing mechanism, checking the repeatability of the test results, evaluation of the effects of the rubbing period and fabric structural parameters on electrocharging properties, and determination of the best pair of clothing-lining fabrics according to the lowest static electricity results. A total of 51 different fabric types were used in order to examine the electrostatic charging properties. In the following part, all details about the test fabrics, test mechanism and test procedure are explained.

Material

In the present study, four sets of woven clothing fabrics consisting of 51 different types were used. The test fabrics were classified into four groups, such as three systematic fabric groups (A, B and C) and one non-systematic commercial fabric group (D). In the first and second fabric groups (A and B), there are 12 systematic polyester fabrics for each with two weave patterns, two different weft yarn counts and three levels of weft settings. There are nine cotton systematic fabrics in Group C with three weave patterns and three levels of weft settings. In the fourth group (D) there are 18 non-systematic commercial fabrics of various raw materials and weave patterns.

The effect of the rubbing time and repeatability of the test results was checked, and then the effects of the fabric structural parameters on electrostatic charging properties were evaluated by using systematic polyester and cotton fabrics

Table 1. *Basic structural properties of systematic woven fabrics.* ***Note:*** ** f shows the number of filaments in the yarn structure for polyester fabrics.*

Fabric No.	Raw material	Weave	Yarn linear density, tex		Setting, cm^{-1}		Mass per unit area, g/m^2	Fabric thickness, mm
			warp	weft*	warp	weft		
A1	Polyester	Plain	10	16.6(48f)	60	20	104.7	0.22
A2	Polyester	Plain	10	16.6(48f)	60	23	108.1	0.22
A3	Polyester	Plain	10	16.6(48f)	60	26	118.0	0.21
A4	Polyester	Plain	10	33.3(96f)	60	14	118.0	0.24
A5	Polyester	Plain	10	33.3(96f)	60	17	131.1	0.24
A6	Polyester	Plain	10	33.3(96f)	60	20	141.9	0.25
A7	Polyester	3/1 Twill	10	16.6(48f)	60	30	121.9	0.25
A8	Polyester	3/1 Twill	10	16.6(48f)	60	33	128.9	0.24
A9	Polyester	3/1 Twill	10	16.6(48f)	60	36	135.8	0.25
A10	Polyester	3/1 Twill	10	33.3(96f)	60	24	153.7	0.30
A11	Polyester	3/1 Twill	10	33.3(96f)	60	27	169.5	0.31
A12	Polyester	3/1 Twill	10	33.3(96f)	60	30	184.8	0.33
B1	Polyester	Plain	7.8	16.6(48f)	30	20	60.0	0.19
B2	Polyester	Plain	7.8	16.6(48f)	30	23	66.9	0.19
B3	Polyester	Plain	7.8	16.6(48f)	30	26	75.7	0.16
B4	Polyester	Plain	7.8	33.3(96f)	30	16	81.3	0.23
B5	Polyester	Plain	7.8	33.3(96f)	30	19	92.2	0.24
B6	Polyester	Plain	7.8	33.3(96f)	30	22	106.2	0.24
B7	Polyester	3/1 Twill	7.8	16.6(48f)	30	27	74.1	0.19
B8	Polyester	3/1 Twill	7.8	16.6(48f)	30	30	78.1	0.19
B9	Polyester	3/1 Twill	7.8	16.6(48f)	30	33	82.2	0.20
B10	Polyester	3/1 Twill	7.8	33.3(96f)	30	20	95.7	0.25
B11	Polyester	3/1 Twill	7.8	33.3(96f)	30	23	106.7	0.26
B12	Polyester	3/1 Twill	7.8	33.3(96f)	30	26	115.5	0.27
C1	Cotton	Plain	30	30	36	14	148.0	0.37
C2	Cotton	Plain	30	30	36	18	163.0	0.37
C3	Cotton	Plain	30	30	36	22	175.0	0.36
C4	Cotton	2/1 Twill	30	30	36	18	158.0	0.38
C5	Cotton	2/1 Twill	30	30	36	22	171.0	0.38
C6	Cotton	2/1 Twill	30	30	36	26	186.0	0.40
C7	Cotton	3/1 Twill	30	30	36	18	161.0	0.40
C8	Cotton	3/1 Twill	30	30	36	22	186.0	0.41
C9	Cotton	3/1 Twill	30	30	36	26	190.0	0.41

Table 2. *Basic structural properties of non-systematic commercial fabrics.* ***Note:*** **these fabrics were also used as lining when checking the performance of clothing-lining pairs.*

Fabric No.	Raw material, %	Weave	Mass per unit area, g/m^2	Fabric thickness, mm
D1	100% Polyester	Fancy twill	169.5	0.45
D2	100% Cotton	Plain	163.0	0.45
D3	100% Linen	Plain	167.9	0.44
D4	100% Silk	Fancy twill	129.3	0.30
D5	100% Wool	Plain	138.6	0.25
D6	45% Wool, 55% Silk	Plain	125.9	0.23
D7	50% Wool, 50% Linen	2/2 twill	161.8	0.36
D8	55% Wool, 45% Cotton	Plain	124.1	0.27
D9	68% Cotton, 32% Viscose	Plain	125.5	0.21
D10	67% Cotton, 33% Ramie	Plain	190.5	0.38
D11	70% Cotton, 30% Silk	Plain	105.2	0.24
D12*	100% Viscose	Fancy twill	106.9	0.20
D13*	100% Cupro	Plain derivative	78.9	0.14
D14*	100% Acetate	Plain	54.8	0.09
D15*	49% Acetate, 51%Viscose	Plain	82.5	0.12
D16*	46% Acetate, 54% Cupro	Fancy twill	82.7	0.12
D17*	55% Acetate, 45% Cupro	Plain derivative	76.0	0.13
D18*	100% Polyester	Plain	75.7	0.16

(Groups A, B and C). The effect of the rubbing period was evaluated for systematic polyester fabrics (Groups A and B) by considering that the period of the rubbing effect is more important for those fabrics compared to the other test fabrics. It was decided not to use cotton fabrics to examine the effect of the rubbing period because of their low electrostatic charging values and the difficulty of examining the differences. Non-systematic clothing fabrics (Group D) were also tested to examine the electrostatic charging properties of different types of woven fabrics of different raw materials. In the fourth and last stage of the experimental part, some fabrics from Group D were selected as lining fabrics (D12, D13, D14, D15, D16, D17 and D18), which were also used to examine a pair of the best lining-clothing fabrics according to static electrificiaton test results. The basic structural properties of all the test fabrics are given in ***Tables 1*** and ***2***. ***Table 3*** shows the summary of the experimental plan conducted by using the testing mechanism explained in detail.

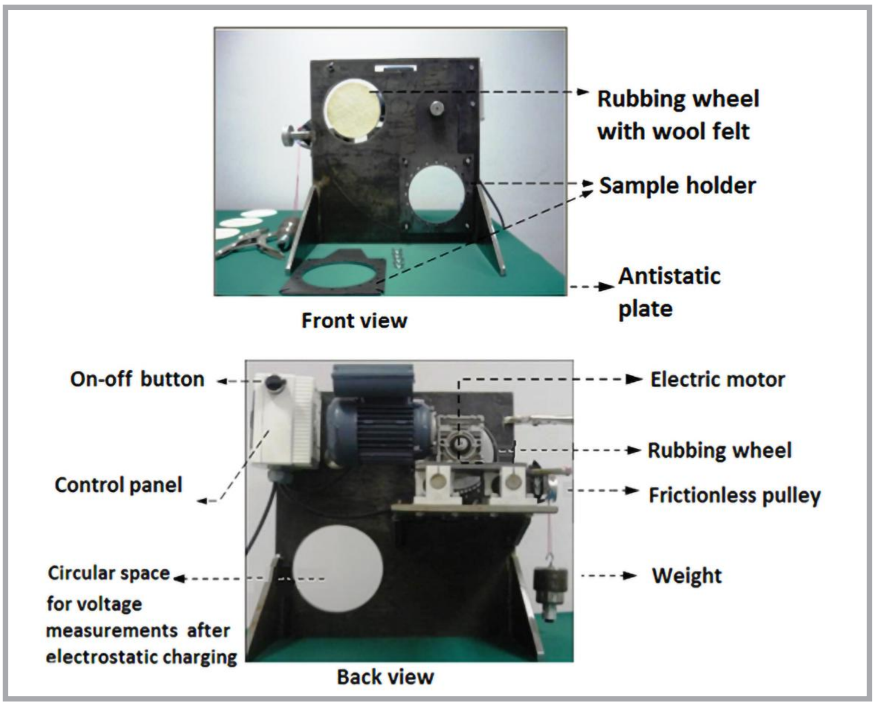

Figure 1. *Static electrification mechanism developed for the experimental study.*

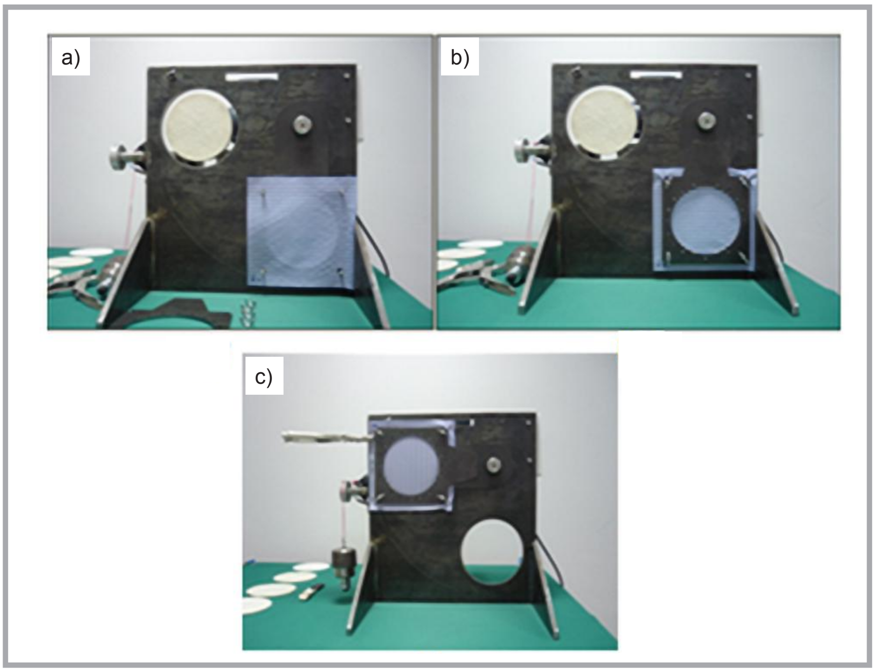

Figure 2. *Stages of the static electrification test by rubbing: a) placing the test sample on the sample holder, b) fixing the sample between the parts of the sample holder, c) placing the sample holder in the rubbing position.*

Table 3. *Summary of experimental plan.*

Evaluated property			
The effect of the rubbing period on electrostatic properties	The effects of fabric structural properties on electrostatic properties	Electrostatic charging properties of different clothing fabrics	Selection of the best clothing-lining pair
Fabrics used			
⇩	⇩	⇩	⇩
Groups A and B (systematic fabrics)	Groups A, B and C (systematic fabrics)	Group D (non-systematic commercial fabrics)	Clothing fabrics from Group D (1-11) Lining fabrics from Group D (12-18)

Method

In the context of the study, a test mechanism that creates a electrostatic charge by the rubbing effect was manufactured to examine the electrostatic properties of fabrics, and a voltmeter was used just after the rubbing process to measure electrification results. The test mechanism was inspired by the report prepared by the Materials Science Laboratory in the USA [9]. Details of the testing mechanism are given below, and original photographs of it are illustrated in ***Figures 1-2*** for a general view.

The main parts of the mechanism consist of an electric motor, rubbing wheel, sample holder, weight, frictionless pulley and microswitch. The mechanism is equipped with an electric motor to power the rubbing wheel at a speed of 200 rpm. The rubbing wheel was covered with nonwoven wool felt of 140 mm diameter, suitable for a Nu-Martindale Abrasion Tester. The wool felt was changed for a new one after three rubbing tests. Test samples were fixed between the two separate parts of the sample holder, which was located on the right side of the mechanism (***Figure 2.a*** and ***2.b***). After placing the test sample, the sample holder was rotated to the rubbing position, placed on the upper left side of the mechanism (***Figure 2.c***). Contact between the test sample and wool felt was supplied

Table 4. Variance analysis results of test fabrics (Groups A and B) for repeatability and fabric type.

Source	Fabric Group A						Fabric Group B					
	Rubbing period for electrification						Rubbing period for electrification					
	8 sec		24 sec		48 sec		8 sec		24 sec		48 sec	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Repeat	0.811	0.594	1.047	0.407	1.514	0.162	1.370	0.219	0.808	0.597	1.220	0.295
Fabric type	0.723	0.000	4.605	0.000	5.498	0.000	5.783	0.000	7.837	0.000	4.111	0.000

by hanging a weight of 1.36 kg on a frictionless pulley, in accordance with literature [13]. A microswitch was used to start the rubbing process simultaneously with the contact moment of the test sample on the wool felt. The test was finished after the required rubbing period by pushing the microswitch for a second time, and electrostatic voltage values occurring on the test fabrics were immediately measured by an electrostatic voltmeter (model 7100. EFM 51, Wolfganfg Warmbier). It is possible to change the rubbing period on the control panel by the user, and three rubbing periods: 8 sec, 24 sec and 48 sec were also tested for a group of fabrics in the present study.

Test procedure

Before measurements, all the test fabrics were washed at 40 °C by using an ECE reference non-phosphate detergent (5 g/l) with the F program of a domestic washing machine according to the TS 5720 EN ISO 6330 standard. For every fabric type, three test samples with different warp and weft yarns were cut into a square shape of 20 × 20 cm dimensions. All test fabrics were conditioned for 24 hours at standard atmospheric conditions (20 °C ± 2 temperature and 65% ± 2 RH) before the tests in accordance with ASTM D1776/D1776M-15. As a precaution, all the test fabrics were kept on an antistatic plate during all experiments. Furthermore, the person who performed the tests wore a lab coat made of 100% cotton and used a grounded antistatic wristband so as not to affect the static electricity results.

Three repetitions were made for every test sample of each fabric type, and in total nine test results were handled for every fabric type for one rubbing period. Average electrostatic voltage values were reported as the means of nine measurements for every fabric type. Three different time durations of rubbing (8 sec, 24 sec and 48 sec) were considered for systematic polyester fabrics (Groups A and B). For other measurements, the rubbing period was always taken as 48 sec.

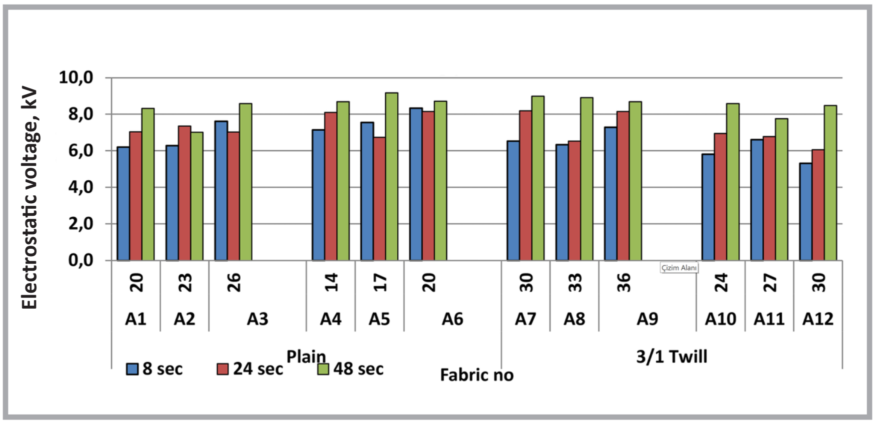

Figure 3. Average electrostatic voltage values of polyester test fabrics (Group A) for three different rubbing periods.

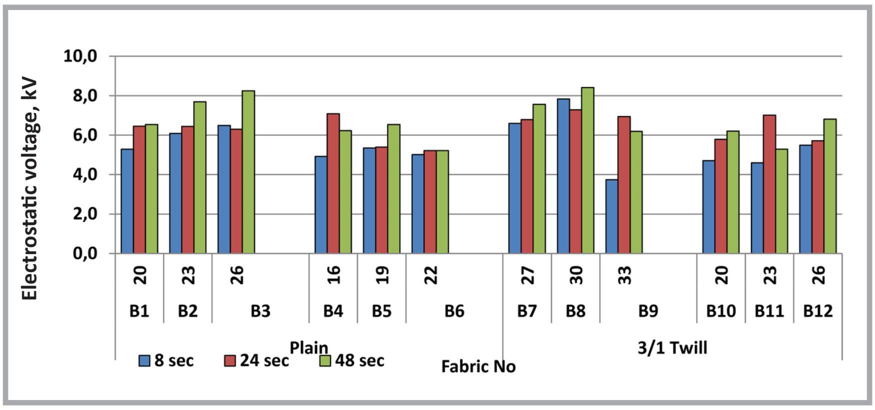

Figure 4. Average electrostatic voltage values of polyester test fabrics (Group B) for three different rubbing periods.

All test samples were kept for 24 hours between all the repetitions.

Statistical analysis

SPSS 22.0 Statistical Software was used for statistical analysis of the results. Variance analysis was applied to determine significant differences, and a 95% confidence level was used for all statistical analyses. Variance analyses were conducted to examine the repeatability of test results. The differences between fabric types and the effect of structural parameters and the rubbing period on electrostatic charging properties of the test fabrics were also evaluated by variance analysis. The best pairs of clothing-lining fabrics were evaluated according to values given in a previous study.

Results and discussion

The electrostatic charging properties of 51 woven fabrics were evaluated with the testing mechanism proposed.

Effect of rubbing period and repeatability

The rubbing period was statistically evaluated, and then the repeatability of the measurements was checked for each rubbing period. Polyester fabrics (Groups A and B) were tested to examine the effects of the rubbing period on static electrification. According to the variance analysis results of Group A and B fabrics, the effect of the rubbing period on electrostatic voltage values was found to be statistically significant ($p < 0.05$). Af-

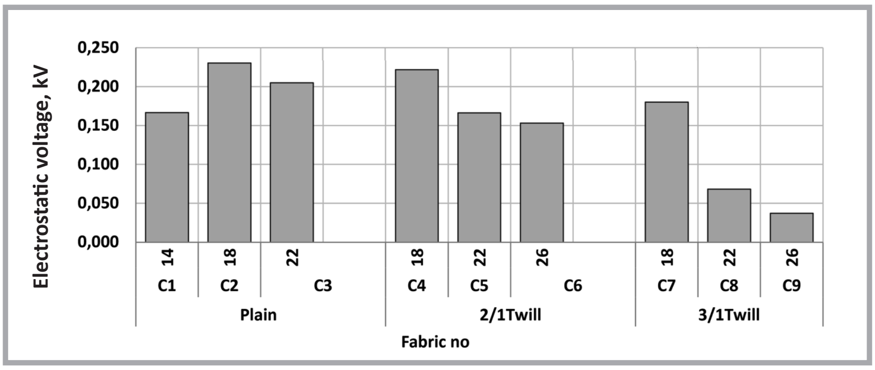

Figure 5. Average electrostatic voltage values of for cotton test fabrics (Group C) for a rubbing period of 48 seconds.

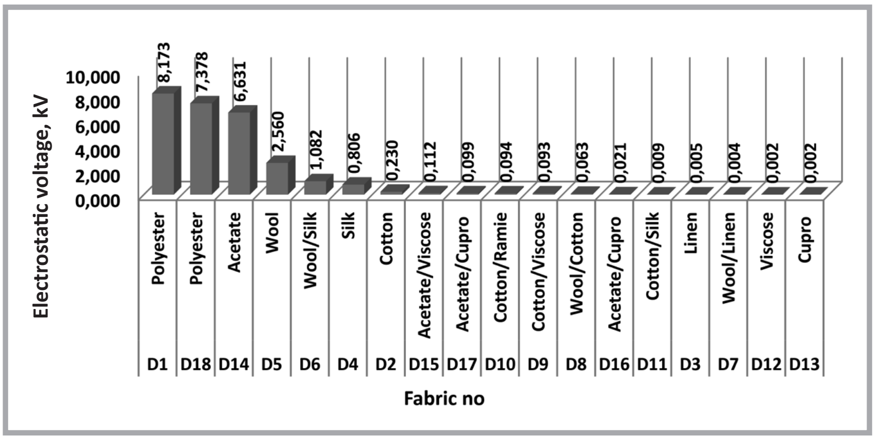

Figure 6. Average electrostatic voltage values of test fabrics (Group D) for a rubbing period of 48 seconds.

ter this stage, test results were examined separately for every rubbing period.

In order to check the repeatability of test results, a variance analysis was conducted. When the differences between repetitions are evaluated, it is seen that the differences between the repetitions are not statistically significant at a 95% confidence level ($p < 0.05$). This result means that there is no statistically significant difference between the repetitions. Moreover, it was found that the fabric type is statistically significant ($p < 0.05$) for each rubbing period. This finding shows that statistically significant test results can be handled for different fabric types and that differences between fabrics can be detected using this testing mechanism for electrostatic voltage values. All of these variance analysis results are summarised in ***Table 4***.

Table 5. Variance analysis results of test fabrics (Groups A and B) for fabric structural parameters.

Polyester fabrics (Group A)						
Variation source	Rubbing period: 8 sec		Rubbing period: 24 sec		Rubbing period: 48 sec	
	F	Sig.	F	Sig.	F	Sig.
Weave (W)	9.537	0.003	2.201	0.141	0.888	0.348
Linear density of weft (L)	0.442	0.508	1.627	0.205	2.082	0.152
Weft setting (S)	1.170	0.315	4.723	0.011	1.011	0.368
Polyester fabrics (Group B)						
Variation source	Rubbing period: 8 sec		Rubbing period: 24 sec		Rubbing period: 48 sec	
	F	Sig.	F	Sig.	F	Sig.
Weave (W)	24.789	0.000	66.416	0.000	0.825	0.366
Linear density of weft (L)	0.000	0.984	0.041	0.840	0.436	0.511
Weft setting (S)	17.633	0.000	2.611	0.079	14.209	0.000

Effect of structural parameters on static electrification of polyester woven fabrics

The effects of structural parameters on the static electrification of polyester woven fabrics were examined separately for fabric groups A and B. The average test results of nine measurements for each fabric type are shown in ***Figures 3-4*** for three different rubbing periods. The variance analysis results are tabulated in ***Table 5***. For Group A fabrics, the effect of the weave is found to be statistically significant, while that of the weft yarn linear density and setting are not.

When the electrostatic voltage results of Group A fabrics were examined for the rubbing period, it is clearly seen that the electrostatic voltage increases with an increasing rubbing period. Even though the effect of the weft density on electrostatic voltage values is statistically significant for a 24 second rubbing period, electrostatic voltage values do not increase or decrease parallel to the weft density increments. For a 48 second rubbing period, the effect of the weave type, weft density and weft yarn count is found to be statistically non-significant at a 95% confidence level ($p > 0.05$).

When the average electrostatic voltage values are examined, electrostatic voltage occurring on the test fabrics generally increases with the rubbing period increments. A graph presenting the electrostatic voltage results of fabrics in Group B is given in ***Figure 5*** for three different rubbing periods. Even though the effect of the weft yarn number on electrostatic voltage values is statistically significant, it is not possible to say that there is a regular increase or decrease in electrostatic voltage values as the weft yarn number changes. The effect of weave type on electrostatic voltage is statistically insignificant for the three rubbing periods. While the effect of weft density on electrostatic voltage is statistically significant for a rubbing period of 8 seconds, it is insignificant for rubbing periods of 24 and 48 seconds.

Even though the effect of weft density on electrostatic voltage values is statistically significant for a rubbing period of 8 seconds, it is not possible to say that there is a regular increase or decrease in electrostatic voltage values as the weft density changes. For fabrics in group B, the effect of the rubbing period on electrostatic voltage values is statistically significant.

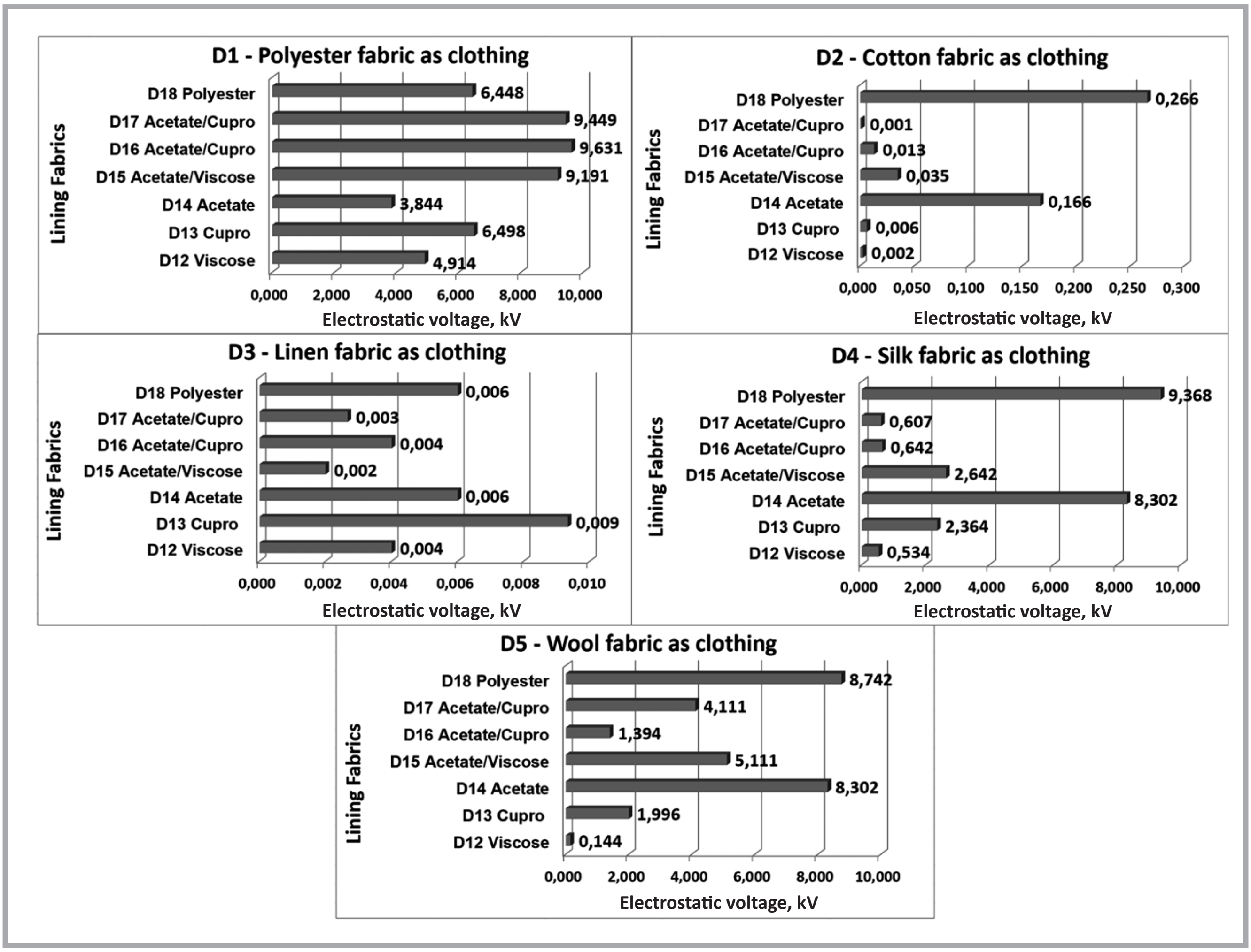

Figure 7.a. *Electrostatic voltage results of the lining-clothing fabric pairs for the most common clothing fabrics.*

When the average electrostatic voltage values are examined, it is seen that the test results increase with an increasing rubbing period for many of the test fabrics in this group.

Effect of structural parameters on static electrification of cotton woven fabrics

The electrostatic voltage values of cotton woven fabrics (Group C test fabrics) were measured for a rubbing period of 48 seconds. A graph representing the results is given in ***Figure 5***.

According to the variance analysis results given in ***Table 6***, the effect of the weave and weft setting on electrostatic voltage for Group C fabrics was found to he statistically significant ($p < 0.05$). When the average voltage values are examined, it is seen that they decrease for fabrics coded C4, C5, C6 (2/1 twill) and C7, C8, C9 (3/1 twill) along with increments in the weft density. This systematic approach was not obtained for plain fabrics with weft setting values different from those of the twill fabrics.

Electrostatic voltage results of various commercial clothing fabrics

The electrostatic voltage values of various commercial fabrics were measured for a rubbing period of 48 seconds. A graph arranging the results from the highest to lowest values is given in ***Figure 6***.

According to the perceptible level given in BS EN 7506 [3], the test results can be divided into two main groups. In the test standard mentioned, any value up to 3.6 kV is "perceptible", while 11.5 kV is a source of "definite sensation". The fabrics with the maximum electrostatic voltage are the ones made of polyester and acetate fibres (D1, D18, D14), and these fabrics were found to be close to the definite sensation level. Beginning with the wool fabric (D5), all the other fabrics have electrostatic voltage values lower than 3.6 kV, which is perceptible.

However, it may be useful to examine the differences between the test fabrics. Amongst all the test fabrics, the cupro (D12) and viscose (D13) fabrics are found to have the minimum electrostatic voltage values. Independently from other fabric properties, there are important results emphasising the effect of fibre type on electrostatic properties. While an electrostatic voltage with an amount of 2.560 kV was determined on 100% wool fabric, only 0.004 kV was obtained for wool/linen fabric. Fabric with acetate and another fibre type were found to have lower electrostatic values in comparison to 100% acetate fabric. 100% silk fabric had 0.806 kilovolt

Table 6. *Variance analysis results of test fabrics (group C) for fabric structural parameters.*

Cotton fabrics (Group C)		
Variation source	Rubbing period: 48 sec	
	F	Sig.
Weave (W)	12.347	0.000
Weft setting (S)	3.334	0.041
W*S	3.125	0.020

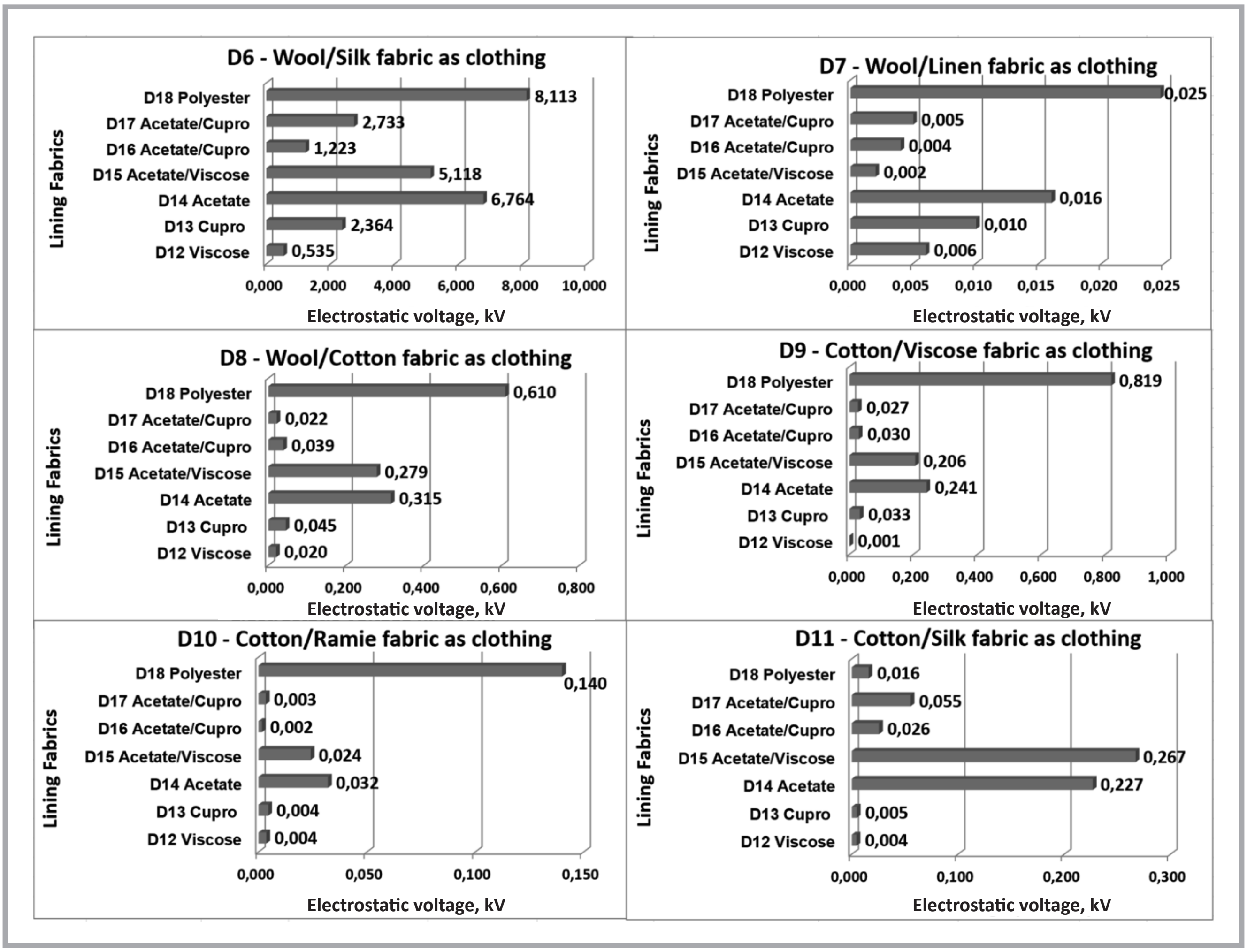

Figure 7.b. *Electrostatic voltage results of the lining-clothing fabric pairs for blended clothing fabrics.*

electrostatic voltage while cotton/silk fabric had 0.009 kV. According to the results obtained, it is seen that the tendency of static electrification by rubbing decreases significantly in fabrics where fibres with a high tendency of static electrification are mixed with one of the cellulose-based fibres.

Electrostatic voltage results of lining-clothing fabric combinations

Electrostatic charge occurs on clothing fabrics by a rubbing effect between the body and clothing fabric or/and between fabric layers during putting on/taking off and the wearing period. It is an important matter to choose clothing fabrics that will cause minimum static electrification on the body so as to provide better clothing comfort.

Considering this important point, electrostatic voltage values were measured on lining and commercial clothing fabrics by preparing lining-clothing fabric pairs. A set of lining fabrics selected from a commercial fabric group was used as rubbing material, and tests were conducted for a 48 second rubbing period. Graphs showing the electrostatic voltage results of the lining-clothing fabric pairs are given in ***Figure 7.a*** and ***7.b***.

According to the results, a summary table was prepared for good or bad lining-clothing fabric pairs using the perceptible levels given in BS 7506-1. As seen in ***Table 7***, selecting the lining fabric is very important when clothing fabric is made of polyester, silk, wool and wool/silk fibres. For polyester fabrics, whatever lining is selected, the perceptible level is always exceeded for the fabrics used in the current study. There is no need to think about the selection of lining for fabrics made of cotton or cotton blends because electrostatic voltage values found to be lower than 3.6 kV, meaning it is perceptible. In that situation, according to the electrostatic properties, here will be no problem while wearing these fabrics, and any disturbance in clothing comfort occurring can be tolerated.

Table 7. *Comparison of the perceptible level of electrostatic voltage values of the lining-clothing fabric pairs.* ***Note:*** ** comparisons were made according to BS 7506-1 [3].*

Over the perceptible level* (Electrostatic voltage higher than 3.6)		Perceptible level* (Electrostatic voltage lower than 3.6)	
Clothing fabric	**Lining fabric**	**Clothing fabric**	**Lining fabric**
Polyester	All the lining fabrics used in the current study	Cotton, Linen, Wool/linen, Wool/cotton, Cotton/ viscose, Cotton/ramie, Cotton/silk	All the lining fabrics used in the current study
Silk	Polyester, acetate		
Wool	Polyester, acetate, acetate blends		
Wool/silk	Polyester, acetate viscose		

Conclusions

In this research a test mechanism that creates electrostatic charge on fabrics by the rubbing effect was produced, inspired by a previous study [9]. Variance analysis results proved that it is possible to handle repeatable test results and that differences between fabric types can be determined by the test method used in the current study.

As a result of the measurements, it is determined that structural parameters of woven fabrics have some effects on static electrification; however, these effects are not as determinative as raw material. It was determined that the highest electrostatic voltage occurs on fabrics made of polyester, acetate, wool and silk fibre, respectively, in the current study. When the effect of the rubbing period on the electrostatic voltage values was examined regarding polyester fabrics, it was observed that the electrostatic voltage increases by increasing the rubbing effect for three different rubbing periods (8, 24, 48 sec).

While determining electrostatic voltage values occurring on clothing fabrics, the effect of lining fabrics was taken into consideration, and lining-clothing fabric pairs were also arranged. As a result of the lining-fabric combination test, it was determined that the perceptible voltage level can be exceeded with polyester clothing fabrics. The highest voltage values were obtained for the polyester clothing-other lining pairs. When polyester fabric was selected as the clothing fabric, only the acetate lining was showed the lowest electrostatic voltage. Cotton and cotton blend fabrics were found to have the lowest electrostatic voltage after a 48 second rubbing period. It is thought that the present study provides the promotion of a simple test mechanism and initial findings obtained by this mechanism. These may be useful findings for researchers studying clothing comfort and garment performance. For further studies investigating electrostatic charging properties. wearer trials under different environmental conditions will be useful in terms of clothing comfort.

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