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The Features of Electric Charge Decay in the Polyester Fabric Containing Metal Fibres

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The aim of the research was to reveal the features of electrical charging and dissipation of charges in the polyester fabric containing metal fibres. The woven fabrics for protective clothing to avoid incendiary discharges were manufactured in Lithuanian Textile Institute for the study. Warp threads of the fabrics were of polyester (PES) 8.4 tex (f 72) yarns. PES/INOX 20 tex union yarn (80 % : 20 %) was taken as a thread containing metal fibres. INOX is known as stainless that contains at least 10.5 % of chromium. This conductive yarn was inserted in the fabrics in three different variants: 1) 25 picks PES + 1 pick PES/INOX; 2) 49 picks PES + 1 pick PES/INOX; 3) 71 picks PES + 1 pick PES/INOX. The fabric with only the PES picks was used as control fabric. Vertical electrical resistance (R), surface resistivity (ρ), half decay time (t_{50}) of electric field strength and shielding factor (S) values were determined according to EN 1149 series standards for the fabrics as received and for those after 5 washing cycles (40 ºC). It is shown that vertical electrical resistance and surface resistivity are the parameters which values are very sensitive to quantity of conductive PES/INOX yarns in the fabrics. Half decay time and shielding factor also depend on the distance between the yarns with metal fibres. Although washing of fabrics impairs electrostatic properties, fabrics with the shortest distances between PES/INOX yarns have the best shielding effect and can be used in working clothing to prevent the static charges build-up.

Keywords: charge dissipation, vertical resistance, surface resistivity, shielding factor, half decay time, metal fibres.

INTRODUCTION

Applications of conductive textiles are more and more numerous in the technical areas to satisfy such functions as conduction or prevention of static charges build-up.

Textile fabrics are always in contact with the textile fabrics that are parts of machine devices during the manufacturing process and with human bodies during use [1 – 5].

Static electricity arises when surfaces that were in contact are separated [2, 3, 6]. Time, during which charge spreads out over the surface of fabrics or leak away to earth, is very important [6, 7]. Humans feel the amount of static electricity depending on factors such as dimensions of body and foot size. The fabric material of clothes can influence static electricity too, especially of synthetic fibers having very high resistances [1, 8, 9]. Weather affects the static electricity as well – there is more build-up of static charge when the air is dry [7, 8, 10].

The conductive threads are inserted into the fabric (mostly used in the materials for personal protective products) to limit surface potential [11, 12]. Low surface potential let to avoid risks of damage by direct electrostatic discharge and by indirect induction effects [12]. A high capacitance can limit the maximum surface potential as well [13]. The quantity of charge transferred divided by the initial highest voltage is equivalent to a capacitance [12].

Electromagnetic radiation barriers of non-woven containing flax fibres and polypropylene fibres were studied in [14]. Thermal and electrical resistance in dry and wet conditions were measured and it was found that insert of flax fibres into the polypropylene non-woven structure at amount ~14 % resulted in 20 ÷ 100 times decrease of blend electrical resistance.

The aim of this research was to reveal features of the electrical charging and dissipation of charges in a polyester fabric containing metal fibres appropriate for protective clothing to avoid incendiary discharges.

MATERIALS AND EXPERIMENTAL METHODS

Polyester/INOX 20 tex union yarn (80 % : 20 %) produced by Schoeller GmbH & CoKG is taken as a thread containing metal fibres. INOX is known as stainless steel that contains at least 10.5 % of chromium [15].

Figure 1 presents a longitudinal microscopic view of the conductive polyester/INOX yarn, where the diameter of metal fibres is 8 μm.

Fabrics in plain weave with warp density 54 ends per cm, and the weft density 28 picks per cm were

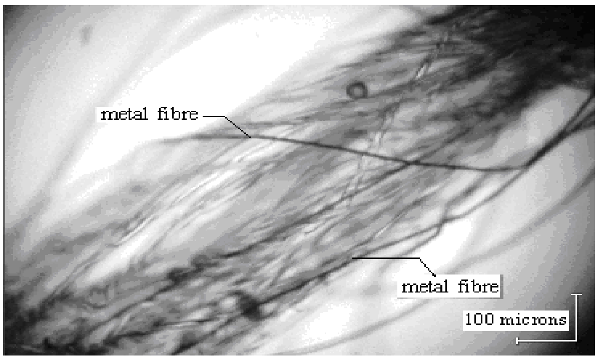

Fig. 1. Longitudinal view of polyester/INOX yarn

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Table 1. Physical characteristics of the investigated fabrics

Fabrics	Mass per unit area, g/m^2	Tensile strength, N		Elongation, %		Tear strength, N	
		Warp	Weft	Warp	Weft	Across warp	Across weft
1	102	824.6	928.6	27.0	17.9	20.2	32.4
2	101	870.8	927.4	28.7	16.4	20.8	34.1
3	100	862.3	910.5	29.4	20.1	20.6	35.4
Control	106	1160.8	744.8	20.7	23.5	20.8	27.9

manufactured in Lithuanian Textile Institute. The warp was of polyester 8.4 tex f 72 yarns. Among polyester 16.7 tex f 96 weft yarns the PES/INOX was inserted into the fabric at specified intervals in three ways:

1: 25 picks PES + 1 pick PES/INOX;
2: 49 picks PES + 1 pick PES/INOX;
3: 71 picks PES + 1 pick PES/INOX.

The fabric with only PES wefts (no PES/INOX) was used as control fabric.

Some physical characteristics of investigated fabrics, obtained with a universal tester MICRO 350/10AX, produced by SDL International Ltd, are presented in Table 1.

Five circular fabric specimens of all types of 110 mm diameter were cut to measure surface and vertical resistances and five specimens of 300 mm × 300 mm were cut to determine half decay time and shielding factor. They all were conditioned for 24 hours prior to experiments and were investigated in the following atmosphere: air temperature (23 ±1) °C, relative humidity (25 ±5) %.

Vertical and surface resistances and electrostatic charge decay were measured for the fabrics as received and for those after 5 washing cycles (40 °C). The resistance values were determined with a Tera-Ohm-Meter 6206 at applied voltage of 250 V. The device selects the voltage automatically to measure resistances depending on their magnitude. Values of the vertical and surface resistances were taken after 15 s of measuring. The charge decay was determined with an electric charge meter ICM-1. The instrument is controlled by a microprocessor and makes measurements with automatic calculations and display of the measured data. (see display of the data for the fabric 2 in Figure 2). All the experiments were carried out according to EN 1149 series standards.

During measurements of the vertical resistance the fabric specimen is placed on the base plate electrode, while measuring surface resistance the specimen is placed on an insulating place. In both cases the fabric is pressed of about 10 N load pressure by a cylindrical and an annular electrodes which are arranged concentrically with each other.

From the measured surface resistance the fabric surface resistivity (ρ) was calculated using equation:

$$\rho = k \cdot R_s , \tag{1}$$

where R_s is the measured surface resistance, k is the geometrical factor of the electrode (k = 19.8).

Fabric vertical resistance (R) was calculated by the formula:

$$R = \frac{\rho_V \cdot L}{S} , \tag{2}$$

where ρ_v is the vertical resistivity, S is the surface of the electrodes, L is the length of the fabric.

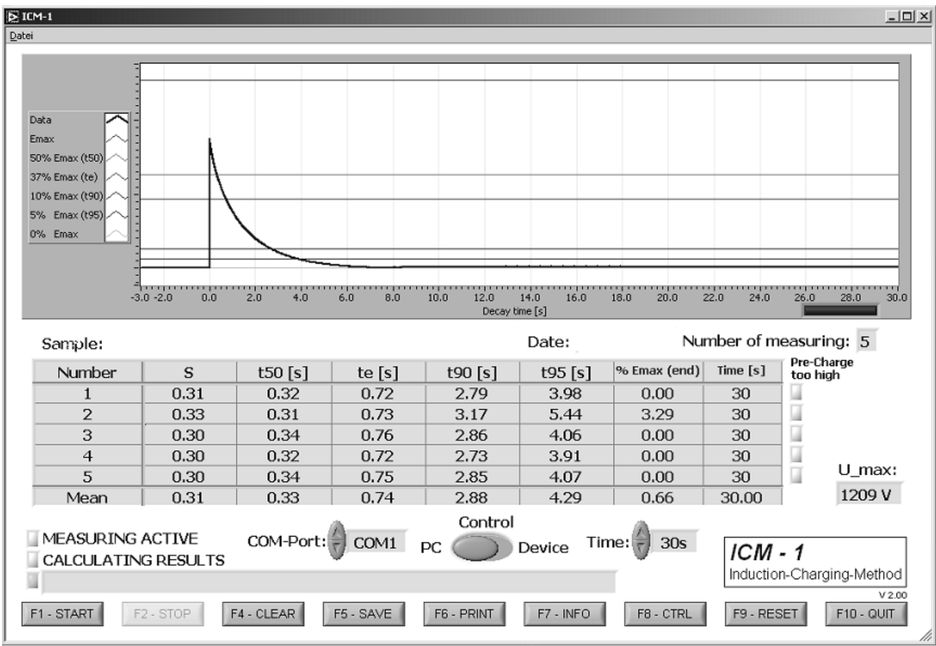


Fig. 2. Display of charge decay data (fabric 2 as received)

The accuracy of ohmmeter to measure resistances is of ±5 %. The coefficient of variation of surface resistivity did not exceed 3.5 % and those of vertical resistance did not exceed 5.1 %.

The electric field strength was measured to obtain the electrostatic charge characteristics: E_R – maximum electric field strength indicated on the recording device with the test specimen in the measuring position, and E_{max} – electric field strength indicated on the recording device with no test specimen present.

Half decay time of the electric field strength means the time, in which electric field decreases from E_{max} to $E_{max}/2$. This value was taken from the graph, obtained by a microprocessor of the electric charge meter ICM-1 (see Figure 2).

The shielding factor (S) was calculated using equation:

$$S = 1 - \frac{E_R}{E_{max}} \quad . \qquad (3)$$

The fabric specimen to measure half decay time and shielding factor was clamped between an outer and inner ring over the field electrode.

The distance between the bottom of the field-measuring probe and the top of the ring was 50 mm. Resolution of an electronic electrometer is 0.05 pC, output voltage maximum ±20 V. The coefficient of variation of the values of half decay time was less than 5 %, while for the half decay time it was less than 1 %.

RESULTS AND DISCUSSION

Surface resistivity and vertical electrical resistance are the parameters, which values are very sensitive to quantity of the conductive PES/INOX yarns in the fabrics. As it is seen in Fig. 3, the fabric wash resulted in little increase in surface resistivity of the fabrics, but the changes are within the same order of magnitude.

With shortening the distances between conductive weft yarns vertical resistance of the fabrics decreases as well.

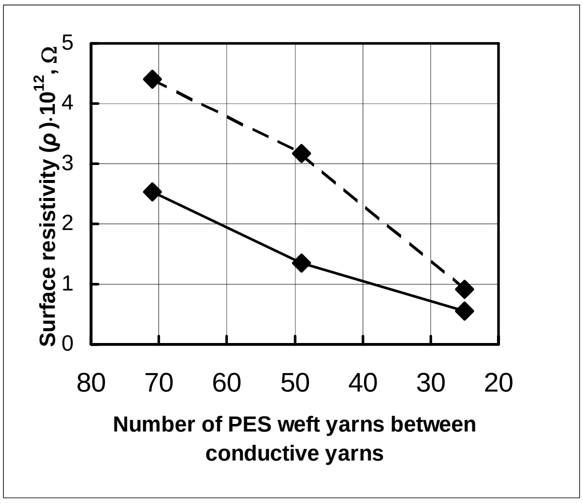


Fig. 3. Surface resistivity of the fabrics versus number of PES weft yarns between the conductive yarns (——— as received; — — — after 5 washing cycles) (Control fabric: as received $\rho = 9.43 \times 10^{12}$ Ω; after 5 wash. cycles $\rho = 9.98 \times 10^{13}$ Ω)

For the fabrics with conductive yarns as received very small values of vertical resistance are obtained. However, after treatment by 5 washing cycles the measured resistance increases very distinctly, e. g. for fabric 1 the value of vertical resistance increases from $6 \cdot 10^3$ Ω to $0.24 \cdot 10^{10}$ Ω. The shorter is the distance between conductive weft yarns the lower is the vertical resistance. Possibly the main reason of increase in resistance of the fabrics after washing is loss of some metal fibres due to abrasion impacts in washing machine.

The bigger quantity of conductive weft yarns shortens the half decay time distinctly and increases values of the shielding factor. For the fabric 1 the shielding factor is 0.44 and half decay time is less than 0.01 s while for control fabric (with no PES/INOX yarns) the factor is zero.

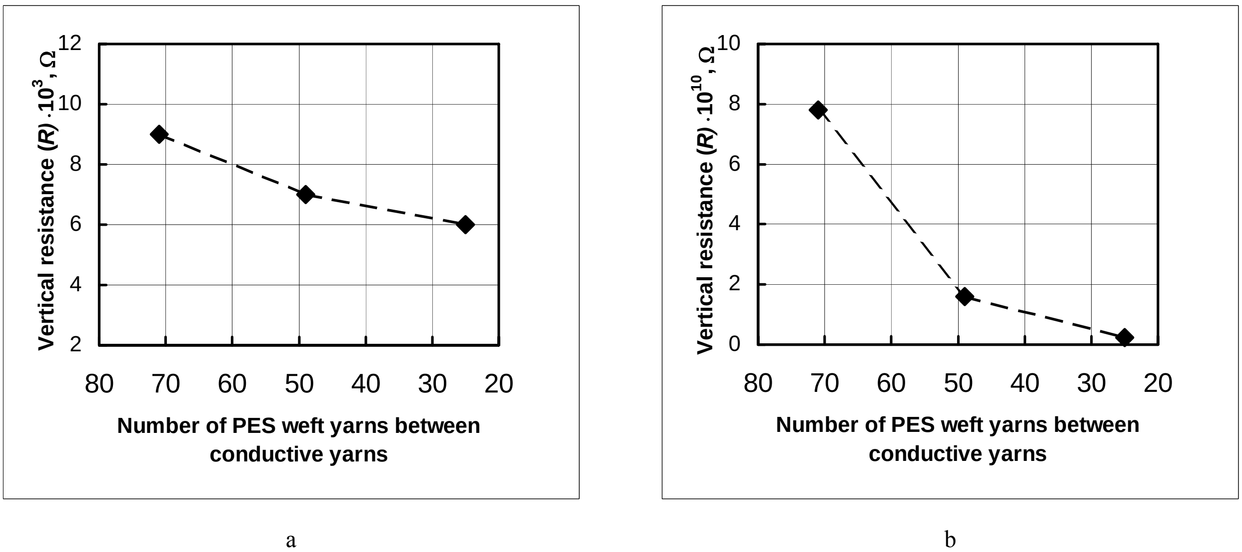
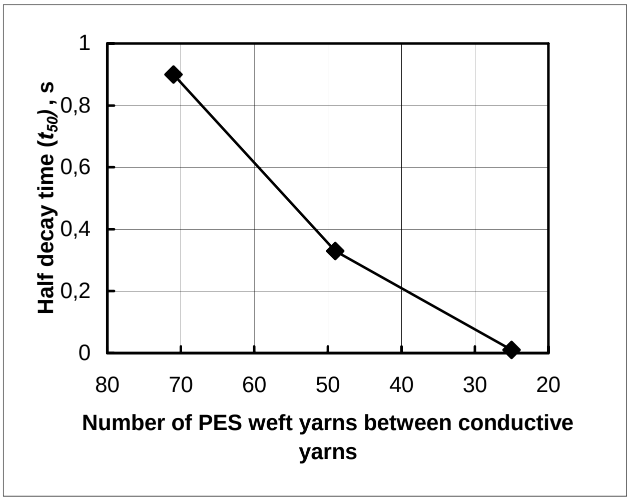
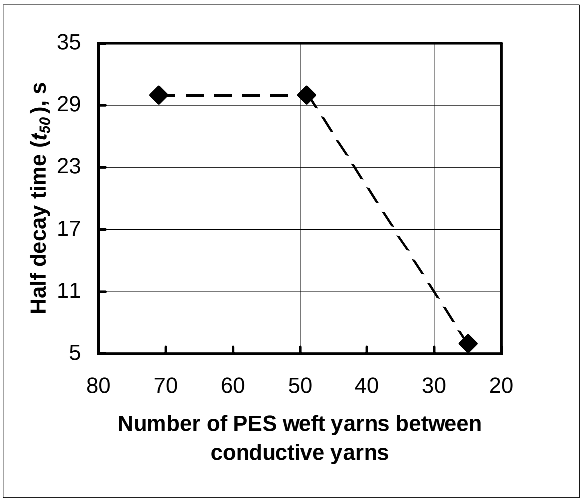


Fig. 4. Vertical resistance of the fabrics versus number of PES weft yarns between the conductive yarns: a – as received; (control fabric: $R = 2.82 \times 10^{10}$ Ω); b – after 5 washing cycles (control fabric: $R = 1.36 \times 10^{12}$ Ω)



a



b

Fig. 5. Half decay time of the fabrics versus number of PES weft yarns between the conductive yarns: a – as received (control fabric: t_{50} = 5.55 s); b – after 5 washing cycles (control fabric: t_{50} > 30 s)

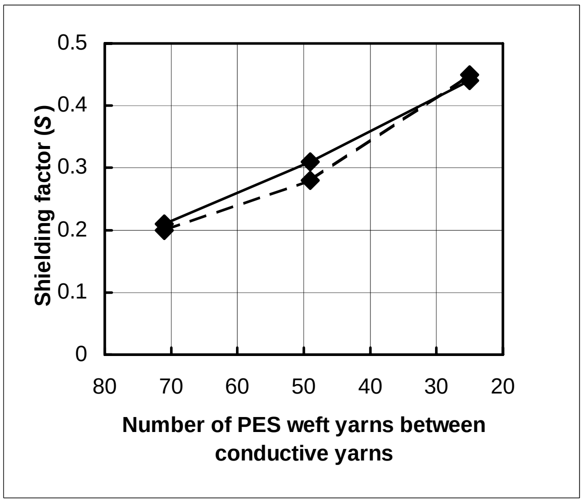


Fig. 6. Shielding factor of the fabrics versus number of PES weft yarns between the conductive yarns (——— as received; — — — after 5 washing) (control fabric: as received $S = 0$; after 5 washing cycles $S = 0$)

It means that control fabric does not have any shielding effect. After 5 washing cycles the values of shielding factor of the fabrics remain almost the same as before washing, but half decay time distinctly increases. Fabrics 2 and 3 lost their ability to dissipate electric charges quickly.

According to the European standard prEN 1149-5, which specifies requirements for electrostatic dissipative material, the fabrics should meet half decay time of electric field strength $t_{50} < 4$ s or shielding factor $S > 0.2$. It is seen from Figures 5 and 6 that the investigated fabric 1 (unwashed as well as after 5 washing cycles) met these requirements.

CONCLUSIONS

Vertical electrical resistance and surface resistivity are the parameters which values are very sensitive to quantity of conductive PES/INOX yarns in the fabrics. The shorter is the distance between conductive weft yarns the lower are values of resistances.

Lesser are vertical resistance and surface resistivity values, shorter is half decay time of charges. Shorter half decay time results in increase of shielding factor.

Values of the vertical resistance and surface resistivity for the control fabric are the biggest and this fabric does not have any shielding effect.

Although washing of fabrics impairs their anti-electrostatic properties, fabric 1, even the washed, met requirements of European standard prEN 1149-5 for half decay time and shielding factor. So, the fabric 1, with the biggest quantity of conductive PES/INOX weft yarns, can be used in working clothing to prevent the static charges build-up.

Further reduction of the fabric resistances is still needed. One way to improve these values may be to create an electrical chain by using not only conductive weft yarns, but also conductive warp yarns at different intervals in the fabrics. The investigations are continued.

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