

Evaluation of Electrostatic Properties of Fiber-forming Polymers

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In present work surface accumulation processes of electrostatic charge due to friction and induction charge of four new fiber-forming polymers is analyzed. The location of these polymers in triboelectric series has not yet been fixed. Three test methods (devices DER-3R, FMX-002 and ICM-1) for determination of potential and its relaxation control versus time were applied in this work. It was stated that electrostatic behaviour (polarity and potential value) of soybean protein, tencel and bamboo fiber is approximately equal to the corresponding parameters of cotton fiber. The exception was polylactide fiber, which electrification intensity because of friction was determined several times, was higher than other evaluated objects.

Keywords: electrostatics, fiber-forming polymers, induction charge, materials science, triboelectric charge.

1. INTRODUCTION

Clothing materials, depending on their fiber composition and method of production, experience a stronger or weaker electrostatic charge accumulation on the surface during processing or exploitation. In many cases charge appearance and accumulation are stated as negative factor. Charge accumulation disturbs technological processes, reduces wear comfort or even leads to dangerous work conditions [1, 2].

Previous measurements of cotton and wool fibers' electrical resistance changes in various processing stages, provided information about alternation regularities of fiber-forming polymers' electrostatic properties during the production period [3].

It was found, that electrons-releasing polymers are situated on the positive side of triboelectric series, while the electrons-attracting polymers appear on the negative side [4].

It is also shown, that the process of the human body electrification, when walking, depends on type of floor material and soles of footwear [5].

However, there is no information about the electrification processes of fiber-forming polymers, during their mechanical tests.

However in some cases influence of electrostatic charge is positive. In particular, this applies to some of the technological finishing processes. When the textile material is treated with cationic chemical softener, bonding between negative fabric surface charge and positive charge of softener's molecules is favorable [6–11]. There are cases where an electrostatic charge influences the results of mechanical tests of materials, for example friction characteristics values [12, 13].

Electrostatic charge on the fabric surface may appear because of tribological interactions or induction charging.

In both cases the charge accumulation process is not stable. Its course depends on the intensity of exposure (friction or induction charging mode), environment (especially humidity) conditions and the time factor. Rubbing different types of materials to one another, electrostatic charge of opposite sign and alternating value is accumulating on the surface of the fabrics. According to charge polarity and potential many well-known materials are located on a triboelectric series [14]. However the place of new fiber-forming materials in the series has not yet been fixed. Therefore works of electrostatic charge measurement are essential in both the scientific and technological terms.

The aim of this work is to evaluate electrification phenomena of new fiber-forming materials (polylactide, soybean protein, tencel and bamboo), influenced by tribo and induction charging processes, and compare them with corresponding parameters of cotton fiber.

2. MATERIALS AND METHODS

For the investigation 5 knitted materials of terry weave were selected. These materials had the same linear density (14.8 tex) of fiber but different fibrous composition (Table 1). Evaluating the influence of softeners on fabric triboelectrical properties, investigated objects were treated with cationogenic industrial softener "Belfasin SI" ("COGNIS"). Textile fabrics' treatment was performed periodically using 5 % of softener from fabric weight, modulus 1 : 50, temperature 40 °C, duration – 20 min. After the treatment, fabrics were squeezed and dried. In comparison, the same fabrics were soaked in the pure water in the same conditions, then squeezed and dried.

Electrostatic charge measurements were carried out according two methods: a) after charge generation by friction, and b) after charge generation by induction.

Electrostatic charge generation by friction was made in pairs of flat pads of glass, plexiglas and polyethylene. Qualitative state of their surface (smoothness) was in the same level. During the cyclic friction (period 10 s) of the

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Table 1. Objects of investigation

Symbol	Composition	Density Course/Wale, cm ⁻¹	Area density, g/cm ²	Thickness δ , mm
P	100 % Polylactide	20/17	305	0.87
M	100 % Cotton	19/16	227	0.75
S	100 % Soybean protein	19/17	240	0.77
T	100 % Tencel (reclaimed cellulose)	18/15	235	0.70
B	100 % Bamboo	19/15	248	0.70

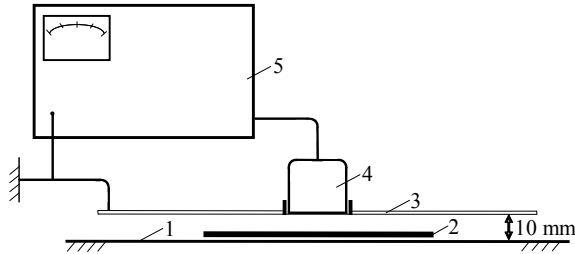


Fig. 1. Scheme of the electrostatic charge measurement (potential and polarity) on the specimen's surface using dynamic electrometer DER-3R: 1 – pad (insulator), 2 – specimen, 3 – plate (200 mm × 200 mm) for homogeneous electric field, 4 – sensor (rotary electrostatic generation), 5 – electronic power-amplify supplier

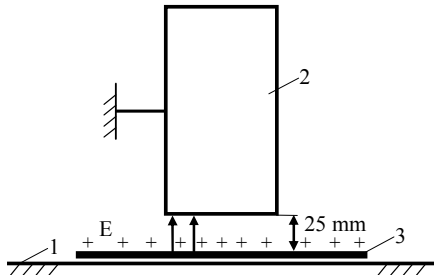


Fig. 2. Scheme of the electrostatic charge measurement (potential and polarity) on the specimen's surface using device FMX-002: 1 – pad (insulator), 2 – device, 3 – specimen sample (60 mm × 120 mm) into a pad surface, charge potential level was measured according two methods: using device DER-3R (Fig. 1) and device FMX-022 (Fig. 2).

Charge polarity (+ or –) and potential were also measured during the experiments. All measurements were performed at the same climate conditions ($t = (20 \pm 2)^\circ\text{C}$, $\varphi = (60 \pm 5)\%$), repeating the cycle of sliding and measurements for 5–10 times. The collateral use of two devices was required to ensure reliable results.

Using this method the conditioning of sample was carried out in the camera of conditioning „JCI IB1-JCI-192“ $t = (23 \pm 1)^\circ\text{C}$, $\varphi = (40 \pm 5)\%$. The voltage generator created 1210 V step voltage on the field electrode within 30 ms. Shielding factor (S) and charge decay time (LST EN 1149-3: 2006) [15], surface resistivity ρ (LST EN 1149-1: 2006) [16] were measured during the experiments.

The electrostatic charge generation was carried out with apparatus of determination charge decay „JCM-1“, induction charging method (Fig. 3).

The pulsation of dynamic friction force F_D was determined during sliding of the sample over the surface of the pad (DIN EN ISO 8295) [17, 18], and friction curve $l-F$ (displacement–force) was registered. Sliding speed was $v = 100$ mm/min. In order to not exceed 5 % value of coefficient of variation, the number of tests was varied.

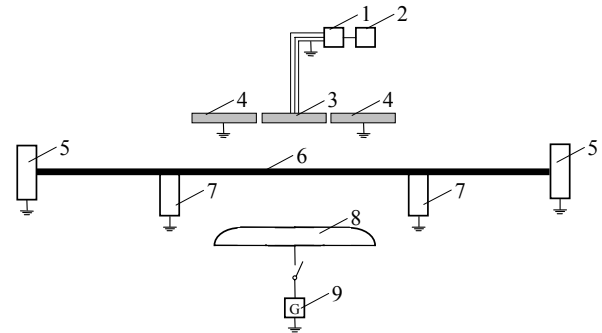


Fig. 3. Arrangement of equipment for induction charging test method: 1 – charge amplifier; 2 – recording device; 3 – field-measuring probe; 4 – guarding ring; 5 – specimen clamping ring; 6 – specimen; 7 – supporting ring; 8 – field-electrode; 9 – voltage generator

3. RESULTS AND DISCUSSIONS

Comparison of electrostatic field parameters' (polarity and potential, electric field strength) test results determined while employing two evaluation devices, is presented in Table 2.

It was determined that after the friction of test samples into pads of different surface, polarity remained the same, though potential level was different. It might occur due to specific measurements using different devices. It's important to notice that peak charge accumulation on the surface was determined after rubbing the sample into a plate of plexiglas, though the lowest one – using glass plate.

Analyzing the shapes of friction curves (Fig. 4) some deviation from typical shapes is apparent. It's the result of electrostatic charge accumulation on the surface of the fiber-forming polymer, which was caused by tribo effect. Concerning charge variation (increase and decrease) the behavior of dynamic friction force was pulsating, also coefficient of dynamic friction significantly varied in all phases of specimens' displacement [19].

It should be noted that in most cases higher values of friction coefficient tended to decrease after chemical softening (Table 3). This is related to the improvement of fiber surface smoothness and antistatic effect of the softener.

Comparative analysis of obtained data (Table 4) showed quite similar charge decay and field strength E values of three investigated fabrics: cotton, tencel (reclaimed cellulose) and bamboo. Significant differences were obtained comparing curves of charge decay factor and charge variation within time of polylactide and soybean protein fibers (Fig. 5). It was determined that behaviour of the following fabrics differed a lot after chemical softening (Fig. 5). Charge decay time has

Table 2. Electrification parameters of investigated objects influenced by friction into pads

Pad	Symbol	Device FMX-002	Dynamic electrometer DER-3R
		Polarity and potential, kV	Polarity and electric field strength, kV/cm
Glass	P	+0.11	+0.1
	M	+0.06	+0.2
	S	+0.07	+0.1
	T	+0.09	+0.8
	B	+0.07	+0.6
Plexiglas	P	-0.92	-3.4
	M	-2.7	-4.2
	S	-4.6	-0.5
	T	-4.2	-1.3
	B	-3.5	-4.5
Polyethylene	P	-0.16	-0.3
	M	-0.00	-0.05
	S	-0.16	-0.1
	T	-0.30	-0.02
	B	-0.52	-0.35

Table 3. Average coefficients of dynamic friction of investigated objects

Symbol	Pad	
	Plexiglas	Glass
P	0.36	0.39
M	0.24	0.38
S	0.21	0.29
T	0.22	0.40
B	0.16	0.42

decreased from a few times (soybean protein) to several hundreds (polylactide) after finishing process.

Comparing polylactide and soybean protein fabrics with other ones, significant differences were also determined for the results of surface resistance. In both cases the increase of parameter values was obtained not only in initial stage but also after the chemical softening (especially for polylactide fiber).

Presented experimental data obtained from the studies on electrostatic properties of new fiber-forming polymers, compared with previous research works performed by other researches [1–5, 14], showed that the alteration in friction curves' shape in tribo process plays a significant role in rise of electrostatic charge and shows its probable impact on values of some mechanical properties.

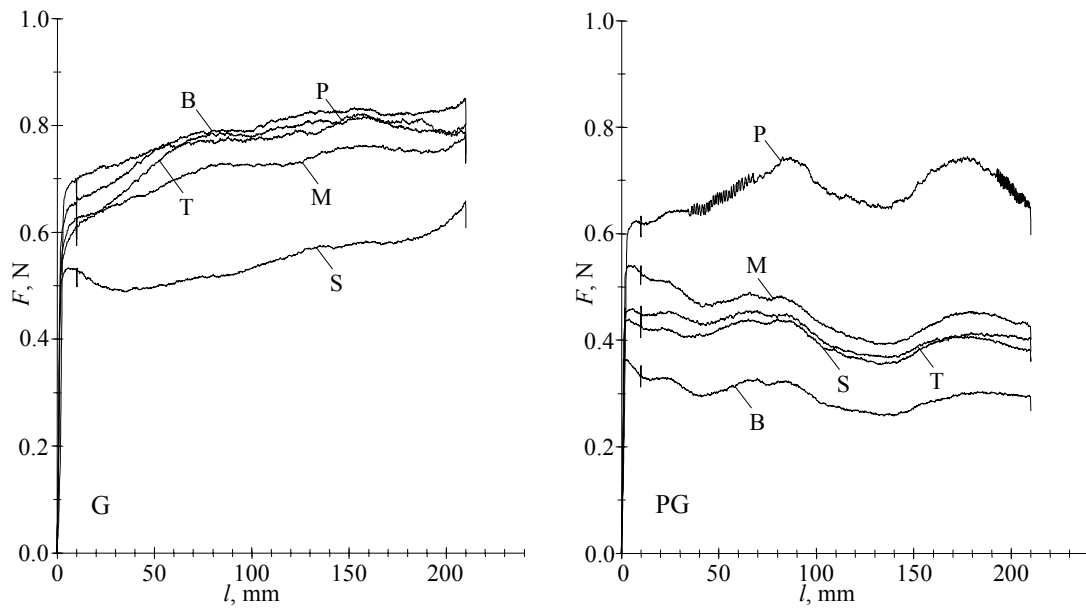


Fig. 4. Typical friction curves of investigated objects: employing pads of glass (G) and plexiglas (PG): P – Polylactide, M – Cotton, S – Soybean protein, T – Tencel, B – Bamboo

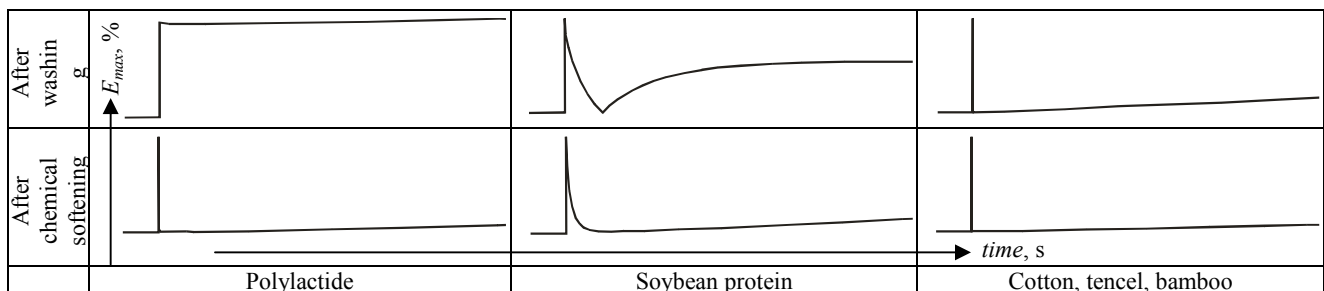


Fig. 5. Schematic view of induction charge alteration with time of various fiber compositions after different finishing

Table 4. Electrical properties of investigated objects

Evaluated objects	Finishing process	Shielding factor S	Charge decay time t_{50} , s	Surface resistance ρ , Ω	Field strength $E_{\max}^{(end)}$, %
Polylactide	Washing	0	>600.00	2.25×10^{14}	104.52
	Softening	0.02	0.15	5.09×10^{10}	8.49
Cotton	Washing	0.03	0.10	1.02×10^{11}	10.49
	Softening	0.03	0.13	1.39×10^{11}	8.98
Soybean protein	Washing	0	17.50	3.24×10^{13}	0.00
	Softening	0	7.15	1.21×10^{13}	9.36
Tencel	Washing	0.02	0.22	2.17×10^{11}	8.75
	Softening	0.01	0.21	2.55×10^{11}	13.78
Bamboo	Washing	0.02	0.14	1.30×10^{11}	8.49
	Softening	0.02	0.15	2.17×10^{11}	9.09

Note: number of tests for surface resistivity determination – 5; step voltage 1210 V.

In the research works performed by Lithuanian Textile Institute [1, 2], the investigations of accelerated discharge possibilities of clothing materials with inwoven conductive yarns were carried out.

Our studies in range of electrostatic charge revealed the principal differences between five completely new investigation objects, while in the works of other authors natural discharge has not been fixed.

4. CONCLUSIONS

1. Integrated study of the electrostatic charge accumulation and kinetics on the surface of five fiber-forming polymers influenced by friction and induction charging has shown that the most significant parameters of tribo charge were determined during the contact of investigated objects with a plexiglas pad. However values of dynamic friction coefficient obtained using this pad were the lowest ones.
2. It was determined that chemical softening of fiber-forming polymers decreased the dynamic friction coefficient and inhibited the process of static electrification.
3. According to the results of electrostatic charge alteration (charge decay time) applying induction charge method, all objects of investigation might be grouped into several groups: polylactide, soybean protein, cotton – tencel – bamboo.

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