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The Influence of Triboelectricity on Textile Polymer Friction Parameters

Abstract
The influence of the electricity of five fibre materials and five polymeric films on the friction parameters determined according to Standard DIN 53375 was analysed in this work. The variations in kinetic friction force between the components of friction of a pair of "specimen-stands" were demonstrated by applying three stands made of different materials (nonorganic glass and organic glass). The influence of polymer nature and stand mode on these variations was investigated. The values of kinetic frictional force and friction coefficient determined for different friction pairs are presented. Differences in these cases are described. The results presented show that friction parameters depend on triboelectricity and adhesion bonds between the sliding pair components arising under their influence.

Key words: *materials science, textile polymers, friction, triboelectricity.*

Introduction

Because of highly expressed dielectric properties, the surfaces of polymeric materials produce an electric charge resulting from sliding friction or loss of contact with the conductor or dielectric [1 - 3]. Most chemical fibres or films, primarily synthetic, can easily produce an electric charge resulting from the friction between them, or due to contact with machinery or equipment components. Because of the hydrophobic properties of polymers, it is complicated to eliminate the electric charge. Due to the contact between two different polymers, they produce adhesive bonds between each other. The strength of the adhesion bond decreases after an increase in the similarity of polymer nature. Nonpolar polymers do not produce strong adhesive bonds as they cannot act as electron donors.

In almost all cases the electricity of polymers negatively influences the processes of their manufacture, exploitation and testing [4 - 7]. The adhesion bond produced between the surfaces of polymer and parts of machines or apparatus troubles manufacturing processes or distorts the results of investigations.

The aim of the present work is to determine the influence of polymer nature on its friction parameters during its sliding on different surfaces.

Methodology

Tests were performed using a Z005 Zwick tension tester equipped with a special device (Figure 1), designed for the determination of friction parameters according to Stabdard DIN 53375 .

A slider (1) was covered with specimen (2) and moved on made of glass (G) or organic glass (OG) stand (3) extended up to 700 mm and covered with the polymer material investigated. The velocity of slider (1) was 500 mm/min. All the tests were performed at ambient conditions: temperature T = 22 ± 1 °C and humidity φ = 65 ± 2%.

The subjects of investigation were five fiber materials and five polymer films (Table 1).

A friction curve *F-l* (Figure 2) was recorded and four friction parameters, μ_S - coefficient of static friction, μ_D - coefficient of kinetic friction, F_S – force of static friction and F_D – force of kinetic friction were calculated automatically. The number of specimens was determined according to the variation coefficient, which was below 10 %.

The stand material (glass (G) and organic glass (OG)) were identical to the structural materials of the plates of a KTU-Griff-Tester [8 - 15], designed for the evaluation of the mechanical behaviour of polymer materials during the process of being pulled through a rounded hole made in the centre of two limiting plates; the top (glass) and the bott-om (organic glass) plates (Figure 3).

Electric charges were produced and accumulated on the surface of the polymeric specimen. The polymer electricity

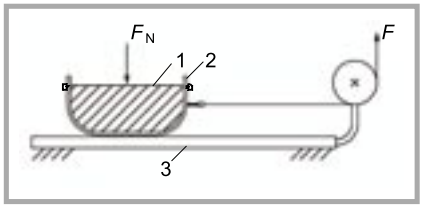

Figure 1. *The scheme of determination of friction parameter.*

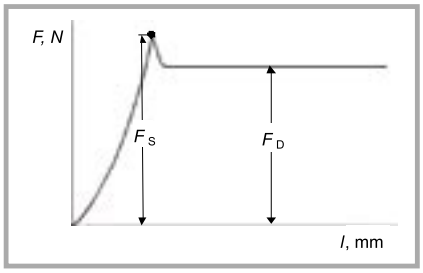

Figure 2. *Typical friction curve.*

was able to initiate the formation of an adhesion bond between the specimen and the glass or organic glass.

The character of the charges produced during the rubbing together of the two dissimilar substances were also determined, i.e. which of the substances became positively charged, and which one was negatively charged.

Table 1. *Characteristics of fabrics investigated.*

Polymeric material	Structure	Symbol	Thickness δ, mm
Polyethylene (high pressure)	Film	PEHP	0.12
Polypropylene	Film	PP	0.05
Polypropylene (with filler)	Film	PPv	0.03
Polyvinylchloride	Film	PVC	0.28
Polytetraflouretylene	Film	FE	0.07
Cotton	Knitted fabric	CO	0.72
Viscose	Knitted fabric	CV	0.64
Acetate	Knitted fabric	CA	0.60
Polyester	Knitted fabric	PET	0.50
Polyamide	Knitted fabric	PA	1.00

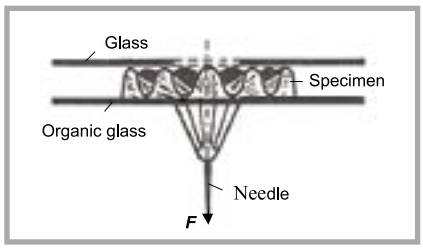

Figure 3. *Schematic diagram of KTU-Griff-Tester.*

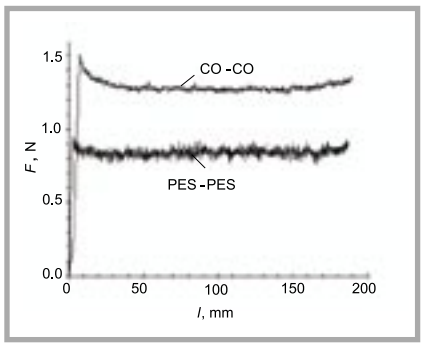

Figure 4. *Sliding friction curves for identical polymers.*

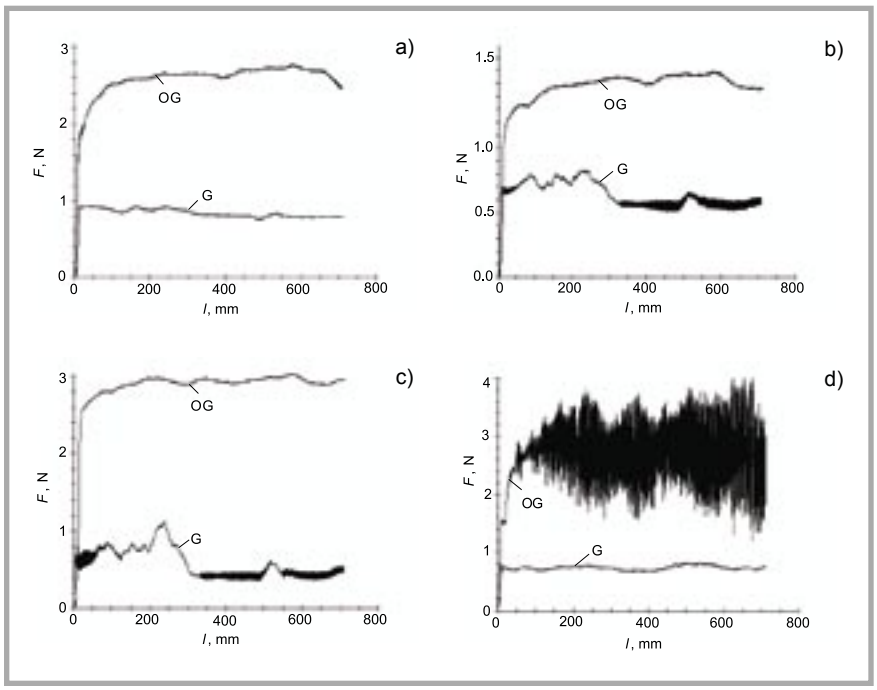

Figure 5. *Friction curves for acetate (a), polyester (b), polyamide (c) and polyethylene (d) during their sliding on glass (G) and organic glass (OG) surfaces.*

Results and discussion

Triboelectricity research with various materials has proven that during the sliding of polymer on glass or other stand material, the kinetic frictional force F_D does not remain stable, which is typical for a pair of conductors or dielectrics (stand-specimen), made of one type of material (Figure 4), which assists variations within a wide range (Figure 5). Force F_D variation depends upon the type of polymer specimen and stand mode. In some cases F_D varies within the limits of several hundred percent (Figure 5.c and 5.d).

The variation in friction force during polymeric material sliding on different surfaces occurs because of triboelectricity, i.e. the accumulation of electric charges on frictional surfaces, and the formation of an adhesion bond between the specimen and stand. The pulsation of friction curve *F-l* (Figure 6) should directly depend on the size of electric charges accumulated on the sliding surfaces. Despite this, the pulsation of friction force is haphazard, i.e. even in the case of an extended stand (being about three times longer than the length of a standard stand) the separate parts of friction curve F-l were determined as different. Therefore, these results allow to assume that the process investigated is not cyclic.

The force F_D is constant and independent of the chemical structure of the specimen while sliding on the surface of a stand made of the same material as the specimen (Figure 4). The friction force F_D is different in the cases of glass (G) and organic glass (OG) stands. In the second case, the kinetic friction force F_D^{OG} is higher, except for FE film. These forces sometimes differ by 4-6 times. The differences in the kinetic friction force for acetate (T13) (Figure 5,a), polyester (T14) (Figure 5,b) and polyamide (Figure 5,c) were maximal.

It should be noted that while sliding on the stand, polymeric specimen exhibited distinct variations in F_D which likely depend on the periodic pulsation of the electric charge. This is illustrated in friction curves (Figure 7). Differences in the extreme points of curves F_D^G exceed up to 3 times (for material T15) (Figure 5.c and 5.d).

While analysing the results determined from the friction curves (Table 2) of 10 different materials (Table 1), it was noticed that:

1) In the case of the specimen sliding on the organic glass stand, the friction force for 9 of 10 polymers was higher compared to that when sliding on the glass stand.
2) The kinetic friction force for polytetraflouretylene FE (Figure 8) was higher during the sliding of the specimen on the glass stand compared to that when sliding on the organic glass stand, i.e. $F_D^G > F_D^{OG}$.
3) The shape of friction curve F-l for the friction pair "PE-G" (Figure 5) is the most "clear" (Figure 5.d). The sliding of the polyethylene specimen on the

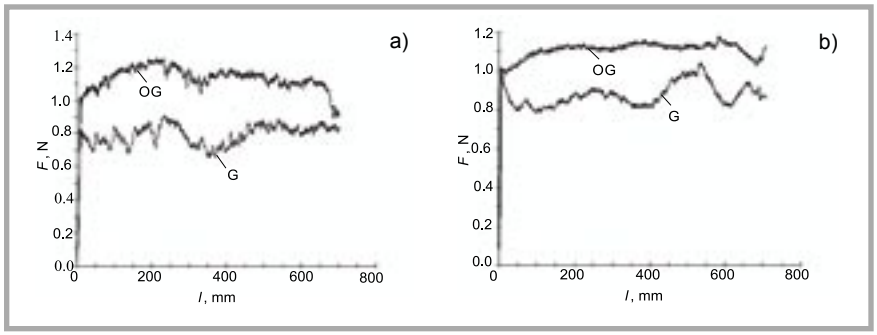

Figure 6. *Friction curves for PVC (a) and PP (b) during their sliding on glass (G) and organic glass (OG) surfaces.*

organic glass stand was accomplished by sharp jerks. Supposedly, this occurs because of the electricity between the components of the friction pair "OG-PE".

4) The materials investigated can be classified according to the decrease in the average values of kinetic friction force F_D in an order (Table 2):
   - In the case of the glass stand → PP-CO-CV-PPv-CA-PVC-PE-PA-PET-FE;
   - In the case of the organic glass stand →PE-PA-CA-PET-CV-PVC-PP-PPv-CO-FE.

The greatest and the lowest difficulties in sliding on the glass stand were exhibited by PP and FE, respectively. The difference is about 2.5 times. The greatest and least difficulties in sliding on the organic glass stand were determined for materials PE and FE, respectively. The difference is about 12 times.

Analysis of electrostatic charge parameters (Table 3) show that in the case of the triboelectrical effect between the specimen and glass stand (except for polyester polymer PET), the specimen potential is "–" and the stand potential is "+".

In case of polyester both the specimen and the stand are positively charged. In case of the organic glass stand, the analogical situation remains valid for PE, PP, PVC and FE, and in the case of polymers PPv, CO, CV, CA and PA, the potential changes i.e. the specimen is positively charged and the stand is negatively charged. Again, PET material is in an exceptional position as both the specimen and stand are negatively charged .

It should be noted that in the case of the organic stand, values of electric charge potential are higher compared to those of the glass stand. It is especially clear in case of polymers PE, FE, CV, CA and PA. The differences in the kinetic friction

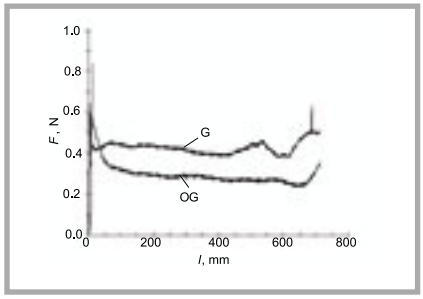

Figure 8. *The friction curves for FE in its sliding on glass (G) and organic glass (OG).*

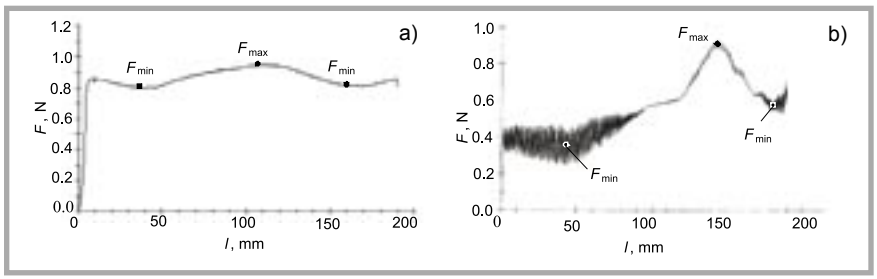

Figure 7. *The friction curves for polymers CO (a) and CA (b) during their sliding on glass (a) and organic glass (b) surfaces.*

Table 2. *Friction parameters;* ***Notes:*** **The results presented were determined from the average values automatically calculated by the Zwick/Z005 tension machine. **$F_{D\,max}$/$F_{D\,min}$ was determined from the friction curves l-F according to the variation of the friction force F_D during the material testing.*

Polymer symbol	μ_S*		μ_D*		F_D*, N		$F_{D\,max}$**/$F_{D\,min}$	
	G	OG	G	OG	G	OG	G	OG
CO	0.48	0.38	0.50	0.59	0.96	1.11	1.22	1.56
CV	0.42	0.39	0.47	0.60	0.89	1.14	1.31	1.55
CA	0.48	0.79	0.43	0.34	0.81	2.54	1.11	1.61
PET	0.38	0.40	0.33	0.76	0.63	1.43	1.51	1.21
PA	0.32	0.76	0.34	1.50	0.65	2.84	1.78	1.16
PEHP	0.37	0.83	0.37	1.75	0.70	3.31	1.22	2.21
PP	0.58	0.55	0.58	0.59	1.08	1.12	1.27	1.50
PPv	0.51	0.55	0.47	0.58	0.89	1.11	1.32	1.07
PVC	0.42	0.54	0.42	0.59	0.80	1.12	1.40	1.23
FE	0.35	0.38	0.23	0.15	0.44	0.28	1.39	1.25

Table 3. *Character (+, -) and potential values (kV) of electric charge during sliding of specimen against stand. Note: The values were measured with an FMX-002 electrostatic fieldmeter (made by the company SIMCO, Worldwide Leaders in Electrostatics, the Netherlands).*

Polymer symbol	Glass				Organic glass			
	Specimen		Stand		Specimen		Stand	
CO	–	0.18	+	0.48	+	0.34	–	4.4
CV	–	0.08	+	0.42	+	0.15	–	16.3
CA	–	0.14	+	0.18	+	0.19	–	10.9
PET	–	0.09	+	0.42	+	0.03	–	0.10
PA	–	0.08	+	0.44	+	0.5	–	15.7
PE	–	0.42	+	0.16	–	0.12	+	13.1
PP	–	0.05	+	0.42	–	0.08	+	0.46
PPv	–	0.05	+	0.16	+	0.11	–	0.,75
PVC	–	1.13	+	0.20	–	16.0	+	0.49
FE	–	0.34	+	0.46	–	0.51	+	13.3

force of the above-mentioned polymers regarding stand material (glass and organic glass) were the highest (Figure 5). Therefore, these differences in friction curves F-l and kinetic friction forces F_D should depend on polymer electricity.

Conclusions

1. The mechanical friction test can be used to investigate the electric charge accumulation and formation of adhesive bonds caused by pairs of dielectrics rubbing against each other.
2. The variation in kinetic friction force depends on the dynamics of the changes in electric charge produced during the rubbing together of two dissimilar substances.
3. More intensive accumulation of electric charge due to the rubbing together of the stand and polymeric specimen was determined in the case of the organic glass stand compared to that of the glass stand, except for the nonpolar polymer – polytetraflouretylene which exhibits the best antifrictional properties under dry friction conditions.

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