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## INVESTIGATION OF THE INFLUENCE OF THE NATURE AND TYPE OF FILLERS ON THE ANTI-FRICTION-WEAR-RESISTANT PROPERTIES OF COMPOSITE POLYMER COATINGS

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**Abstract:** This study investigates the influence of the nature and type of fillers on the antifriction and wear-resistant properties of composite polymer coatings. The aim of the research is to determine the patterns of changes in tribotechnical and physical-mechanical characteristics of coatings depending on the composition and structure of the introduced fillers. Carbon-based, graphite, and fibrous fillers with different particle sizes and concentrations were used as modifying components. The composite coatings were applied onto a metal substrate followed by thermal treatment. Experimental tests were conducted to evaluate the coefficient of friction, wear rate, adhesion strength, and surface microstructure after friction. The results show that the incorporation of specific types of fillers significantly reduces the coefficient of friction and increases wear resistance due to the formation of a protective transfer film and structural optimization of the composite.

**Keywords:** composite polymer coatings, fillers, antifriction properties, wear resistance, tribological characteristics, coefficient of friction.

**Introduction.** This study examines the antifriction properties of composite polymer coatings formulated with thermosetting oligomer ED-16 and thermoplastic pentaplast. Testing was conducted under friction conditions with raw cotton of the C-6524 variety, characterized by a contamination rate of 3–7.6% and a moisture content (W) of 8.2%.

To assess these properties, experiments were conducted using a disc tribometer we developed, operating at  $P=0.02$  MPa and  $V=2$  m/s.

The results, presented in Table 5.1, indicate that composite epoxy coatings filled with mineral fillers such as talc and kaolin exhibit a low coefficient of friction ( $f$ ) but a higher rate of linear wear ( $I$ ) than unfilled coatings. In contrast, coatings with other mineral fillers, such as asbestos, marl, and cement, exhibit a high  $f$  and a low  $I$ .

Inorganic fillers such as copper powder and iron powder reduce  $f$ , and  $I$ , and molybdenum disulfide and aluminum powder dramatically increase both  $f$  and  $I$ . Organic fillers such as soot decrease  $f$  and increase  $I$ , and fluoroplastic (PTFE) greatly increases  $f$  and  $I$ . From this, it can be seen that fillers of the same nature do not always have an unambiguous effect on the antifriction properties of composite polymer coatings. Therefore, to fully explain the mechanism of fillers' effect on the antifriction properties of composite polymer coatings, it is necessary to consider them separately in each case, depending on their structure and type.

Building on these findings, our studies included measurements of the coefficient of friction  $f$ , the intensity of linear wear  $I$ , the temperature and density of the triboelectric charge in the friction zone ( $T_{tr}$  and  $q$ ), and several physical and mechanical properties (microhardness  $N_m$ , glass transition temperature  $T_c$ , thermal conductivity coefficient  $\lambda$ , and surface resistivity  $\rho_s$ ) of composite polymer coatings.

Analyzing these results (Table 1) allowed us to identify the mechanisms by which fillers influence the antifriction properties of composite polymer coatings when rubbing with cotton.

Table 1 shows that in composite polymer coatings filled with graphite, talc, and kaolin, which have a lamellar structure, the coefficient of friction ( $f$ ) decreases, while the wear intensity ( $I$ ) increases.

The decrease in  $f$  in these coatings is due to the lamellar structure of the fillers. Previously, we found [1-4] that triboelectric charges and the temperature generated in the friction zone have a significant impact on the strength of interaction between polymer coatings and raw cotton. Therefore, due to the low temperature and the low triboelectric charge density in the friction zone, graphite-filled coatings have a relatively low  $f$ .

The increase in  $I$  is mainly due to a decrease in the coatings' microhardness. The increase in the  $I$  coatings filled with graphite is also facilitated by the lamellar structure of the filler and the low shear resistance between the layers of the graphite crystal lattice. Among the studied coatings, the soot-filled coatings have the highest  $\lambda$  and the lowest  $\rho_s$ , which determine  $q$  and  $T_{tr}$ . However, the introduction of soot into the polymer greatly reduces the microhardness of the resulting coating, which increases  $I$ .

It is of interest to study the antifriction-wear-resistant properties of composite polymer coatings filled with PTFE and molybdenum disulfide ( $MoS_2$ ) when rubbing with raw cotton. It is known [5-7] that these fillers in polymer-metal friction pairs have good antifriction properties, especially PTFE at low values of sliding speed and specific pressure.

In the interaction of raw cotton with composite polymer coatings, PTFE proved ineffective as a filler, which can be explained by the specific nature of this pair.

**Table 1**  
**Tribotechnical and some physical and mechanical properties of composite epoxy coatings (at P=0.02 MPa and V=2 m/s)**

Composition Coatings	Coefficient of friction	Linear Intensity Wear 1010	Temperature in the friction zone, Ttr, K	The density of triboelectric who is charged in the friction zone 104, Cl/m <sup>2</sup>	Micro fidelity coating Nm, MPa	Temperature Glass transition, Tc, K	Surface resistivity of coatings Ohm	The coefficient of thermal Conductivity W/m.city
ED+16	0,275	0,8	303,0	4,0	193	342	1•10 <sup>14</sup>	0,18
ED + soot	0,243	1,31	299,0	0,4	158	356	3,1•10 <sup>5</sup>	5,85
ED + graphite	0,248	1,51	300,6	0,8	166	356	1,8•10 <sup>5</sup>	4,23
ED+talc	0,263	0,98	302,0	6,2	164	342	6,4•10 <sup>15</sup>	0,91
ED+kaolin	0,268	0,91	302,4	3,4	192	347	7,3•10 <sup>12</sup>	0,86
ED+Marshallit	0,285	0,48	305,0	4,6	266	379	8,8•10 <sup>14</sup>	0,78
ED + cement	0,296	0,51	306,8	4,4	258	381	2,7•10 <sup>14</sup>	0,58
ED+PTFE	0,36	1,92	310	7,2	118	318	3,4•10 <sup>16</sup>	0,20
ED + asbestos	0,336	0,42	308,0	5,8	223	356	3,1•10 <sup>15</sup>	0,95
ED + glass and fiber	0,320	0,36	305,6	5,1	251	387	9,2•10 <sup>14</sup>	1,07
ED+ Aluminum Powder	0,283	1,15	302,1	1,5	210	347	1,3•10 <sup>9</sup>	3,91
ED+molybdenum disulfide <sup>x</sup>	0,330	0,97	304,7	3,7	201	348	4,9•10 <sup>13</sup>	1,19
ED+iron powder <sup>x</sup>	0,262	0,60	300,7	3,0	261	368	4,6•10 <sup>10</sup>	3,16
ED+ copper powder <sup>x</sup>	0,253	0,61	300,0	2,7	232	365	8,7•10 <sup>8</sup>	3,72
ED+Iron Oxide <sup>x</sup>	0,278	1,00	302,1	3,4	215	354	3,5•10 <sup>12</sup>	2,04
ED+copper oxide <sup>x</sup>	0,272	0,76	301,5	3,3	202	356	2,8•10 <sup>11</sup>	2,38

Note: the content of fillers is 100 wt. h., and for the rest - 40 wt.h.

Experiments have shown that composite epoxy and pentaplast coatings filled with MoS<sub>2</sub> exhibit high values of f and I when rubbed with raw cotton. It is known that with a slight increase in the humidity of the medium, the antifriction properties of MoS<sub>2</sub> sharply decrease [8]. Apparently, this property of MoS<sub>2</sub> increased the f and I composite polymer coating when rubbed with raw cotton, since the latter's moisture content during the experiments was 8.2 %.

Cement and marl fillers interacted actively with the polymer matrices, and the resulting coatings exhibited high Nm and Tc. During the friction between these coatings and raw cotton, it appears that cement and marshalite also interact with the raw cotton fibers (a natural polymer), thereby increasing the frictional force. The high values of Nm and Tc of these coatings provide them with good wear resistance when rubbing with raw cotton.

Aluminum powder is among the most finely dispersed and active fillers for polymers studied. The tendency of aluminum powder to clump when it is introduced into the polymer matrix (especially at high contents) has led to the production of a heterogeneous composition with large microdefects. At the same

time, aluminum powder actively interacts with raw cotton. Therefore, polymer coatings filled with aluminum powder, when rubbed with raw cotton, have high f and I. Among the polymer composite coatings studied, relatively high f values and low I values are observed in compositions filled with asbestos and glass fibers. The increase in f when a filler, such as asbestos, is introduced is explained by the filler's frictional properties. Our studies of the contact interaction of polymer coatings with raw cotton have shown that, in contrast to the friction of solids, in the process of friction of raw cotton with polymer coatings, the fiber is hooked on the micro-irregularities of the surface [9]. The surface of coatings filled with glass fiber had Rz values of 60 μm or more, which are commensurate with the diameter of cotton fiber. This circumstance also contributes to an increase in the tangential resistance of raw cotton as it moves relative to the coating surface. At the same time, the decrease in I is mainly due to an increase in the strength and thermophysical properties of the compositions, resulting from the high strength and heat resistance, as well as the reinforcing ability of these fillers. Tc and λ, therefore, I. This is also due to the high strength of

the glass fiber and its active adhesive interaction with binders.

The results of the study show that, under equal conditions, fillers that improve the electrical, thermal-physical, and mechanical properties of composite coatings enhance their antifriction properties when interacting with raw cotton. But at the same time, the most significant influences are the filler's structure and nature, as well as those of the binder. Thus, the good electrical and thermal conductivity of copper and iron powders enabled the formation of composite coatings, as friction with raw cotton,  $T_{tr}$ , and  $q$  decreased. In addition, coatings filled with copper and iron powders increased  $N_m$  and  $T_c$ . All of these factors contribute to the decline in  $f$  and  $I$ .

In coatings filled with metal powders, upon rubbing with raw cotton, micro-irregularities form on the coating surface due to particles of the polish in the surface layer. The surface roughness depends on the shape and dispersion of the filler. These micro-irregularities, due to their relatively high hardness

during interaction with raw cotton, penetrate the fibers, increase friction, and damage them. Therefore, in the case of friction of coatings based on ED-16 (higher content of fillers) filled with copper and iron powders, despite the improvement in physical and mechanical properties, the coefficient of friction  $f$  decreases slightly.

The difference in the form of copper powder and iron powder coatings is explained by the fact that copper powder coatings have a greater  $\lambda$  and a lower  $q$  than iron powder coatings.

Thus, the antifriction properties of filled polymer coatings when interacting with raw cotton depend on the nature and type of the polymer matrix and the injected fillers. Analyzing the study's results, it can be concluded that the  $f$  and  $I$  of the polymer composite coating depend on the temperature  $T_{tp}$ , the triboelectric charge density  $q$  in the friction zone, and the coating's  $N_m$  and  $T_c$ . Fillers that decrease factors ( $q$ ,  $T_{tp}$ ) and increase  $N_m$  and  $T_c$  yield minimum values of wear intensity and coefficient of friction.

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