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Development and application of composites based on polytrifluorochlorethylene

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Abstract: The influence of the content of organic fiber Tanlon of the brand T700 is considered on the physico-mechanical and tribological properties of organoplastics based on polytrifluorochlorethylene. It was found that implementation introduction of 5-20 wt. % fiber Tanlon T700 leads to the positive effect: it increases modulus of elasticity, hardness and yield stress to 45-69, 30-60% and in 1,1-1,2 times respectively. It has been shown that in conditions of friction without greasing implementation of filler positively affects on polymer: reduces the coefficient of friction to 15-40% and wearing by two orders of magnitude (from 91.75 to 0.15). The developed composition can be used for production details of mobile joints of machines and mechanisms that used in various spheres of industry.

Keywords: organoplastic, polytrifluorochlorethylene, polysulfonamide, physico-mechanical, tribological characteristics

1. Introduction

Automobile transport of the XXI century cannot be provided without the use of polymer composite materials (PCM). Friction knots of vehicles in the process of operation are exposed to various external factors: increased loads, temperatures and humidity, the effects of aggressive environments, dust, vibrations, particles of abrasive (that cause deterioration of the surfaces of rubbing pairs) influenced by that in the material of structures develop deformations that lead to the destruction, that reduces the duration of their trouble-free operation [1,2].

The use of PCM will increase service life of aggregates, minimize costs during the operation to 50%, increase reliability, resistance to damage and cost-effectiveness (due to the simplicity of technological process of production and the possibility of automatization of the process) [3].

Fluoropolymers (FP) are one of the promising materials for the creation of PCM, capable to work in difficult conditions. FP are characterized by the row of properties that aren't inherent for other polymer materials: high thermal stability, inertia to aggressive chemical environments and oils that are kept in the wide temperature range. But these materials also have disadvantages, the main of them is low wear resistance (which is confirmed by the obtained experimental data) using it for the production of slide bearings [4].

Different fillers, including Organic Fibers (OF), are used to improve the tribotechnical characteristics of FP. The positive effect of reinforcement of the OF is due to the weakening of intermolecular bonds in the polymer, the formation of optimal structure of the material. Organic fibers,

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in comparison with carbon and fiberglass, are characterized by high adhesion to the matrix, strength-to-weigth ratio and hardness.

In view of the above, the purpose of this work was to research the physico-mechanical and tribotechnical characteristics of Organoplastics (OP) based on Polytrifluorochlorethylene (PTFCE) -reinforced by the fiber polysulfonamide brand Tanlon T700.

2. Objects and methods of researches

As a polymer matrix was chosen polytrifluorochlorethylene [-CF2-CFCl-] - solid white powdered product, which is characterized by high compressive strength, chemical resistance (which brings it closer to the resilience of polytetrafluoroethylene) and plasticity, is easy machining, which allows to give exact size to the product. Products based on PTFCE can be operated at temperatures from 78 to 403 K (elastic) or even up to 463 K (crystalline), depending on the regime of product formation.

Table 1. The main properties of polytrifluorochlorethylene [5]

Indicator	**Value**
Density, g/cm^3	2.1-2.16
The softening temperature for Vicka, K	403
Water resistance (growth in water), %	0.00-0.01
Degree of crystallinity at 293 K, %	40-70

However, in the production of products from it there are difficulties associated with the use of high temperatures, close to the temperature of decomposition of the polymer, and also with the need in some cases, the tempering of products for giving them elasticity. Therefore, the formation of products with PCTFE should be carried out at strictly controlled temperature, pressure and time of extinction.

As a filler, was used heat-resistant fiber (see Table 2.) polysulfonamide of the brand Tanlon T700 (China). To determine the optimal composition of PCM were produced samples with different ratios of component.

Table 2. Main properties of fiber [6]

Indicator	**Value**
Length, mm	3
Density, g/cm^3	1.42
Strength, MPa	650
Extension,%	20-25
Modulus of elasticity, MPa	7450

Preparation of compositions based on PTFCE containing 5-20 wt % of discrete fiber polysulfonamide Tanlon T700, carried out by the method of dry mixing in the machine with rotating electromagnetic field (0,12-0,15 Tl) using ferromagnetic particles taking out by magnetic separation.

Samples for tests were made in form of cylinders with a diameter 10 and a heigh 10 mm. The prepared mixture was tabletted at room temperature and 40 MPa. The resulting prepreg was charged in a mold heated to 423 K, after that the temperature in the mold increased to 510-515 K and kept at this temperature for 10 minutes, then gave pressure 40MPa. For fixation the product was cooled under pressure to the temperature 490-495 K and pushed from the mold in water for hardening.

Modulus of elasticity, yield stress and unit strain under compression determined according to the GOST 4651-78 on the machine FP-100. Hardness was found by the Rockwell method on the HRE scale according to the GOST 9013-59 on the hardness 2074 TPR.

The tribological characteristics were explored in conditions of friction without greasing the friction machine SMC by the scheme "disk-block" under the load 1 MPa, slip rate 1 m/s, friction path of 1000 m. As a counterbody was used steel 45 (45-48 HRC, R_a = 0.32 μm).

3. The results of researches

Important information on the elastic characteristics of material, nature and magnitude of plastic deformation, hardness and yield strength is given by the method of compression.

As it is shown in Fig. 1, the curves of the OP dependences of hardness (σ) - unit strain (ε) under compression, according to the classification of Herzberg [7], belong to the type V, which characterizes the elastic heterogeneous plastic behavior. At the section of curves up to 30 MPa, there is a completely elastic behavior of materials. Further, the shape of the curves is the result of the competitive development of two processes. The first process is characterized by plastic flow, due to the destruction of original structure of the polymer, resulting in usually a fall in of load. The second process is characterized by the restructuring of the destroyed structure into the new, due to accumulated deformation tensions. Such a structure is characterized by a high degree of orientation and hardness. It is due to the competition of these processes and there is a change in the angle of inclination of the curves σ-ε. Further elevation of the angle of inclination indicates the deformation strengthening stage: a large number of sections of the polymer acquires a new structure, which leads to an increase in the resistance of the material.

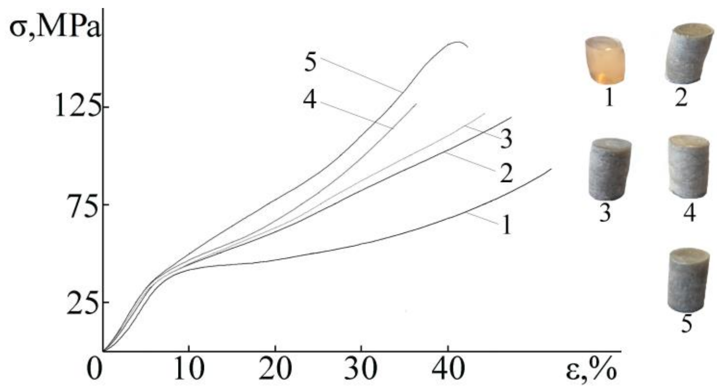


Figure1. Curves "tension -deformation" of polytrifluorochlorethylene (1) and organoplastics on its basis, reinforced 5 (2); 10 (3); 15 (4); 20 (5) wt % of fiber

The implementation of polysulfonamide fiber leads to the increase in modulus of elasticity and yield strengths to 45-69% and in 1.1-1.2 times, respectively, in comparison with PTFCE (see Table 3), which is a consequence of a decrease in the flexibility of macromolecules resulting in appear bonds between particles of filler and macromolecules of binder. During mixing component in the electromagnetic field, each fiber is covered with a layer of PTFCE, in which the macromolecules are oriented in such a way that their polar groups are turned to polar fiber groups.

Table 3. Influence of organic fiber on the properties polytrifluorochlorethylene

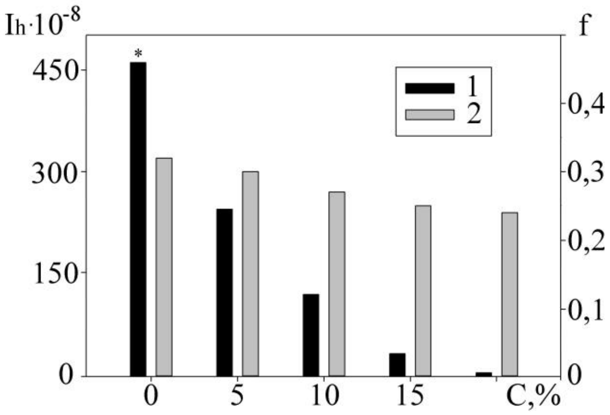
Indicator	Fiber content, wt %				
	0	5	10	15	20
Limit of proportionality (σ_{pr}), MPa	27	30.5	30.8	32	31.1
Relative lengthening of proportionality (ε_{pr}), %	5.4	5.2	5.1	5	4.2
Yield strengths low limit (σ_p), MPa	44	49.4	50	52.6	53.8
Relative elongation of yeld (ε_p), %	17	12.9	12	13.2	13.3
Ultimate strength (σ_s),MPa	-	119.5	121.5	126	152
Relative elongation of strength (ε_s), %	-	36	41	44.2	47.3
Modulus of elasticity (E), MPa	455	655	695	755	760
The shear modulus (G), MPa	194	267.7	281.7	304.3	307
Volume bulk density (K), MPa	220	394.4	435	485.3	482.8
Poisson's coefficient (ν)	0.16	0.22	0.23	0.24	0.24
Parameter Lame (λ), MPa	91	215.9	247.2	282.4	278.1

The growth of the shear modulus, bulk elasticity, the Lame parameter and the Poisson's coefficient of developed of OPs in 1.4-1.6, 1.8-2.2, 2.4-3.0 and 1.37-1.5 times respectively, in comparison with the basic material, it shows the increase in the material resistance to landslide deformations, which leads to the increase of the stability of the shape of parts during the transfer of load. Confirmation of the above can serve as sample images after compression (Fig. 1).

The coefficient of friction and the intensity of linear wear, are one of the important indicators used in the fulfilment of technical calculations and making decision, that characterize the frictional interaction of two bodies.

The results of tribological explores (Fig. 2) showed the following: in identical conditions, the organoplastic exceed the base polymer by the intensity of wear and the coefficient of friction in 1.9-85 times and 15-40% respectively.

Through friction of PTFCE on its surface appear deep furrows - roughness of more rigid surface (counterbody) and plough softer (Fig. 3, a), forming a friction path, indicating the adhesion mechanism of wear, when the molecular bonds of contacting surfaces under certain conditions are stronger than bond of the surface layer of friction. The distinctive feature of adhesion mechanism is the frictional transfer of the adhesive tapes of binder to the counterbody (see Fig. 3, b), which is due to the presence of local bonds between the contact surfaces.



*trekking trap 500 m

Figure 2. Influence of polysulfonamide fiber content on: the intensity of linear wear (1) and the coefficient of friction (2)

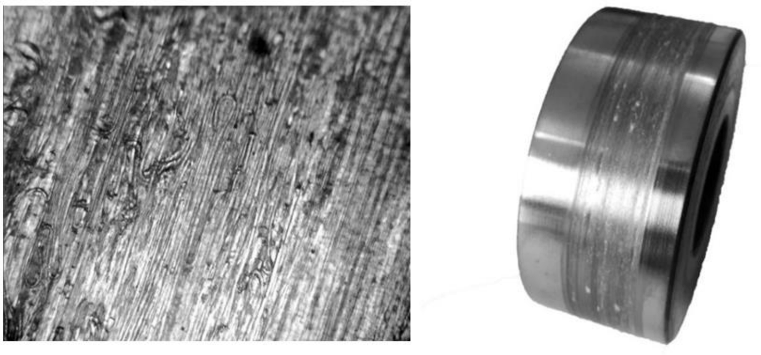
(**a**)

(**b**)

Figure 3. Microstructure (× 100) of friction surface of basic polymer (**a**) and products of its wear (**b**)

Research of the friction surface of OP (Fig. 4, a) showed that during abrasion of samples is formed smooth glassy surface (occur increase the actual contact area), on which are clearly visible chaotic organic fibers. The superficial layer of ground-in sample is characterized by the low coefficient of friction and wear. These facts reflect the pseudo-elastic abrasion mechanism of organoplastics that is realized between sample and counterbody: transfer film is formed on the surface of counterbody (Fig. 4, b), and sample isn't rubbed on the steel, but on the products of wear, that results in the shear deformation localizes inside the film that has low shear resistance, which leads to the decrease of the frictional force [8].

It is known [9] that one of the important contributions to the overall enhancement of tribotechnical characteristics is the hardness, which measures the possible areas of application of PCM. Solid and durable PCMs can be used in the production details of machines and mechanisms working in heavily loaded knots of friction: gear wheels and crowns, bearings. From Fig. 5 it is seen that the implementation of fiber leads to the increase of hardness of polymer matrix to 30-60%, which can be explained as both the high stability of the filler and the transformation of the structure of polymer under the influence of fiber.



(**a**) (**b**)

Figure 4. Microstructure of friction surface **(a)** (× 100) and transfer film **(b)** of organoplastic containing 15 wt % of fiber

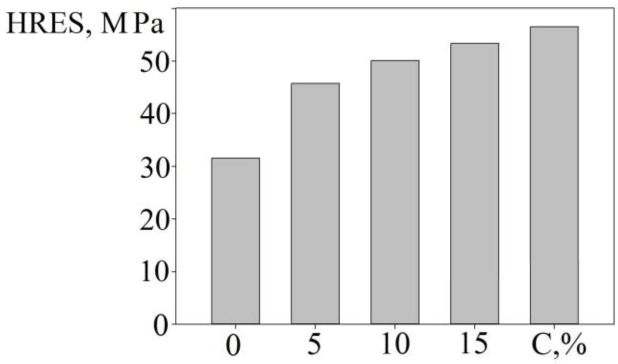


Figure 5. Influence of fiber on hardness of polytrifluorochlorethylene

Positive results of laboratory researches allowed us to proceed to production tests.

The safety of the operation of freight transport directly depends on the braking system: the simultaneous activation of all wheels. If this condition isn't implemented, then the freight transport can lead to the car accident, which can lead to fatal consequences. One of the main details of braking system of the car KamAZ (Fig. 6) is S-shaped brake expander.

During braking, the pads (7) are pushed apart by the S-shaped brake expander 12 and pressed against the inner surface of the drum. Between the expansion cam 12 and the pads there are rollers 13 that reduce friction and improve productivity of braking. The expansion cam scrolls in the bracket 10, attached to the caliper. The necks of the expansion cam are tucked together with the sleeves with bracket with the clearance, which provides the turn expansion cam [10].

The expansion cam of the car KamAZ works in difficult conditions: actions of aggressive environments, variable temperatures (especially in winter), high humidity and high contact tensions in the place of working profile of the brake expander, lead to quite intense wear of cast-iron rollers.

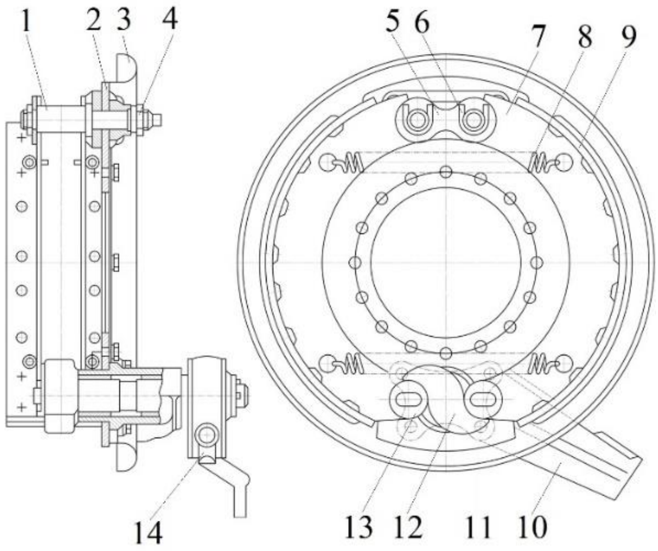


Figure 6. Brake mechanism of the car KamAZ 1-axis pad; 2- caliper; 3- flap; 4-nut axis; 5-lining of axes pads; 6- linchpin axis pad;7-brake pad; 8-spring; 9-friction pad; 10-bracket of the expansion cam; 11-roller's axis; 12- expansion cam; 13-roller; 14-regulating roller

5. Conclusions

In general, the analysis of the physico-mechanical and tribotechnical characteristics of the developed organoplastics shows that the use of organic fiber Tanlon T700 5-20 wt % , as the filler for polytrifluoroethylene is a promising way of increasing the modulus of elasticity, hardness and yield strength, respectively, to 45-69 30- 60 and 10-20%, while reducing the coefficient of friction to 15-40% and increasing the wear resistance in 1,9-85 times. Thanks to this, this organoplastic can be recommended for the production details of mobile joints of machines and mechanisms that can work in conditions of friction without greasing.

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