

THE INFLUENCE OF SULFONE-T FIBER CONTENT ON TECHNICAL CHARACTERISTICS OF ORGANOPLASTICS BASED ON AROMATIC POLYAMIDE

ВЛИЯНИЕ СОДЕРЖАНИЯ ВОЛОКНА СУЛЬФОН-Т НА ТЕХНИЧЕСКИЕ ХАРАКТЕРИСТИКИ ОРГАНОПЛАСТИКОВ НА ОСНОВЕ АРОМАТИЧЕСКОГО ПОЛИАМИДА

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Abstract: In this paper, the possibility of creating new structural organoplastics based on aromatic polyamide of phenylone, fiber-reinforced sulfone-T, is considered. Analysis of the results of physical and mechanical properties showed that, on the one hand, the introduction of an organic fiber into the polymer matrix leads to an increase in hardness, modulus of elasticity, and Poisson's ratio of 1.7; 1.9 and 1.3 times, respectively, on the other hand, there is an insignificant increase in the relative strain and yield stress at compression in the range of 10%, which is due to the presence of micropores formed at the polymer-fiber interface in the structure of organoplastics with the introduction of fiber filler over 15 wt.%. An increase in wear resistance of 1.6 times was observed, while a reduction in the coefficient of friction by 60%, compared with pure phenylone. Positive results of the research made it possible to switch to industrial ones - replacement of roller bearings of pins on sliding bearings made of polymeric composite material, which led to an increase of 3-4 times the working life as compared to serial ones.

KEYWORDS: AROMATIC POLYAMIDE, ORGANIC FIBERS, ORGANOPLASTICS, STRENGTH CHARACTERISTICS, TRIBOTECHNICAL CHARACTERISTICS

1. Introduction

Today, the world industry of plastics has moved far ahead. Polymer products are widely used in various industries. According to PlasticsEurope data for 2014, the world produced about 311 million tons of polymer products (including thermoplastics, polyurethanes, thermoreactive polymers, adhesives and sealants, as well as polymer coatings and seals). Europe accounted for about 59 million tons of this "pie" (19%). This result allows Europe to take the second place in terms of production of plastic products in the world. In Europe itself, leading manufacturers in the production of polymer products are industrial leaders: Germany, Italy, France, Great Britain and Spain. They account for about 75% of all the plastic produced in Europe [1].

It is doubtful that the automobile and engine manufacture could find the economic (and other) incentive necessary to develop alternatively fuelled products strictly on their own volition.

2. Preconditions and means for resolving the problem

Mechanical engineering today is experiencing an upsurge, and as a result, there is a growing need for new polymer products used both in the automotive industry and for domestic use. This direction takes 18% of the world consumption of polymers, yielding to building polymers by only 4% [2]. The increase in the service life of the structures largely depends on the reliability of the moving joints, which are subject to high loads, high speeds and temperatures. Therefore, there is a need to create new materials that could meet such requirements. Among the existing polymer composite materials (PCM), organoplastics, also called multifunctional materials, are of particular interest. They differ from the typical representatives of PCM by the polymeric nature of both components - matrices and fibers, characterized by high strength, low density and thermophysical characteristics [3]. They are widely used for the manufacture of products for various purposes: structural, electrical and radio engineering, heat insulation and others.

3. Solution of the examined problem

The purpose of this work was the development and investigation of the performance characteristics of new polymer composite materials based on aromatic polyamide phenylone, reinforced with organic fiber sulfone-T.

4. Methods and subjects of investigation

Phenylone aromatic polyamide C-1 (TS 6-05-221-101-71) was used as a binder; this represents finely divided pink powder with a bulk density of 0.2 - 0.3 g / cm³ and a specific viscosity of 0.5 % in dimethylformamide solution with 5 % of lithium chloride not less than 0.75, characterized by the following properties: density of 1.35 g / cm³, toughness of 20 kJ / m², hardness of 18 HRB, the tensile breaking stress of 100 MPa. Phenylone is reinforced by thermostable organic fibers sulfone-T with the following characteristics: the length of a no. 8-9 fiber is 3 mm, the strength is 240- 270 mN/tex, elongation at breakage is 17-21%, and the twist is 120-140 tpm.

Press-composition of the compound: phenylone +5-20 mass % of organic fibers was prepared by mixing the components in a rotating electromagnetic field in the presence of ferromagnetic particles. The tablets were charged in a mold preheated to 523 K, heated to 593-598 K and maintained at this temperature for 10 min, 10 min without pressure and under pressure of 30 MPa. To fix the shape of a product, the goods were cooled under pressure to a temperature of 523 K and pushed out of the mold later.

Brinell hardness was measured by indentation under a given load on the hardness tester BTSHSPS GOST 46-70-77 and specific toughness, which is a dynamic test of polymers, a single blow bending according to GOST 4647-69. Compressive yield point was determined on a test machine with the mechanical loading of the sample and mechanical force measure, Universal servo test machine UIT STM (GOST 4651-2014). The investigation of tribological properties in the frictionless mode was carried out at room temperature on a friction disk machine. The wear of the sample was evaluated according to the disk scheme (steel 45, HRC 50, Ra 0.08) - a composite finger (Ø 10, 10 mm high) at a specific load of 0.4-1.0 MPa, sliding speed of 1 m / sec, friction paths of 1000 m. The wear of the samples was determined on analytical scales VLR-200 with an accuracy of 0.0002 g. The microstructure of the samples after the tests was examined with an optical microscope Biolam-M at an increase of 200 times.

5. The results and their discussion

The most complete use of the strength of reinforcing fibers in organoplastics is achieved when, along with high adhesion and wetting power, the binder possesses a set of properties that allows for joint work of the fibers during deformation and the greatest monolithic nature of the system [4], i.e. uniform distribution of organic fiber within the binder. Investigation of the microstructure

of the obtained samples showed that the chosen method of mixing and pressing the compositions with a content of 5-20 wt. % of sulfone-T fiber in the polymer matrix of phenylene provides an ideal distribution of reinforcing fibers (Figure 1).

Analysis of the results of physical and mechanical properties showed that, on the one hand, the introduction of an organic fiber into the polymer matrix leads to an increase in hardness, modulus of

elasticity, and Poisson's ratio of 1.7; 1.9 and 1.3 times, respectively; on the other hand, there is an insignificant increase in the relative strain and yield stress at compression around 10%, which is due to the presence of micropores formed at the polymer-fiber interface in the structure of organoplastics and the lack of the uniformity of the filler distribution at the introduction of organic fiber more than 15 wt. % (Figure 2).

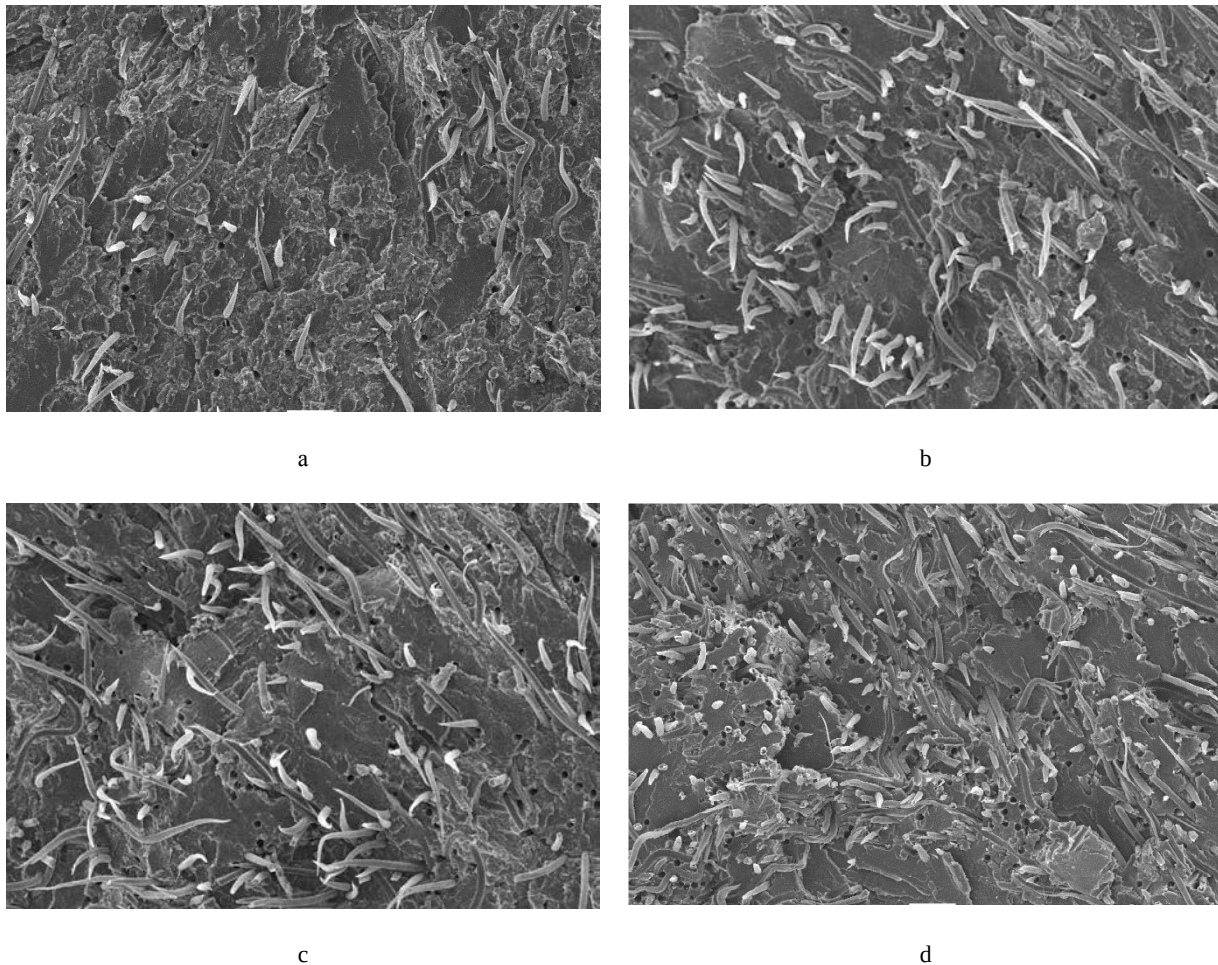


Fig.1. Electronic microphotographs of the starting polymer (a) and organoplastics based on it, containing 5 (a); 10 (b); 15 (c) 20 (d) wt% of the fiber

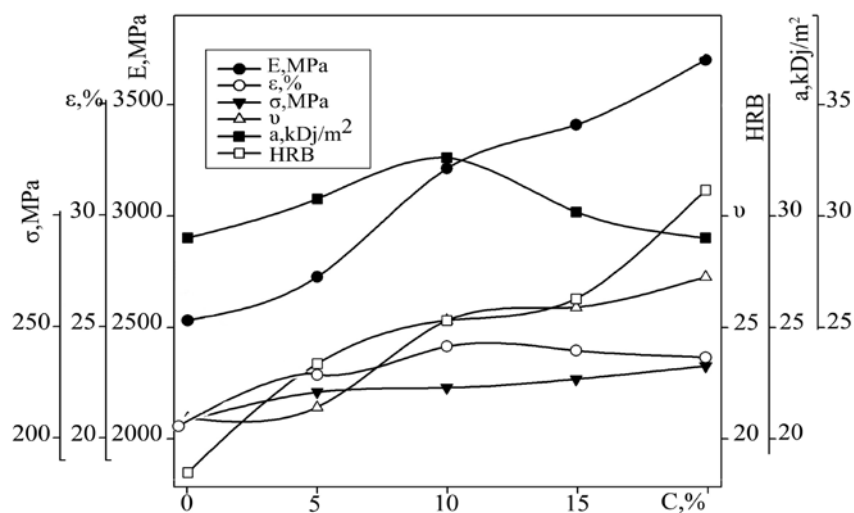


Fig.2. The influence of the sulfone-T fiber content on the strength characteristics of organoplastics based on it, where: E, MPa - modulus of elasticity or Young's modulus; ε, % - elongation at compression; σ, MPa - Compressive yield strength; ν - Poisson's ratio; a, kJ / m² - toughness; HRB - Brinell hardness

Along with the induced applied load, the destruction of brittle particles, the development of fracture along the interface between the matrix and the fiber contributes to the formation of microcracks or pores in the test samples. They are mainly formed in connection with the reorientation of the polymer molecules, and grow in a plane normal to the stress application axis. As the stress level increases, the pores grow more and finally coalesce to form a wide crack front [5], which reaches critical dimensions, accompanied by complete destruction for pure phenylone samples and samples with

a high degree of fiber filling with sulfon-T (15-20 wt. %) (Figures 3a, d, e).

The investigation of tribotechnical characteristics under conditions of dry friction at varying pressure values from 0.4 to 1.0 MPa allowed to establish that the optimum fiber concentration in the polymer matrix is 10 wt. %, over the entire range of loads studied. Compared with pure phenylone, an increase in wear resistance of 1.6 times was observed, with a simultaneous decrease in the coefficient of friction by 60% (Fig. 4).

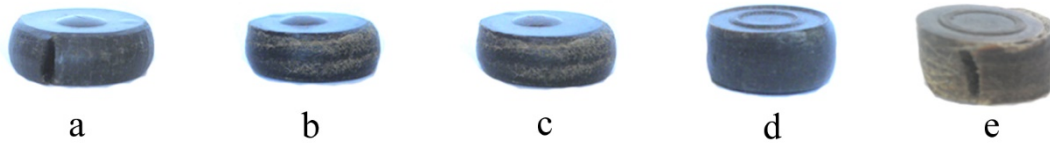


Fig. 3. Nature of destruction of samples of phenylone (a) and organoplastic based on it, containing 5 (b); 10 (c); 15 (d) 20 (e) wt. % Fiber after compression test

As for the microanalysis of the tribosurface, as a result of abrasion of the phenylone over ground steel under conditions of room temperature, a surface with apparent gouging paths is formed (Fig. 5a). Organoplastics are characterized by a pseudoelastic mechanism of abrasion [6]. This is testified to by shots of the microstructure of organoplastics surface (with a content of 10 wt% fiber), which

becomes specular, traces of the tracks from the introduction of roughness of the metal counterweave are hardly visible, fiber breakage from the surface was practically not observed (Figure 5b), which characterizes the strong adhesion bonds of components in organoplastics.

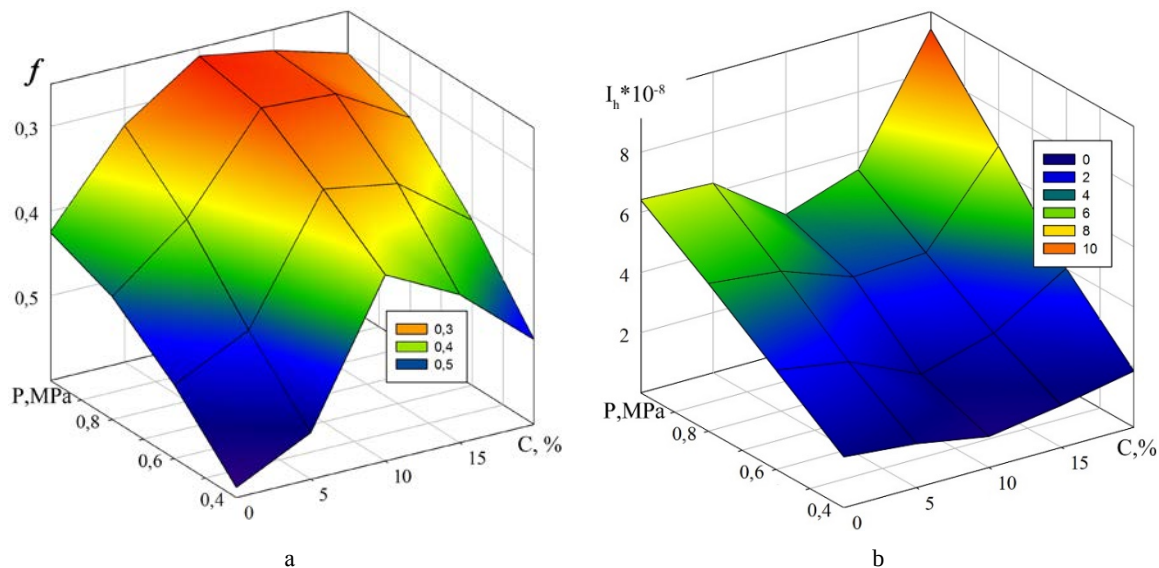


Fig. 4. Dependence of the coefficient of friction (a) and wear intensity (b) of phenylone and organoplastics on its basis on the influence of the load and the content of sulfone-T fiber in the polymer matrix

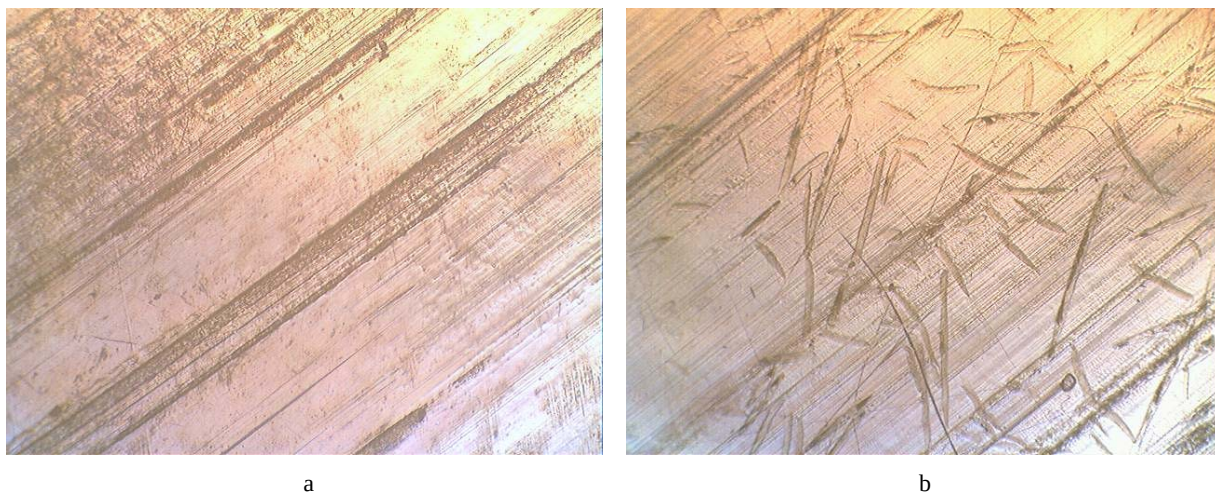


Fig. 5. Microstructure of the friction surface of phenylone (a) and organoplastics (b), with an increase of $\times 200$

Based on the positive results of laboratory studies, the replacement of the roller bearing of pins No. 6-7409a, mounted on the cradle of the axial-plunger pump NP-90, the sliding bearings made of organoplastic based on aromatic polyamide phenylene reinforced with discrete chemical fiber sulfone-T was proposed. The experimental bearing includes an outer steel ring (Figures 6, 3) and an inner conical ring (Figure 6, 2) made of organoplastic. The cone of conjugated surfaces is $200 \pm 5^\circ$. The outer steel rings of the

bearings are pressed into the mounting holes of the tube, while the inner ones, made of organoplastics, are pressed onto the journal (Fig. 6, 1), which is installed in the pump housing holes [7]. This replacement leads to an increase in the working resource by 3 - 4 times in comparison with the serial ones, which makes it possible to recommend details from organoplastics for use in hydrostatic transmissions of GST-90 (112) in pumps NP-90.

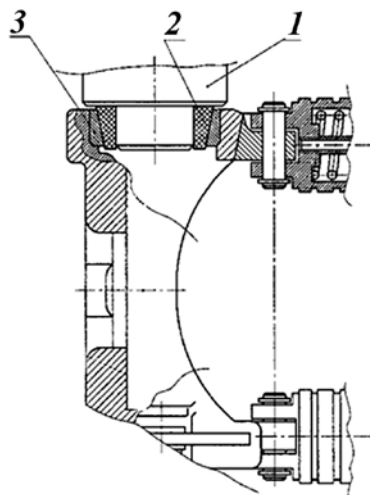


Fig. 6. General view of roller bearings of pins No. 6-7409a mounted on the cradle of the axial-plunger pump NP-90, where 1 - the outer steel ring; 2 - internal conical ring of organoplastics; 3 - outer steel ring

6. Conclusion

Thus, during the research of new polymer composite materials, it has been established that the reinforcement of aromatic polyamide phenylene with an organic discrete sulfone-T fiber leads to an increase in its strength characteristics, namely hardness, elastic modulus and Poisson's ratio by 1.7; 1.9 and 1.3 times, respectively; a significant increase in wear resistance (by 1.6 times) and a decrease in the coefficient of friction (by 60%). Experimental details from organoplastics were tested as an internal conical ring instead of a roller bearing of pins No. 6-7409a mounted on the cradle of the axial-plunger pump NP-90, which led to an increase in the working life.

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