COMPOSITE POLYMERIC MATERIALS MODIFIED BY NANODISPERSION FUNCTIONALIZED PARTICLES

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Abstract: *The paper considers the impact of functionalized nanosized carbon particles on the physicomechanical characteristics of composite materials based on polyamides. The concentration of the modifier varied both in the field of "doping" concentrations and in the field of concentrations used in the industrial production of nanocomposite materials based on polymer matrices. It was found that the use of cryogenic treatment of the initial polyamide leads to an increase in physical and mechanical characteristics. The introduction of nanodispersed particles in the field of "doping" concentrations increases the strength and hardness of the developed compositions based on a polyamide matrix.*
KEYWORDS*: COMPOSITE MATERIAL, STRUCTURE, STRENGTH, HARDNESS, FRICTION*

1. Introduction.

Composite materials on a polymer matrix modified with various types of micro-sized and nanosized particles are classified as technological materials of a new functional generation. These composites are among the most successfully introduced into the production processes of various types of manufacturing products and structures for various functional purposes. In this regard, the volume of production of these materials is increasing annually, replacing traditional types of polymeric materials and filled compositions. Simultaneously with the development of the above trend, energy-resource-saving technologies and materials are of particular relevance in modern production. A promising direction in the field of reducing wear and corrosion protection was the use of functional composite polymer materials. A special place in the hierarchy of engineering materials is occupied by multifunctional polymer nanocomposite materials, which replace traditional composites when creating damping couplings, friction units, sealing elements, medical prostheses and devices [1, 2]. The necessary level of tribotechnical organization, which determines the stability of nanocomposites to the influence of operational factors, is achieved by using modifiers of a certain molecular weight, composition, external shape, geometric particle sizes, filler preparation methods, nanocomposite materials processing modes, methods of activation of rubbing surfaces that allow changing the topography of contacting materials, the influence of external factors that make a fundamental contribution to tribochemical processes of formation of stable separation layers in the area of frictional contact.

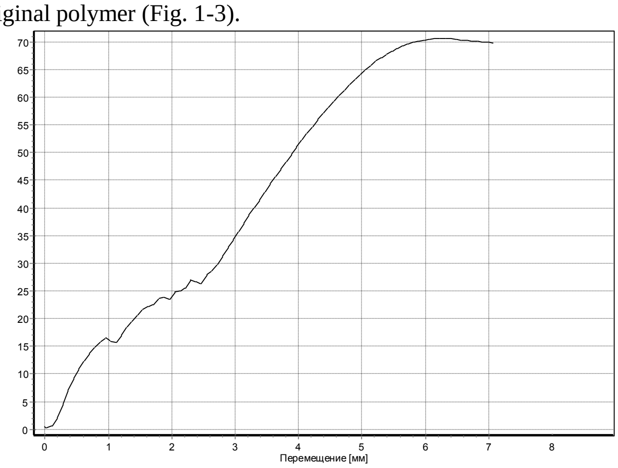
The aim of this work is to develop nanocomposite materials by using functionalized nanocarbon particles to increase the physicomechanical characteristics of the formed systems.

2. Preconditions and means for resolving the problem.

As samples, composite materials based on a polyamide polymer matrix PA 6 210/310 (manufactured by PTK Khimvolokno OJSC Grodno Azot, Belarus), which was filled with nanodispersed functionalized carbon particles (NFUCh), were obtained. An ultrafine diamond with a single cluster size of 4–6 nm was used. The percentage of nanomodifier in the polymer matrix ranged from 0.17 to 1 wt.%. The starting polyamide was processed at cryogenic temperatures. Nanodispersed particles were preliminarily treated in a solution of a fluorine-containing oligomer. Composite samples were molded by injection molding on a vertical injection molding machine manufactured by RUE SKTB Metallopolymer (Belarus). The samples had standardized sizes: length - 10 cm, width –1 cm, thickness - 0.5 cm. Tribological testing of the samples was carried out on an FT-2 friction machine according to the sphere – plane scheme. ShKh15 steel was used as a counterbody, the load was 30 N, and the sliding velocity v = 0.06 m / s.

Tests to determine the strength characteristics were carried out on a tensile testing machine IR 5047-50 for universal use with an electronic force meter for testing samples under tension, compression and bending with a load limit of 50 kN. Samples of materials are installed between the grips of the tensile testing machine when fixing the ends of the sample. Before testing, the basic geometric parameters of the samples are measured. The fixed samples are stretched by moving the beam, on which one of the grips is fixed and a force measuring sensor is installed, which fixes the value of the resistance of the sample under tensile load. The data obtained is transmitted to a computer and presented in the form of a graph of the dependence of the sample resistance force (N), as well as the stress (MPa) on the movement of the beam (tension). The values of ultimate stress and tensile stress of the specimen and elongation are also determined. To assess the physical and mechanical characteristics, the IPM-1K device was used.

3. According to studies [3], the introduction of nanodispersed particles into the polyamide matrix leads to an increase in physical and mechanical characteristics. To increase the wear resistance of the PA-6-based coating, it was modified with "doping" additives of nanomodifiers selected from the group: UDAG, shungite, flint, metal nanoparticles of metals and metal oxides (OM), granite flour, with their content from 0.01 to 1.0 wt.%. Due to the complex modifying effect of nanoparticles, the adhesion of the composite coating to carbon and alloy steels (st 45, st 40X) and the wear resistance index increase. At the same time, despite the adsorption interaction of modifier particles with the polar groups of the polymer matrix (the HNHCO ами amide group), which determine the high adhesion characteristics of polyamide coatings on metals, rather high values of the friction coefficient of coatings remain in contact with a metal counterbody without external lubrication (f = 0.19-0.22). This is explained by an increase in the deformation component of the coefficient of friction with increased adhesive interaction [3]. Studies on the strength and hardness of polyamide 6 modified with nanodispersed particles showed an increase in the values of these parameters compared to the original polymer (Fig. 1-3).



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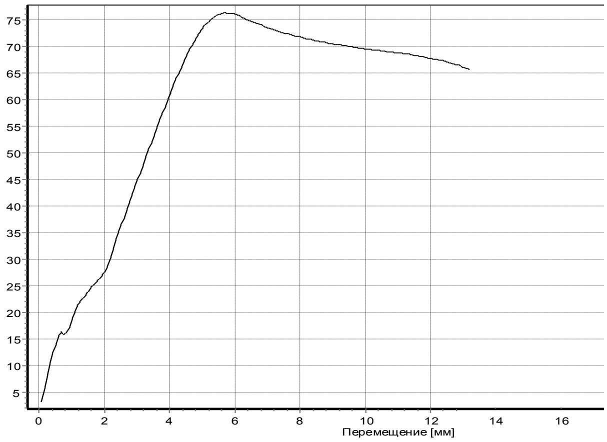

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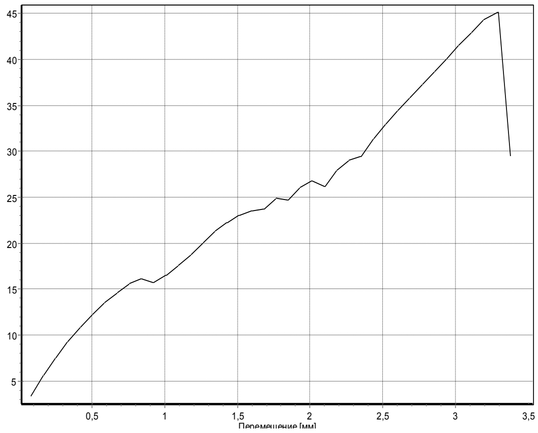
Figure 1. The strain versus strain for compositions based on polyamide 6. a-concentration of the nanocarbon modifier in the polymer matrix 0.17 wt.%, B-concentration of the nanocarbon modifier in the polymer matrix 0.25 wt.%



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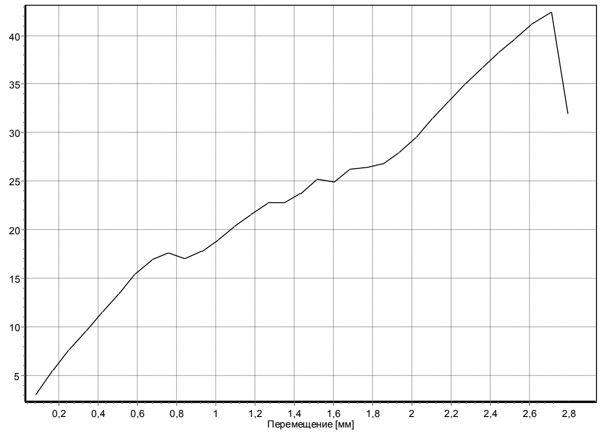

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Figure 2. The dependence of stress on deformation for compositions based on polyamide 6. a-concentration of the nanocarbon modifier in the polymer matrix 0.5 wt.%, b-concentration of the nanocarbon modifier in the polymer matrix 1 wt.%

With the introduction of doping additives of low-dimensional particles having an uncompensated charge, a synergistic effect of increasing the strength, tribotechnical and adhesive characteristics is provided. The effect is due to the formation of a quasicrystalline transition layer in the periphery of the nanoparticle under the influence of an electric field. The charge of a nanoparticle can be formed as a result of a special technological impact (mechanical, tribochemical, temperature, etc.) or due to the crystal chemical structure of the semi-finished product.

This effect of increasing the strength characteristics of polyamide compositions is observed at "doping" values of the concentration of nanomodifier in the polymer matrix. An increase in the concentration (0.5-1 mass%) of nanosized particles in polyamide leads to a decrease in the tensile strength of tensile composites (Fig. 2).

Figure 3 shows the values of the dynamic modulus of elasticity of the polyamide and its compositions. increases with cryogenic treatment. The introduction of nanodispersed modifiers leads to a decrease in the values of the dynamic elastic modulus.

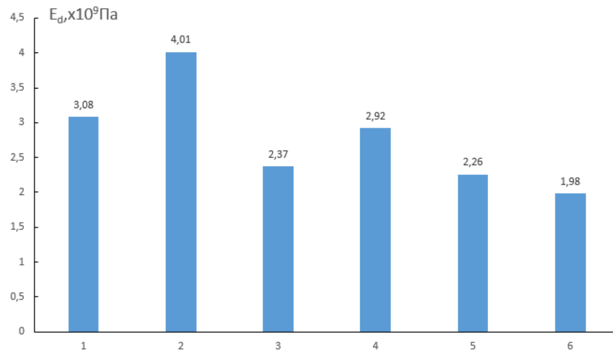

Figure 3. Values of the dynamic modulus of elasticity for polyamide compositions: 1- polyamide 6 (initial), 2-polyamide 6 subjected to cryogenic treatment; 3- polyamide 6, modified with nanodispersed carbon particles with a concentration of 0.17 mass. %; 4-polyamide 6 modified with nanosized carbon particles with a concentration of 0.25 wt.%; 5- polyamide 6 modified with nanosized particles of carbon with a concentration of 0.5 wt.%; 6-polyamide 6 modified with nanodispersed carbon particles with a concentration of 1 wt.%.

Studies on the hardness of the developed compositions based on polyamides 6 showed good agreement with the results of tests to determine the tensile strength values for polymer compositions. For polyamide compositions modified with nanosized particles in the region of low modifier concentrations, hardness values increase by 22-27%. A further increase in the content of modifier in the composition leads to a decrease in strength values. Tribotechnical tests of composite materials containing nanodispersed particles showed a decrease in the coefficient of friction in the friction pair with the steel counterbody at low concentrations of the modifier. With an increase in the concentration of nanodispersed functionalized carbon particles, the values of the friction coefficient increase and the nanocomposite-steel pairs increase (Fig. 4-5).

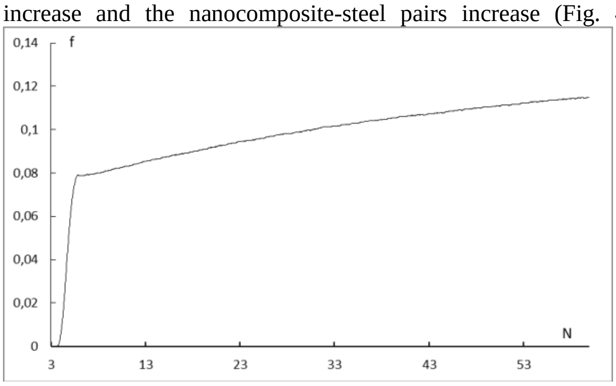

Figure 4. The dependence of the coefficient of a friction pair of nanocomposite material-steel on the number of cycles. The modifier content in the composite is 0.17 mass%.

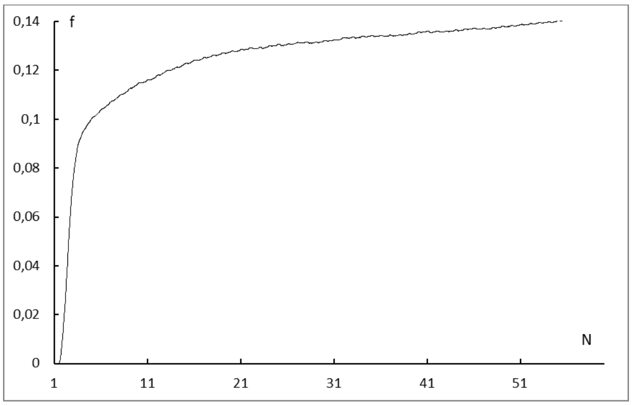

Figure 5. The dependence of the coefficient of a friction pair of nanocomposite material-steel on the number of cycles. The content of the modifier in the composite is 1 wt.%.

Studies on the tribotechnical characteristics of the developed polymer compositions showed a decrease in the coefficient of friction by 2 times with respect to the initial one with a modifier content of up to 0.1 wt.%. An increase in the concentration of functionalized nanodispersed particles in the polymer matrix to 1 wt.% Leads to an increase in the coefficient of friction to 0.14.

Conclusion. Thus, the introduction of nanodispersed functionalized carbon particles leads to an increase in the physicomechanical characteristics of polyamide compositions at “doping” concentrations of the modifier. An increase in the concentration (0.5-1 wt.%) Of nanosized particles in polyamide leads to a decrease in the tensile strength of tensile composites.

4. Literature

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