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ТРИБОТЕХНИЧЕСКИЕ ХАРАКТЕРИСТИКИ СМАЗОЧНЫХ МАТЕРИАЛОВ, МОДИФИЦИРОВАННЫХ УГЛЕРОДНЫМИ НАНОМАТЕРИАЛАМИ

TRIBOLOGICAL CHARACTERISTICS OF LIQUIDS MODIFIED WITH HYBRID CARBON NANOMATERIALS

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Аннотация. В представленной статье рассмотрены вопросы повышения триботехнических характеристик смазочных жидких сред. Эти жидкости были модифицированы гибридными углеродными материалами, представляющими собой смесь графита, графена и углеродных нанотрубок. Углеродные смеси наночастиц были получены методом самораспространяющегося высокотемпературного синтеза. Установлено, что введение смесей наноуглеродных частиц в жидкую смазочную среду существенно изменяет трибологические и вязкостные характеристики.

Ключевые слова: износ, трение, морфология, модификация, вязкость, жидкость, наноуглерод.

Abstract. In the presented article, the issues of improving the tribotechnical characteristics of lubricating liquid media are considered. These liquids were modified with hybrid carbon materials, which are a mixture of graphite, graphene, and carbon nanotubes. Carbon mixtures of nanoparticles were obtained by the method of self-propagating high-temperature synthesis. It has been established that the introduction of mixtures of nanocarbon particles into a liquid lubricating medium significantly changes the tribological and viscosity characteristics.

Key words: wear, friction, morphology, modification, viscosity, liquid, nanocarbon.

Introduction. The main type of defects that lead to the output of parts and products in mechanical engineering are mechanical failures during operation associated with friction and wear. The use of lubricants is a highly effective way to increase energy efficiency and reduce wear power. In engineering applications, lubricants have a significant impact on the mechanical action of tribosystems, while allowing you to adjust the pressure in the contact rubbing bodies, maintain the cooling functions of the systems, increase the stability of the triboassembly and minimize the values of indicators and wear between the contacting bodies [1]. The use of significant carbon nanoparticles as lubricant additives can increase the wear resistance of rubbing bodies and significantly reduce the coefficient. This effect can be increased due to the formation of a separate layer capable of withstanding high contact loads without irritation and expectation to detect microroughness of cracking bodies, which leads to the identification of the development process. In recent years, many studies have highlighted in the UK the anti-friction properties of individual modifiers, such as: MoS2, WS2, graphene and fullerene, nanosized detonation synthesis diamonds corresponding to the type of functionalized nanosized particles (clays, diamonds, metals, metal oxides and ceramics). In particular, a large number of works are devoted to molybdenum disulfide particles used as additives to lubricants (plastic, liquid, etc.). In particular, MoS2 particles with a diameter circulating in the region of 1 μm were studied, in which particles of developed tissue were found. The introduction of data into lubricating oil with a concentration of ~ 2 wt. % to the index of volumetric wear by 10–30 %. However, although solid modifiers lead to a significant improvement in tribotechnical characteristics, the complexity of the manufacturing technology, environmental insecurity, and high cost limit the scope of these modifiers [2–4]. Moreover, the limited mechanical and chemical stability in the lubricating environment of these modifiers can lead to deterioration of the properties of the lubricant composition during long-term operation.

For example, inorganic modifiers such as MoS2 or WS2 are destroyed by friction in the boundary lubrication regime. In addition, some additives containing sulfur can create acidic compounds in the lubricating medium during friction, which accelerate the corrosion of the contacting bodies.

Thus, the development of optimal compositions of lubricant additives to improve tribotechnical characteristics is essential, especially under extreme friction conditions. Carbon particles obtained by SHS synthesis from natural raw materials are of interest as additives in lubricants of various nature due to their unique properties, such as technological ease of production, high dispersion, and chemical stability. These characteristics of carbon particles obtained by SHS synthesis make them a very promising modifier for obtaining environmentally friendly lubricants and can replace additives containing sulfur and phosphorus [5–6].

The purpose of this work is to study the viscosity and physico-mechanical characteristics of liquids modified with nanodispersed carbon particles and their compositions.

Experimental. Tribological studies were carried out on an FT-2 type friction machine, which operates according to the reciprocating motion scheme, the indenter stroke length is 5–50 mm in dry friction conditions (counterbody), made of steel and polished on a flat flat surface with emery cloth or grinding paste to arithmetic mean deviation of the surface profile Ra = 0.1–0.3 µm.

The samples were fixed in the clamp of the friction machine, the working sphere and the working surface of the polymer disk (counterbody) were rubbed with a bleached calico cloth soaked in ethyl alcohol, after which they were dried for two minutes at room temperature. The tests were carried out at a normal load on the sample up to 20 N, a linear sliding velocity of 0.036 m/s, and a surface temperature of the polymer sample (20±5 °C). The nanolubricant was supplied to the friction zone in such a way as to provide a mixed lubrication regime.

The rheological characteristics of the samples were determined by the Engler method. Using this method, the viscosity is determined by the time of flow of the test liquid from a VZ-4 viscometer of a liquid with a volume of 200 ml at a certain temperature when compared with the time of flow of distilled water from a viscometer of the same type at 20 ºC (viscometer constant). During the measurements, it is ensured that the test liquid flows out in a continuous stream.

Viscosity in Engler units at temperature T is determined by the formula:

$$E_t = \frac{J_t}{J_{t1}}, \tag{1}$$

where J_t – time (in seconds) of the expiration of 200 ml of the test liquid sample at a temperature T; J_{t1} – time (in seconds) for 200 ml of control liquid to flow out at a temperature T.

Results and discussion. The preliminary studies on the study of the tribotechnical characteristics of the friction pair PA 6-52100, tested in a lubricating medium of the composition oil SN 150, containing up to 10 wt. % of carbon particles obtained by SHS synthesis, showed a decrease in the friction coefficient for this friction pair (fig. 1). The tests were carried out on an FT-2 friction machine according to the method described above.

Based on the data obtained, it can be seen that the introduction of a lubricating medium into the friction zone leads to a decrease in the values of the friction coefficient by 30–40 %. However, the introduction of carbon-containing particles of various nature into the lubricant composition leads to a certain increase in the friction coefficient, which is possibly due to the presence of a solid diamond core for ultrafine diamond-containing graphite, as well as the presence of solid allotropic modifications of carbon for nanodispersed carbon particles obtained by SHS the concentration of the modifier in the composition (10 wt. %), which leads to thickening of the lubricant, i. e. an increase in the viscosity of the modified liquid material. The experiments carried out to study the tribotechnical characteristics of lubricants at a modifier concentration in the range of 0.1–5 wt. % showed a decrease in the values of the friction coefficient of a metal-polymer pair. It should be noted that for all compositions based on I-20A oil modified with nanodispersed carbon particles, including those obtained by the method of self-propagating high-temperature synthesis, a decrease in wear intensity by 14–32 is observed.

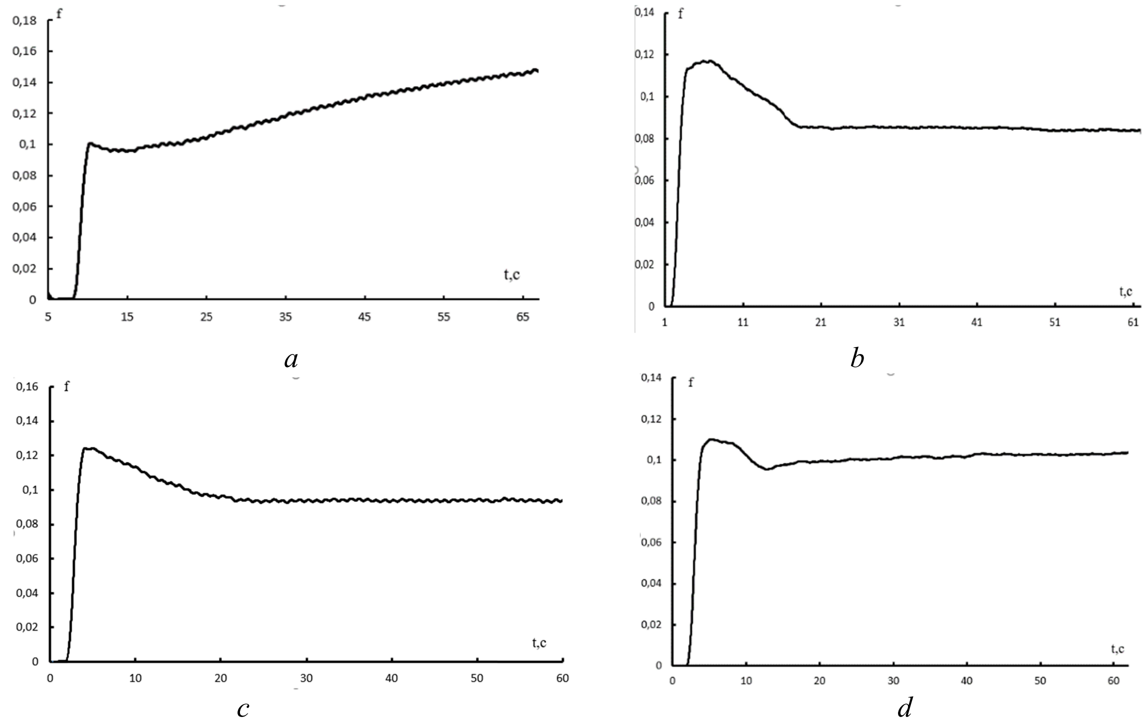


Fig. 1. Dependence of the friction coefficient on the time of tribotechnical tests for a pair of 52100-polyamide 6 steel during friction with lubrication: *a* – initial friction pair tested without external lubricant supply; *b* – friction pair tested with SN 150 external lubricant supply; *c* – friction pair tested with external lubricant SN 150 and modified with 10 wt. % ultrafine diamond-containing graphite; *d* – friction pair tested with external lubricant SN 150 and modified with 10 wt. % carbon-containing particles synthesized by self-propagating high-temperature synthesis. *a* – original friction pair tested without external lubricant supply; *b* – friction pair tested with SN 150 external lubricant supply; *c* – friction pair tested with SN 150 external lubricant supply and modified with 10 wt. % ultrafine diamond-bearing graphite; *d* – a friction pair tested with an SN 150 external lubricant supply and modified with 10 wt. % carbon-containing particles synthesized by the method of self-propagating high-temperature synthesis

Another aspect affecting a slight increase in the coefficient of friction for petroleum lubricants is a sufficiently high concentration of the modifier in the composition (10 wt. %), which leads to thickening of the lubricant, i. e. an increase in the viscosity of the modified liquid material. The experiments carried out to study the tribotechnical characteristics of lubricants at a modifier concentration in the range of 0.1–5 wt.% showed a decrease in the values of the friction coefficient of a metal-polymer pair. It should be noted that for all compositions based on SN 150 oil modified with nanodispersed carbon particles, including those obtained by the method of self-propagating high-temperature synthesis, a decrease in wear intensity by 14–32 % is observed. Studies of the viscosity characteristics of various types of liquids have shown a decrease in the viscosity of modified liquids in the range from 0.01 wt. % to 1 wt. %. An increase in the concentration of the modifier above 1 wt. % leads to an increase in the viscosity of the studied liquids measured in Engler degrees (fig. 2–3).

The presence of nanodispersed particles in the studied carbon modifiers was determined using the method of scanning electron microscopy (fig. 4). Based on the presented data, it can be seen that the studied particles have high values of specific surface, differ from each other in morphology. The conducted studies on the effect of modifiers on the intermolecular interaction with the modified liquid showed the absence of interaction with the formation of new chemical compounds when additives are introduced into the original lubricant.

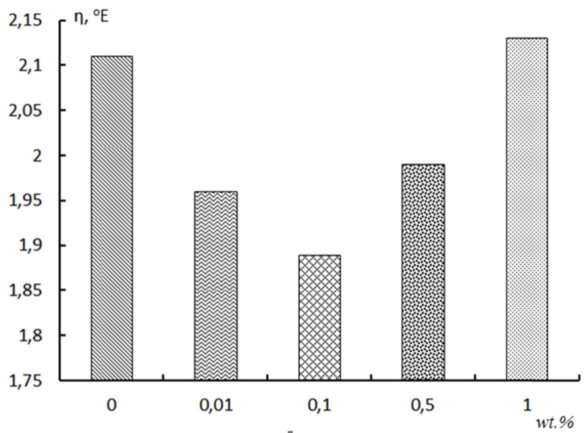


Fig. 2. Viscosity dependence of SN 150 oil modified with nanodispersed graphene-like particles

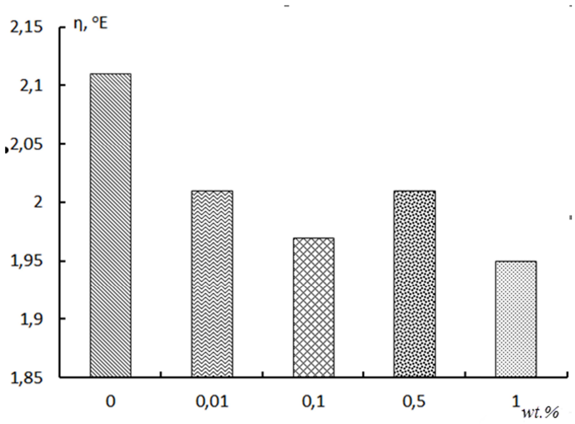
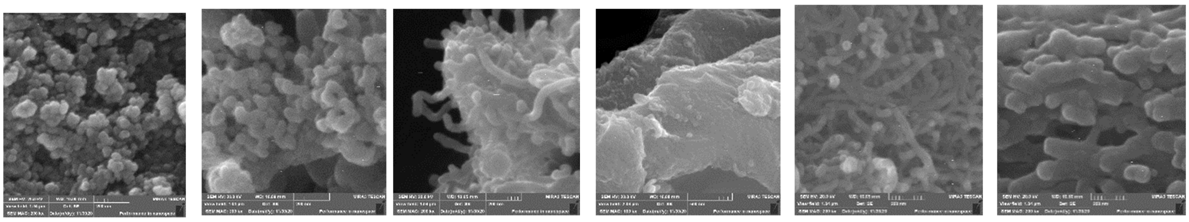


Fig. 3. Viscosity dependence of SN 150 oil modified with nanodispersed carbon particles obtained by SHS synthesis



a *b* *c* *d* *e* *f*

Fig. 4. Morphology of nanodispersed carbon particles obtained by various technologies: *a* – ultrafine diamond-containing graphite; *b* – graphene-like structures; *c* – carbon particles obtained by SHS synthesis from starch; *d* – carbon particles obtained by SHS synthesis from cellulose; *e* – multilayer carbon nanotubes; *f* – highly dispers

Conclusions. Thus, based on the data obtained, it can be seen that the introduction of nanodispersed carbon particles into the lubricant matrix SN 150 oil, distilled water, ethylene glycol) at low modifier concentrations up to 1 wt. % leads to a decrease in viscosity values. Increasing the concentration of the modifier above 1 wt. % increases the viscosity characteristics of the studied liquid media. The introduction of modifiers into lubricants does not lead to chemical interaction with the modified material. Nanodispersed carbon particles have a developed morphology and high specific surface area, which affects the tribotechnical characteristics of the studied lubricating media. The introduction of the studied nanodispersed particles into the matrix of the lubricant leads to a slight increase in the friction coefficient at concentrations above 10 wt. % in relation to the values of the friction coefficient for the base lubricant. When the content of the modifier in the range from 0.1 to 5 wt. % values of the coefficient of friction are reduced by 14–32 % in relation to the values of the coefficient of friction of the base lubricant.

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ИНЖЕНЕРНЫЕ КЛАССЫ
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Аннотация. В связи с улучшением и ростом технологий, на данных момент испытывается нехватка специалистов в области инженерии, а именно «станкостроение». Мы создаем инженерные классы, в которых будут изучаться основные технические науки, а также будут реализованы дополнительные образовательные программы. Тем самым мы формируем техническое мышление у обучающихся и подготавливаем студентов для поступления в Передовую Инженерную Школу (ПИШ).

Ключевые слова: инженерный класс, формирование технического мышления, инженерно-техническая деятельность.

Введение. Инженерные классы – это новая модель образования по программам основных технических предметов дополнительных образовательных программ. Занятия в инженерных классах позволяют сформировать и усовершенствовать самостоятельность, мотивировать к исследовательской и проектной деятельности. Преимущество инженерного класса – практическая профильная подготовка с 1 курса обучения путем прохождения профильных элективных курсов (3D-моделирование, робототехника), а также углубленная подготовка по базовым дисциплинам (физика, информатика, математика). Внедрение учебной деятельности в инженерных классах помогает более качественно подготавливать студентов по техническому профилю, способствовать развитию и самореализации обучающихся с интересом и способностями к инженерному творчеству. Педагоги разрабатывают образовательную траекторию для обучающихся