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THE DEVELOPING OF TRIBOTECHNICAL ORGANOPLASTIC

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It is known that polymeric materials, with a high level of operational properties, make it possible to solve a number of technical issues in a new way, aimed at improving the reliability of operation and increasing the service life of friction units of machines and mechanisms. First of all, this is explained by the fact that traditional materials (steel, cast iron, babbit, bronze, etc.) do not always meet the needs of modern engineering practice.

Organic hardened polymer materials – organoplastics (OPs) – surpass steel, aluminum, and plastics due to their unique properties: high chemical resistance, low density (they are lighter than carbon and fiberglass plastics), and their ability to accumulate damage over time without forming a critical crack. OPs based on thermoplastic binders are widely used, some of the popular heat-resistant representatives of which are fluoropolymers – known for their exceptional resistance to chemicals and corrosion, temperature short-term heating to 533 K, and natural lubricity.

The influence of the content of organic Talon T700 fiber on the tribological properties of organoplastics based on polytetrafluorethylene is considered. It is showed that in the conditions of friction without lubrication the introduction of filler has positive effect on output polymer: it decreases friction coefficient by на 15 - 40 % and reduces wear by two orders of magnitude (from 91,75 to 0,15). The developed composition can be used for manufacturing of the details of moving joints of machines and mechanisms which are used in different industrial spheres.

Key words: organoplastic, polytetrafluorethylene, polysulfonamide, friction coefficient, wear.

Introduction

During the last years the problem of decreasing of friction coefficient and increasing of wear resistance of polymer materials (PMs), which are able to work in the conditions of friction without lubrication (where the use of lubricants is complicated or impossible), in metallopolymeric compounds and polymer-polymer tribo-compounds, is still an actual task, because most of machines and mechanisms (85 - 90 %) fail due to wear of parts. Energy loss of the best examples of equipment reaches 30-35%, and in case of sophisticated technological equipment it reaches 80 - 85 %. The spending on the activities for prevention of premature wear sometimes reaches billions of dollars in developed countries [1, 2].

The use of wear resistant PMs won't only let to reduce the consumption of expensive non-ferrous alloys and energy loss while manufacturing parts of units and mechanisms of friction in different areas of machinery (handling, agricultural, textile, polygraphic etc.), but it will also let to improve maintainability and exclude service maintenance of mechanisms [3].

In addition, the replacement of traditional metallic materials on polymer in the units of friction will let the manufacturer to manage the consist, structure, properties of polymer materials, combine high carrying capacity and wear resistance with strength and hardness of form-building body parts from PMs and metals. It will give the ability of choosing technological processes from the existing set of equipment and implemented processes due to the purposes, constructions, forms, sizes and seriation of products [4].

Goal and target-setting

From a huge variety of polymer materials polytetrafluorethylene (PTFE) can be recommended as polymer material with the best combination of tribological properties for friction units of machines and mechanisms. It has low friction coefficient and it is able to work in dry friction mode without lubrication. Its main disadvantage is low wear resistance. It leads to the need of frequent repair of friction units and joints where this polymer is used. One of the most effective methods of increasing tribological properties of PTFE is the introduction of different fine aggregates into it [5]. Sometimes disperse particles don't give the desired effect when the polymer is modified with them, because due to high surface energy they have a tendency to. The introduction of organic fibers (OFs) into the polymer was the solution of the problem. The fibers are characterized by good polymer matrix composite (high adhesion) and lower tendency to grinding, high indicators of specific strength and stiffness [6].

Objects and methods of research

PTFE (GOST State Standard 10007-80) was used as a binder. It is white powder with bulk density 0,2 - 0,3 g/cm^3 that is designated for manufacturing of products by the method of compression moulding or baking. PTFE is characterized by a number of unique properties such as heat and frost, chemical resistance to many solvents, hydrophobicity, resistance to sunlight etc.

Heat resistant polysulfonamide T700 organic fiber (China) was used as a filler (Table 1). To determine the optimal content of the developed OPs, the samples with different ratio of components were made.

Table 1

Main properties of the fibers [7]

Indicator	Value
Length, mm	5 - 7
Density, g/cm^3	1,42
Strength, MPa	650
Elongation, %	20-25
Elastic modulus, GPa	7,45

The preparation of organoplastics (OPs) based on PTFE that contains 5 - 20 mass. % of organic polysulfonamide fiber [8] was made by the method of dry mixing in the apparatus with a rotating electromagnetic field (0,12 Tl) using ferromagnetic particles which were withdrawn from the prepared composition by magnetic separation. The resultant mixture was tabletted at room temperature and under pressure 60 MPa. Tablets were loaded into the mold heated to 523K. Then the temperature in the mold was raised to 640 - 650 K, and the tablets were kept at this temperature for 10 min. without pressure and for 10 min. under pressure 60MPa. To fix the shape, the product was cooled under pressure to a temperature of 523K and then pushed out of the mold.

Experimental studies of tribotechnical characteristics of composite materials were carried out on a disk friction machine of MDP 1 type according to the contact scheme pin-on-disc. The efforts in friction couple were made using pneumatic cell of unit пневмокамери вузла. The moment of friction was registered using strain-gauge bar which was mounted in the attachment point of pin-type sample from composite materials. The value of wear of the samples was determined by gravimetric method on the assay balance VLR 200. Diameter of the steel disc of friction machine was 350 mm with the roughness of working surface R_a = 0,16 mcm.

Before starting the study, each sample of the composite material passed run-in in operating mode until full contact with the disc material was achieved. The parameters of operating mode of the studies were following: slip speed was 1 m/s; specific load in friction couple was питоме 1,5 MPa; friction path was 1000 m.

Hardness was determined using hardometer 2074 TPR according to Rockwell scale (HRLS). The study of the friction surface of the developed organoplastics was carried out on a scanning electron microscope «Hitachi SU1510». Roughness of the samples was measured using profilometer 170621 by dint of sharp and hard needle (probe) that moved on the studied surface copying its roughness.

Discussion of the results of the research

The results of tribological studiers fig. 1) showed the following: under identical conditions, deveoped organoplastics exceed the base polymer in intensity of wear and friction coefficient by 369-543 times and 15 - 40 % accordingly. These results can be explained in the following way.

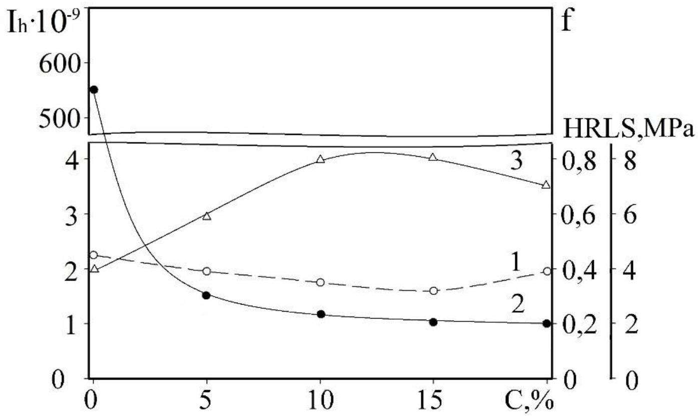


Fig.1 – Influence of polysulfonamide fiber on friction coefficient (1), wear (2) and hardness (3) of organoplatics based on polytetrafluorethylene

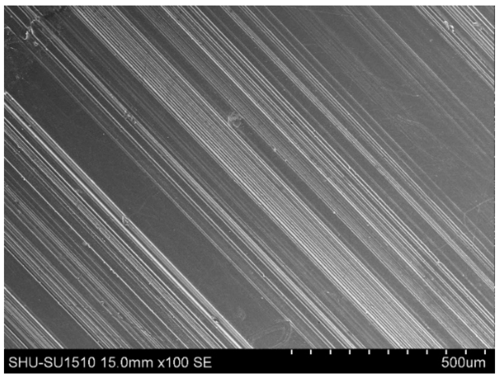
One the one hand, the introduction of the filler leads to an increase in the hardness of polymer matrix by 33 - 50 % that can be explained both by the high hardness of the filler and by the ordering of the structure of PTFE which is characterized by layered arrangement of molecules; the distance between the layers changes in the process of friction that weakens the intermolecular interaction and leads to decrease of relative displacement resistance, and at the macro level this is reflected in a decrease in friction force [9, 10].

On the other hand, a stable transfer film appears on the surface of counterbody (fig. 2, a) that acts as a dry film lubrication and plays a crucial role in the process of friction and wear for PCMs based on polytetrafluorethylene. The formation of transfer film can be explained as follows: finely divided products of wear form in the process of friction of OPs on a steel disc, they fill the micro cavities on the surface of counterbody, and at the same time friction is no longer realized on steel, but on products of wear; as a result, shear deformations are localized inside the film which has low shear resistance that leads to decrease of friction force [11, 12].

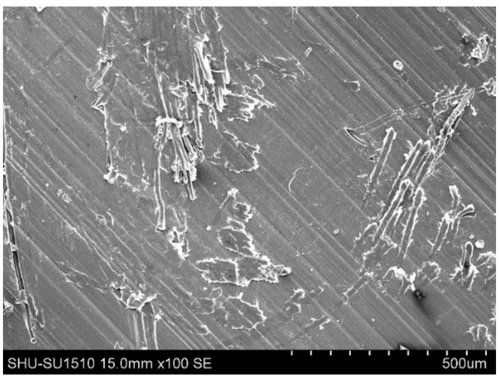
From fig. 2 we can see that when the output polymer friction is under friction deep grooves are formed on its surface; irregularities of the harder surface (of counterbody) plow the softer surface (of PTFE) forming friction path that indicates an adhesive wear mechanism. The distinctive feature of it is frictional transfer of tapes of binder on the surface of counterbody that is due to the presence of local bonds between contacting surfaces [12]. The study of friction surface of OPs (fig.2, b) showed that when the samples were abraded a smooth glassy surface was formed (an increase in the actual contact area occurs). On the surface chaotically placed organic fibers are clearly visible, the surface layer of the material is characterized by low friction coefficient and wear. These facts indicate that there is pseudoelastic mechanism of detrition of organoplastics between the sample and counterbody.

According to the amount of OFs, it can be determined that the optimal content is 10 - 15 mass. %. Addition of the amount of the fiber in composition up to 20 mass. % leads to the increase of friction coefficient by 22 % that is due to decrease in the hardness of organoplastic (fig. 1, curve 3).

a



b



c

Fig. 2 – Microstructure of (× 100):
a – transfer film that contains 10 mass. % of the filler;
and friction surfaces of:
b – polytetrafluorethylene;
c – organoplastic that contains 10 mass. % of fiber Talon

It is known [13] that roughness makes one of the important contributions to improving general tribotechnical characteristics, because if we decrease it specific pressure in the areas of contact decreases. In the study of microrelief and morphology of friction surfaces of the output polymer and OPs on its base (fig. 2), it can be seen that the introduction of the fiber reduces roughness by 2,1 - 3,3 times (fig. 3). In addition, abrupt wear reduction of OPs (by two orders of magnitude) in comparison with output material can be explained by the fact that the fiber, while concentrating on the friction surface, forms cluster structures with the fragments of binder (which are in crude approximation of (fig. 4) fiber aggregations which interacts with each other through the film layers of the matrix environment) that play a role of a protective screen which localizes shear deformations in its volume and prevents the destruction of surface layer of organoplastics [14].

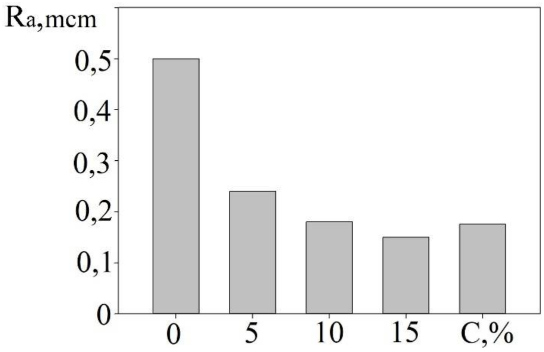


Fig. 3 – Influence of organic fiber on roughness of polytetrafluorethylene

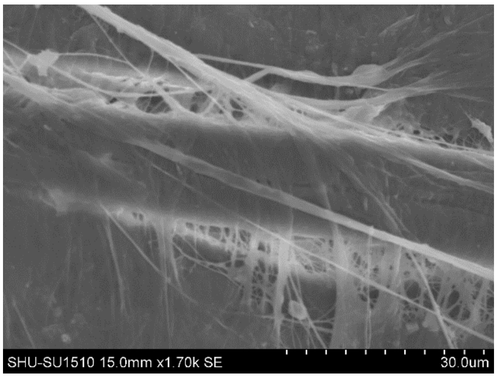


Fig. 4 – Microstructure (×1700) of: cluster of organoplastic that contains 10 mass. % of the fiber

Positive laboratory results allowed us to move to manufacturing tests. Experimental details were installed into the friction units of the drive mechanism of tge doffer of weaving machine Tongda TD set on NPO "Sinergiia" (fig. 5) that worked in the conditions of friction without lubrication, increased pollution and vibration. The details replaced serial rolling bearings made from cast iron. The divergence from the norm of the work of experimental units was not found during 8640 hours.

a **b**

Fig. 5 – Friction unit of the drive mechanism of the doffer of weaving machine Tongda TD from cast iron (a) and organoplastic (b)

Conclusions

On the whole, the analysis of tribotechnical characteristics of the developed organoplastics shows that the using of organic Talon T700 5-15 mass.% fiber as a filler is a promising way of improving the wear resistance of polymer materials while reducing friction coefficient at the same time. Thereby this organoplastic can be recommended as material for manufacturing of the details of moving joints of machines and mechanisms which are able to work in the conditions of friction without lubrication.

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Буря О.І., Калініченко С.В., Томіна А.-М.В., Начовний І.І. **Розробка органопластику триботехнічного призначення.**

Відомо, що полімерні матеріали з високим рівнем експлуатаційних властивостей, дозволяють по новому вирішувати ряд технічних питань, спрямованих на підвищення надійності роботи і збільшення терміну служби вузлів тертя машин і механізмів. Перш за все це пояснюється тим, що традиційні матеріали (сталь, чавун, бабіт, бронза та ін.) не завжди відповідають потребам сучасної інженерної практики.

Полімерні матеріали зміцнені органічними волокнами – органопластики (ОП) за обсягами виробництва перевершують сталь, алюміній і пластмаси завдяки своїм унікальним властивостям: високій хімічній стійкості, низькій густині (вони легше вугле- і склопластиків), здатністю до тривалого накопичення ушкоджень без утворення критичної тріщини. Великого застосування знаходять ОП на основі на термопластичних в'яжучих, одними з популярних термостійких представників яких є фторполімери, які відомі своєю винятковою стійкістю до дії хімічних речовин і корозії, температурою короткочасного нагріву до 533 К і природною змащувальною здатністю.

В статті розглянуто вплив вмісту органічного волокна Танлон марки Т700 на трибологічні властивості органопластиків на основі політетрафторетилену. Показано, що в умовах тертя без змащування введення наповнювача позитивно впливає на вихідний полімер: зменшує коефіцієнт тертя на 15-40% та зношування на два порядки (з 91,75 до 0,15). Розроблена композиція може бути використана для виготовлення деталей рухомих з'єднань машин і механізмів, які використовуються у різних сферах промисловості.

Ключові слова: органопластик, політетрафторетилен, полісульфонамід, коефіцієнт тертя, зношування.