



The impact of organic tanlon fiber on performance indicators of polychlorotrifluoroethylene

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Abstract

The impact of organic polysulfonamide Tanlon T700 fiber on the tribological and thermophysical properties of polychlorotrifluoroethylene is considered in the article. As a result of the researches, it was found out that developed organoplastics exceed base polymer in intensity of linear wear and coefficient of thermal linear growth by 2,5-7,5 times and by 25 %. That is due to the decrease in the size of structural elements of supramolecular structure which becomes more orderly and better focused. The results of the research show that developed composition with optimal fiber content (15 mass.%) can be recommended for the manufacturing of the parts of moving joints of machines and mechanisms in various industries.

Keywords: organic fiber, polysulfonamide, polychlorotrifluoroethylene, wear, coefficient of thermal linear growth, performance indicators

Introduction

Polymer materials (PM) are highly efficient substitutes for structural materials both economically and technologically. On the practical side, the process of manufacturing of parts from PM is characterized with minimum energy consumption and production automation (getting several products for one cycle of formation) [1]; it also completely exclude further labour-intensive and expensive machining operations (even if we are talking about complex geometric shape) [2]. However, there are the factors that constrain widespread introduction of PM. While exploiting, friction units of machines and mechanisms, which are equipped with polymer parts, undergo intensive wear and thermal distortion under the action of variable loads and temperatures [3]. As a result, premature failure of the parts of tribosystems occurs. Therefore, there is a stop of the equipment operation connected with its repair. That leads to a significant economic loss [4].

That is why, nowadays, the actual tasks of modern material science are purposeful increase in wear resistance and decrease of coefficient of thermal linear growth (CTLG) of PM working in tribocompounds of automotive and agricultural machinery, metallurgical and weaving industries [5].

Purpose and Problem Statement

Organic fibers (OF) are perspective fillers for solving this task due to their unique properties (steady friction coefficient, lightness, strength, hygroscopicity etc.) [6]. Composite materials reinforced with OF are characterized with low density (as a result, the mass of the part with PM is 2-5 times less in comparison with the mass of the serial metal part), high resistance to shocks and dynamic loads, stability of the work under the influence of aggressive environment and high humidity etc [7].

Taking into account the above, the purpose of the work was in the researches of the impact of organic polysulfonamide Tanlon T700 fiber on the intensity of linear wear and CTLG of polymer material – polychlorotrifluoroethylene (PCTFE).

Objects and Methods of Researches

Polychlorotrifluoroethylene was used as a polymer matrix [-CF₂-CFCl-] (see Table 1). It is a white dispersed powder that is characterized with high compressive strength, chemical resistance and plasticity; it is also easily machined that allows making the product with exact sizes.



Table 1

Main properties of polychlorotrifluoroethylene [8]

Indicator	Value
Density, g/cm ³	2,1-2,16
Vicat softening temperature, K	403
Water resistance (growth in water), %	0,00-0,01
Degree of crystallinity, at room temperature, K	40-70

Organic polysulfonamide Tanlon T700 fiber (made in Shanghai) was chosen as filler (see Table. 2.). The samples with different ratio of components were made due to the determination of optimal content of organoplastics (OP).

Table 2

Main properties of the fiber [9]

Indicator	Value
Density, g/cm ³	1,42
Strength, MPa	650
Lengthening, %	20-25
Elastic modulus, MPa	7450

The preparation of OP based on PCTFE that contains 5-20 mass.% of discrete Tanlon T700 fiber was carried out by the method of dry mixing in the apparatus with rotating electromagnetic field (0,12 Ts) with the help of ferromagnetic particles which were magnetically separated then.

Ready mix was tableted at room temperature and at pressure of 40 MPa. . Received blanks were loaded in a press-form heated to 423 K, then the temperature was increased to 510-515 K. The blanks were kept at such temperature during 10 minutes, then they were kept at pressure of 40 MPa. Due to the fixation of the form, the product was cooled at permanent pressure to the temperature of 490-495 K and pushed out of the mold in water for hardening. [10].

Tribological properties were studied in the conditions of friction without lubrication on reciprocating movement machine at pressure of 1,5 MPa, sliding speed of 1 m/s. Sliding distance was 1000 m. The samples of composition were cylindrical Ø=10, h=10 mm; steel 45 was used as a counterbody (45-48 HRC, Ra=0,16-0,32 µm).

Before the start of the researches, each sample of the material underwent wear-in, while in operation, to achieve full contact with the material of counterbody. Wear of the samples was determined by weight method on analytical balance VLR-200 (GOST (State Standard) 24104-80) with an accuracy of 0,0001 g.

The intensity of linear wear (I_h) expressed with following ratio was taken as the main engineering characteristic:

$$I_h = \frac{\lambda}{\rho_T} \cdot \frac{dG}{A_a \cdot dL_T},$$

$$\lambda = \frac{A_a}{A_T},$$

where G is the value of mass wear; ρ_T is the density of material that wear out; A_a is the nominal area of the contact; L is sliding distance; A_T is the nominal area of friction.

When calculating, it was believed that $\lambda=1$, that is, we studied the wear of the body which had all the points of surface in contact.

Hardness was determined by 2074 TPR durometer on Rockwell scale (HRLS) according to GOST (State Standard) 24622-91. The researches of the friction surface of developed OP were carried out with the help of «NEOPHOT» optical microscope.

Coefficient of thermal linear growth was determined using DKV-5AV dilatometer according to GOST (State Standard) 15173-70.

Discussion of the Results of the Research

The results of tribological researches in the conditions of friction without lubrication (fig. 1, curve 1) showed following: developed organoplastics exceed base polymer in intensity of wear by 2,5-7,5 times. These results can be explained by increase of elastic modulus and yield strength of PCTFE, while introducing Tanlon T700 OF, by 45-69 % and 14-22 % respectively (studied by the authors in the work [11]) as a result of decrease in the sizes of structural elements of supramolecular structure which becomes more orderly and better focused [12].

The study of friction surface of PCTFE showed that there were deep furrows of ploughing of surface layer on its surface (fig. 2, a). That is due to its low hardness (fig. 1, curve 2). The introduction of OF leads to the increase in hardness of polymer matrix by 30-60 % (fig. 1, curve 2) [13] resulting in the increasing of resistance to deformations. As a result, while detrition of the samples, smoother surface is formed, the products of wear are formed in small quantities and are mainly removed out of the bonds of counterbody in the process of friction (fig. 2, b).

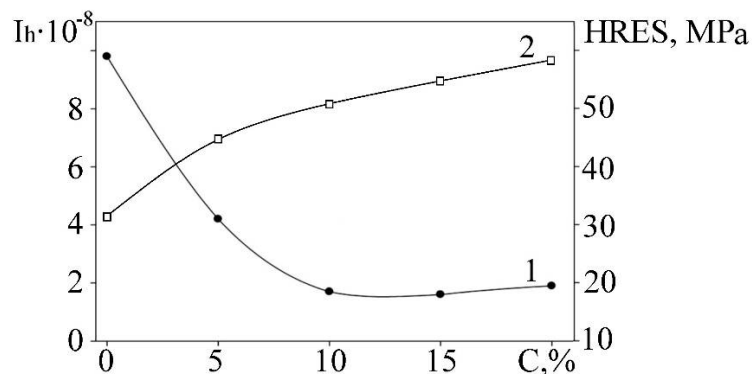


Fig.1. The impact of the content of polysulfonamide Tanlon T700 fiber on the intensity of linear wear (1) and hardness (2) of polychlorotrifluoroethylene

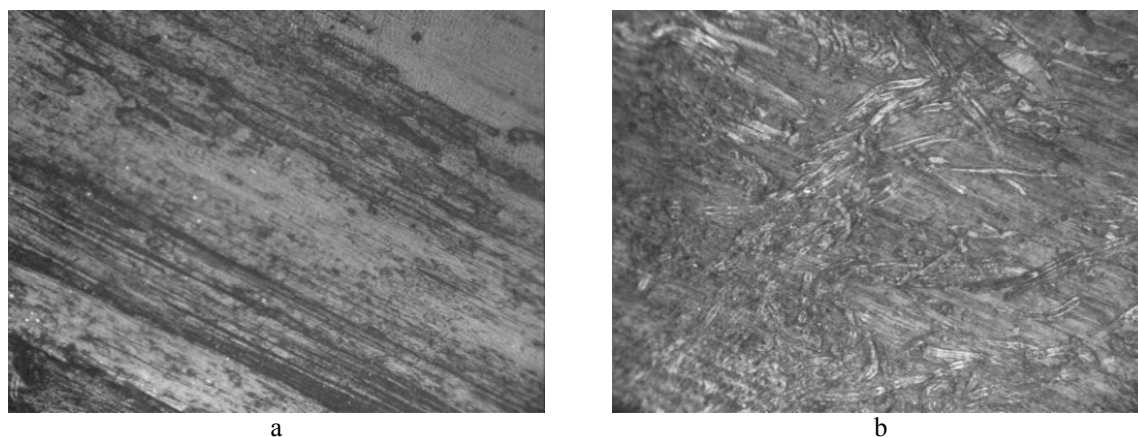


Fig.2. Microstructure (×100) of the friction surface of polychlorotrifluoroethylene (a) and organoplastic (b) that contains 15 mass.% of Tanlon fiber

The increase in the load while friction of OP that contain Tanlon T700 OF (fig. 3,4) leads to the expected increase in intensity of linear wear. For the OP reinforced with 20 mass% of the fiber this indicator is 1,4 and 3,7 times higher at 2,3 and 3,2 MPa than at 1,5 MPa.

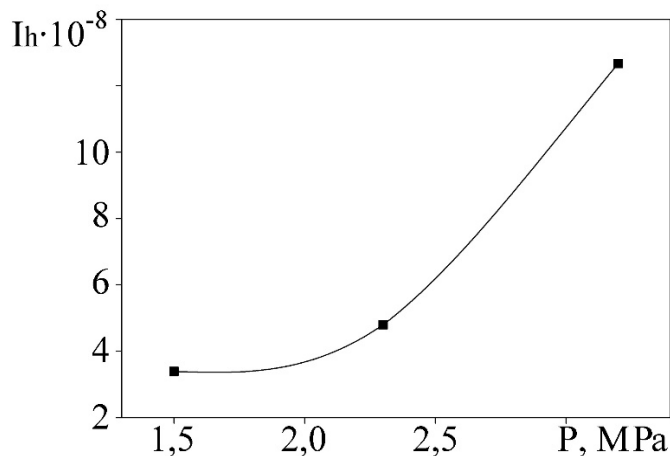


Fig.3. The impact of the load on the intensity of linear wear of the organoplastic based on polychlorotrifluoroethylene reinforced with 20 mass.% of Tanlon fiber



Fig.4. The surfaces of counterbody that worked in the pair with organoplastic based on polychlorotrifluoroethylene reinforced with 20 mass.% of Tanlon fiber at the load: 1,5(a); 2,3(b); 3,2(c) MPa

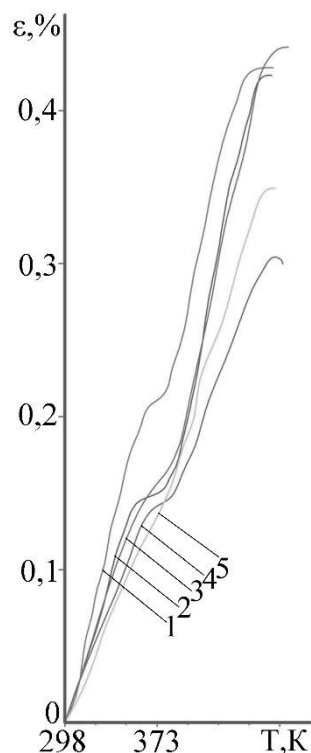


Fig.5. The dependence of elongation on the temperature of PCTFE (1) and organoplastics that contain 5(2); 10(3), 15(4), 20 (5) mass.% of the fiber

It is interesting to indicate that there the correlation between tribological and thermomechanical properties of OP occurs. Research on the curves «elongation (ϵ) – temperature (T)» (fig. 5) showed that the introduction of the filler leads to the decrease of thermal deformation of PCTFE by 25%. It can be explained by intercomponent interaction between the binder and OF through the formation of boundary layers of PCTFE around the fiber. It is known [14] that macromolecules of «binder-fiber» boundary layers are located in parallel with fiber surface, in so doing, the skeleton of macromolecules of PCTFE «straightens up» that provides more dense packing and, as a result, decrease of their mobility.

Positive results of laboratory tests allowed us to go to occupational studies.

Experimental sliding bearings from the proposed OP (fig. 6) with optimal content of the fiber (15 mass.%) were installed in crank mechanism of SO-7B reciprocating air compressor on LLC «Pathon-Elektrod» instead of serial ones which were made from babbit. This mechanism was chosen due to the fact that it is one of the main parts of the SO-7B compressor (fig. 7).

Proposed bearings were working during 2160 hours without fail. That allows recommending them to introduction in the serial production.



Fig.6. Friction unit of the mechanism of crank mechanism of SO-7B reciprocating compressor

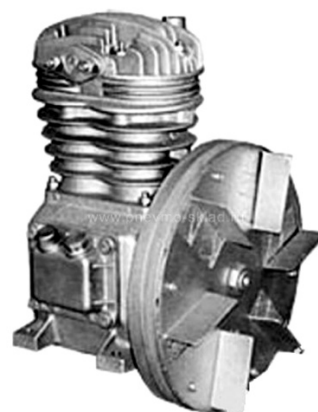


Fig.7. SO-7B reciprocating compressor

Conclusion

In general, the analysis of tribotechnical and thermomechanical properties of the developed organoplastics shows that the use of organic Tanlon T700 fiber as a filler is a perspective way of increasing exploitation characteristics (decrease in wear and thermal deformation) of polymer materials. Due to this fact, this organoplastic can be recommended for the manufacturing of the parts of moving joints of machines and mechanisms that are able to work at high temperatures in the conditions of friction without lubrication.

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Буря О.І., Калініченко С.В., Томіна А.-М.В., Начовний І.І. Вплив органічного волокна Танлон на експлуатаційні показники політрифторхлоретилену

Полімерні матеріали є високоефективними заміниками конструкційних матеріалів як в економічному, так і технологічному плані. Процес виготовлення деталей із полімерних матеріалів із практичної сторони характеризується мінімальною енергоємністю та автоматизацією виробництва (отримання за один цикл формування декількох виробів), повністю виключає подальші трудомісткі та дорогі операції механічної обробки (навіть складної геометричної форми). Але, існують фактори які стримують широке впровадження ПМ. В процесі експлуатації вузли тертя машин та механізмів укомплектовані полімерними деталями, під дією змінних навантажень та температур зазнають інтенсивного зношування та теплової деформації. В результаті чого актуальною задачею сучасного матеріалознавства є розробка полімерних композитів, зміцнених органічними волокнами, з підвищеними експлуатаційними характеристиками.

У статті розглянуто вплив органічного волокна полісульфонамід марки Танлон Т700 на трибологічні та теплофізичні характеристики політрифторхлоретилену. В результаті проведених досліджень встановлено, що розроблені органопластики перевершують базовий полімер за інтенсивністю лінійного зношування та коефіцієнтом термічного лінійного розширення в 2,5-7,5 рази та на 25 %, що обумовлено зменшенням розмірів структурних елементів надмолекулярної структури, яка стає більш впорядкованою і орієнтованою. Отримані результати досліджень свідчать, що розроблена композиція з оптимальним вмістом волокна (15 мас.%) може бути рекомендована для виготовлення деталей рухомих з'єднань машин і механізмів, які використовуються у різних сферах промисловості.

Ключові слова: органічне волокно, полісульфонамід, політрифторхлоретилен, зношування, коефіцієнт термічного лінійного розширення, експлуатаційні характеристики.