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The impact of organic fibers on the tribotechnical properties of phenylone aromatic polyamide

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Abstract

The impact of such organic fibers as Lola, Oxalon and Tanlon on the tribotechnical properties of phenylone aromatic polyamide is considered in the article. It was found that the most intensive improvement of tribotechnical properties of initial polymer, reduce in the intensity of linear wear and friction coefficient 1,8 - 6,5 and 1,7 - 2,3 times is observed for the composites reinforced with organic Lola and Oxalon fibers. The obtained results are due to the introduction of Lola and Oxalon fibers that leads to the formation of new structural elements – fibrils which give improved complex of tribotechnical properties to composites. The use of Tanlon fiber as a filler for formation of organoplastics of tribotechnical purpose leads to modest improvement of the intensity of linear wear and friction coefficient (on average by 20 %) that is due to the proximity of structure of binder and filler.

Key words: organic fiber, Lola, Oxalon, Tanlon, intensity of linear wear, friction coefficient.

Introduction

Nowadays, polymer composite materials (PCM) (including the ones that are based on aromatic polyamides) which are reinforced with mineral fillers (graphite, disulfide, molybdenum, sulfur molybdenum) are among the most widespread polymer materials of tribotechnical purpose [1]. Valuable complex of technological and operational properties provides their intensive usage in agricultural and automotive equipment, heavy and light industries [2].

However, there are factors that hold back the use of them in heavily loaded friction units of modern technics. So, tribotechnical properties do not satisfy working conditions in some cases in the conditions of friction without lubrication at increased loads and speeds. In particular, intensive wear is due to their low enough values of physic-mechanical and thermal properties [3].

The determination of goals and targets

The use of organic fibers (OF) as fillers for polyamides is a perspective way of improvement of their tribotechnical properties. The use of OF allows to get the composites that unite a valuable complex of such operational properties as high reliability (thanks to the increase in wear and chemical resistance, fatigue strength and ability to damp mechanical and sound vibrations), cost-effectiveness (excluding machining from the technological process of manufacturing even when receiving the parts of non-standard shape) and environmental friendliness (the possibility of recycling and self-lubricating ability) [4].

Taking into account the above, the target of the work was in the researches on the impact of organic fibers on the intensity of linear wear and friction coefficient of C-1 phenylone aromatic polyamide.

Objects and methods of the researches

C-1 aromatic polyamide was used as polymer matrix for creation of organoplastics (OP) of tribotechnical purpose. PCM on its base are usually characterized with high values of hardness, strength and stiffness, stability of physic-mechanical values at elevated temperatures (to 523 K) [5]. Polyoxidiazole (Oxalon, “Svitlogorsk Himvolokno”, Belorussia), polyacrylonitrile (Lola, All-Russian Reasearch Institute of Polymer Fibers (ВНДІПВ), Russia) and polysulfonamide (T700 Tanlon, «Shanghai Tanlon Fiber Co., Shanghai) organic fibers were chosen as fillers [6, 7].

The preparation of organoplastics based on phenylone that contain 5 - 20 mass% of the fiber (length is 3 - 7 mm) was made by the method of dry mixing in the apparatus with rotating ferromagnetic field (0,12 T) with the help of ferromagnetic particles. Then the particles were removed from the prepared mixes by the method of magnetic separation. The formation of ready products was carried out by the method of compression moulding.

Scanning electron microscope UEMV-100K was used for the analysis of the morphology of the structural change of polymer matrix while introduction of organic fiber. The analysis of crystalline fracture of the samples, which were received under the influence of liquid nitrogen, with previously spraying graphite film on the researched surface, was carried out.

Tribotechnical properties in the conditions of friction without lubrication according to the "disc-pad" scheme were studied on SMC-2 friction machine at load of 1,0 MPa, sliding velocity of 1,0 m/s. Steel 45 was used as a counterbody (45 - 48 HRC, Ra = 0,32 mcm).

Friction coefficient was calculated by the formula:

$$f = \frac{M}{R \cdot F^{'}},$$

where M – is the moment of force that acts on the sample;

F – friction force of the sample under the test;

R – is the radius of counterbody.

The intensity of linear wear (I_h) expressed as a following dimensionless ratio was taken as the main engineering property:

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

where – $\lambda = \frac{A_a}{A_T}$;

G – is the value of mas wear;

ρ_T – is the density of the material that wears out ;

A_a – is the nominal area of contact;

L – is the path of friction;

A_T is the nominal area of friction.

In the calculations, it was considered that $\lambda = 1$, that is, the wear of the body with all friction points of the surface in contact was studied.

Roughness of the samples was measured on 170621 profilometer using sharp firm needle (probe) that moves along the surface copying its roughness.

The study of friction surface of the developed organoplastics was carried out using «NEOPHOT» optical microscope.

The discuss of the results

The results of tribotechnical properties of organoplastics in the conditions of friction without lubrication show that the use of Lola, Oxalon and Tanlon organic fibers (table 1) is a perspective way of improvement of tribological properties of initial polymer. It is found that the use of Lola and Oxalon organic fibers makes the most effective impact on the improvement of tribotechnical properties of phenylone.

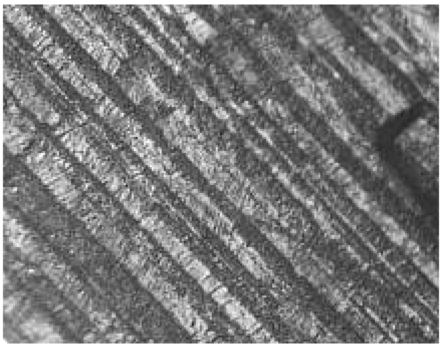
The introduction of Lola and Oxalon organic fibers in the amount of 5 - 20 mass % leads to reduce in the intensity of linear wear and friction coefficient of phenylone 1,8 - 6,5 and 1,7 - 2,3 times reaching minimal values at the content of 15 - 20 mass % of the filler. The increase in wear resistance of basic polymer is connected, from the one hand, with the increase in hardness of organoplastics as it is showed in the work [8, 9].

It should be noted that tribological properties of the developed composites are well-consistent with Ratner regularity which connects tribotechnical and strength properties of materials. It is found that the roughness of the surface for organoplastics reinforced with Lola (Ra = 0,22 mcm) and Oxalon (Ra = 0,27 mcm) fibers is lower by 50 % in comparison with phenylone (Ra = 0,56 mcm) that is due to the increase in the strength of OP. Thanks to this specific load reduces in the areas of "composite-steel counterbody" contact [10] and, as a result, friction coefficient improves.

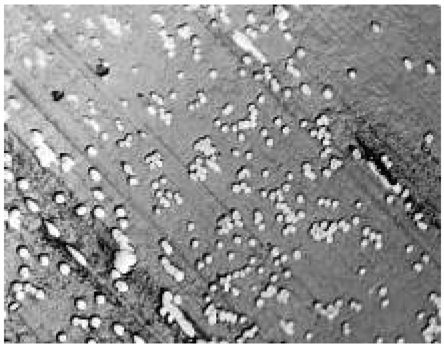
Table 1

The impact of the content of organic fibers on the tribological properties of C-1 phenylone

Content of the fiber, mass %	Friction coefficient, f	Intensity of linear wear, $I_h \cdot 10^{-8}$
-	0,42	7,43
Lola		
5	0,25	4,18
10	0,2	1,35
15	0,18	1,2
20	0,18	1,15
Oxalon		
5	0,32	2,90
10	0,31	1,89
15	0,3	1,54
20	0,35	1,58
Tanlon		
5	0,37	6,91
10	0,33	5,98
15	0,32	6,11
20	0,32	6,16



a



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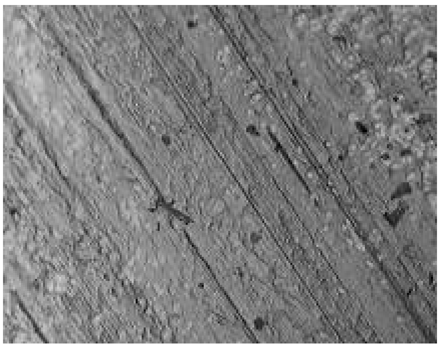
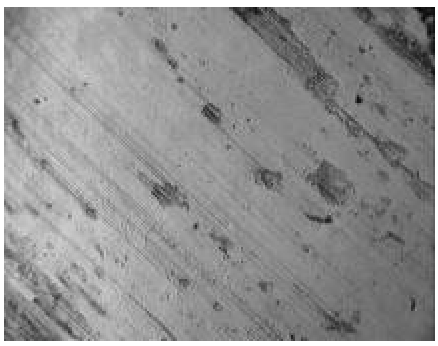


c



d

Fig. 1. Microstructure (×150) of phenylone (a) and organoplastic on its base reinforced with 10 mass % of Lola (b), Oxalon (c) and Tanlon (d) fiber

One more factor that influences on the reduction in friction coefficient is the formation of "antifriction layer" – transfer film on the steel counterbody. Transfer film provides the stability of friction and wear processes due to the self-organization of the structure of surface layers of tribopair. In so doing, several particles, which appeared during wear process and didn't't go to transfer film, are removed from the friction area by tangential velocity component. Due to these factors lifetime of frictional bond between counterbody and sample decreases [11] that reduces friction coefficient additionally.

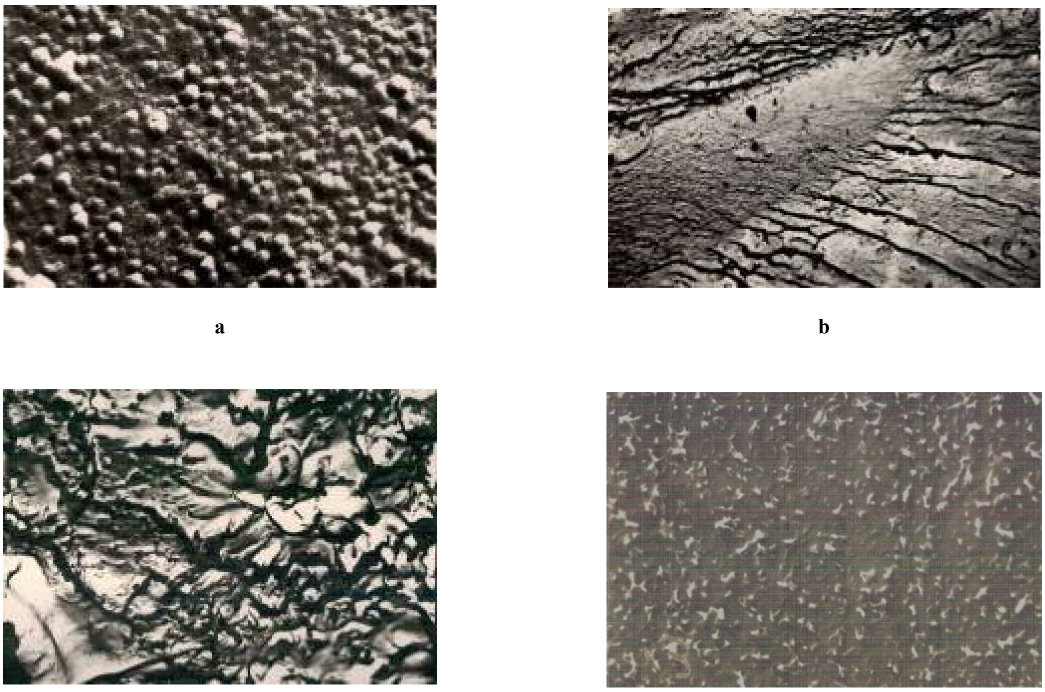
It is also should be noted that when "antifriction layer" spreads on the surface of steel counterbody, following friction happens according to "polymer-polymer" scheme and counterboudy is removed from wear process.

From the other hand, the increase in wear resistance of OP is due to the increased ability of the materials to diffuse energy through the decrease in internal friction as a result of change in the structure of polymer binder that leads to reduce in surface layers temperature. As a result, we almost do not observe the traces of grasping on the friction surfaces of OP (fig. 1, b, c) in contradistinction to polyamide [12].

With regard to Tanlon, the results of researches showed (table1) that the introduction of the fiber leads to slight decrease in the intensity of linear wear and friction coefficient of initial polymer (1,2 and 1,3 times) reaching minimal values at the content of 10 mass % of the fiber. The study of the microstructure of phenylone (fig. 1, a) friction surfaces showed that the introduction of Tanlon organic fiber (fig. 1, b, Ra = 0,32 mcm) was accompanied by reduction in furrows of ploughing by 25 % that was due to inhibition of the development of destruction processes on the friction surface of composite [13].

Obtained results can be explained in such way. It is known [8] that when creating composites of tribotechnical purpose, the interaction on "binder-fiber" division border is determinative, as a result a new boundary layer with more ordered supramolecular structure with improved complex of physic-mechanical and tribological properties forms. Thus, the formed interphase layer significantly affects cohesive and adhesive destruction in the volume of composite and on the division border, the character and value of loads which occur in polymer binder. In particular, it characterizes the resistance of composites to the impact if extreme factors (the effect of increased temperatures and aggressive environments).

Electron microscopic investigations of organoplastics (fig. 2) reinforced with Lola and Oxalon fibers demonstrate essential changes in the character of breaking away of initial polymer in the presence of these fibers. Globular structure of phenylone (that is typical for amorphous plastics) is clearly visible on the fig. 2, a, while the introduction of polyarylene and polyoxadisiol fibers leads to the configuration of the structure into a febrile one (fig. 2, b and c).



a b

c d

Fig. 2 – Microstructure (×10000) of basic polymer (a) and organoplastics on its base that contain Lola (15 mass %, b), Oxalon (15 mass %, c) and Tanlon (10 mass %, d) fibers

It should be noted that the introduction of Tanlon fiber does not leads to essential change of the structure (fig. 2, d), that is why, as a result, a slight improvement of tribotechnical properties for these organoplastics is observed; that is well-consistent with literature data [14]. The use of polysulfonamide fiber as a filler for phenylone does not allow to reach new structural element, that are fibrils, in the cross-border layer and on the division "matrix-filler" border.

Conclusions

In general, the reinforcement of phenylone with Lola and Oxalon fibers can be viewed as a process that promotes structural rebuilding in binder, transformation of globular structure into a febrile one which is characterized by higher indicators of tribotechnical properties. Thus, the reduce in wear and friction coefficient of basic polymer on average 6,5 and 2,3 times occurs, That allows to recommend obtained organoplastics for manufacturing of slide bearings for modern equipment which is able to work in the conditions of friction without lubrication. With regard to Tanlon fiber, the use of it as a filler is not effective enough for creation the composites of tribotechnical purpose.

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Буря О.І., Томіна А.-М.В., Єрьоміна К.А., Томін С.В. Вплив органічних волокон на триботехнічні характеристики ароматичного поліаміду фенілон.

Композиційні матеріали на основі ароматичних поліамідів, зміцнених органічними волокнами сьогодні є одними з розповсюджених матеріалів триботехнічного призначення для вузлів тертя та механізмів сучасної техніки. Цінний комплекс технологічних і експлуатаційних характеристик даних полімерних композиційних матеріалів забезпечує їх інтенсивне використання в сільськогосподарській та автомобільній техніці, важкій і легкій промисловості. Зокрема, використання органопластиків дозволяє зменшити матеріалоємність деталей при одночасному збільшенні їх надійності та робочого ресурсу.

У статті розглянуто вплив органічних волокон: Лола, Оксалон і Танлон на триботехнічні характеристики ароматичного поліаміду фенілон. Встановлено, що найбільш інтенсивне покращення трибологічних властивостей вихідного полімеру, зменшення інтенсивності лінійного зношування та коефіцієнту тертя у 1,8 - 6,5 та 1,7 - 2,3 рази, спостерігається для композитів зміцнених органічними волокнами Лола та Оксалон. Отримані результати обумовлені тим, що введення волокон Лола та Оксалон призводить до утворення нових структурних елементів – фібрил, які надають композиту покращений комплекс триботехнічних характеристик. Використання як наповнювача волокна Танлон для створення органопластиків триботехнічного призначення призводить до незначного покращення інтенсивності лінійного зношування та коефіцієнту тертя (в середньому на 20 %), що обумовлено близькістю структури в’яжучого та наповнювача.

Ключові слова: органічне волокно, Лола, Оксалон, Танлон, інтенсивність лінійного зношування, коефіцієнт тертя.