ELABORATION AND USING OF COMPOSITES BASED ON PHENYLONE AS FRICTION-TYPE BEARINGS OF PLATE CHAINS

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Abstract: Composites based on phenylone exceed serially released materials by wear-resistance without lubrication and by lubrication in 7 - 19 times by simultaneous decrease of friction coefficient on 20-30 %.

Keywords: composites, phenylone, wear-resistance, friction coefficient

1. INTRODUCTION

The researches of Ukrainian scientists show that nowadays only 10-15 % of machines and mechanisms details get out of order because of inadequate strength, the rest of them do because of wear, that's why the aim to increase wear-resistance of moving parts has the leading position in solving a problem of the modern equipment reliabilization [1].

The appliance of polymers as antifriction materials contribute towards reliability and long-term strength, sometimes allows simplifying design and manufacturing technology to make friction units. Nowadays sliding bearings based on thermoset and acyclic polymers are widely-used in the industry. Together with important physical and mechanical properties (low specific density, high mechanical strength, scoring resistance in restricted feeding of lubricant, high elasticity, damping ability etc.) these polymers have low heat-resisting quality (to 433 K), that's why their usage in higher-temperature of the environment and in heavy-duty operating conditions is limited.

Consequently, one of the main directions of polymer chemistry is to create thermo-resistant polymers which can endure high-temperature exposure during a long time without noticeable deterioration of strength properties. Aromatic polyamide phenylone is such polymer of structural purpose, which has continuous exploitation to temperature 523 K and is second in strength only to the best brands of reinforced plastics.

Composites where polymers serve as bonding matrix are one of the most numerous and various material types. Their usage in different branches gives significant economic effect. For instance, usage of polymers in producing of space and aeronautical equipment allows to save from 5 % to 30 % of flight vehicle weight. Therefore, weight reduction of artificial satellite in 1 kg on low earth orbit allows to save 1000 $.

Multitude of different materials are used as composite fillers. New types of organic fibers were elaborated among them over the last years, the most strong and hard fibers of them are those based on aromatic polyamide. Even a small amount of filler in composites of such type lead to brand new mechanical material properties. Change of orientation, the size and concentration of fibers allows to widely varying properties of material. Reinforcement of materials with fibers, filamentary crystals or wires significantly increases both material strength and thermal resistance.

Filling the aromatic polyamides with small-disperse metal powder is also forward-looking direction. By adding 5 %-10 % of reinforcing fillers (refractory oxides, nitrides, borides, carbides) resistance of matrix to load increases. The hardening effect is relatively small, but one can observe useful increase of composite thermal resistance compared to initial matrix.

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An available and almost unlimited raw material base for elaborating aromatic polyamides and a possibility of task-oriented complex of physical and mechanical properties on the basis of contain and structure changes allow concluding prospects of these polymers and necessity to study their properties.

In view of the foregoing, the objective of the study is to examine possibility of using developed materials to make details for metallurgical equipment, in particular plugs of plate chains.

2. SUBJECTS AND RESEARCH METHODS

Aromatic polyamide phenylene C-1 (TU 6-05-221-101-71) was used as polymeric matrix to make composite materials, titanium small-disperse powder (PTK-1(2), TU 14-22- 57-92) and fiber phenylene (F) with strength 676 MPa, elongation 15-20 %, elastic modulus - 8.8 - 11.77·10-3 MPa was used as fillers. The main press-powders properties are given in the table 1.

Table 1. The main components properties.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Component color</th>
<th>Density, kg/m³</th>
<th>Poured density, kg/m³</th>
<th>Melting temperature, K</th>
<th>Particles size</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>pink</td>
<td>1350</td>
<td>200 – 300</td>
<td>543*</td>
<td>35-50 mcm</td>
</tr>
<tr>
<td>Ti</td>
<td>silver-white</td>
<td>4505</td>
<td>2850</td>
<td>1933</td>
<td>30-40 mcm</td>
</tr>
<tr>
<td>F</td>
<td>beige</td>
<td>1370-1380</td>
<td>–</td>
<td>above 573</td>
<td>2-3 mm</td>
</tr>
</tbody>
</table>

* Softening temperature according to Vicat.

Moulded impregnated woods were prepared by mixing components in rotating electromagnetic field with equiaxial ferromagnetic particles [2]. The compounds made in such way, were pelleted on hydraulic press at room temperature and under pressure of 4 MPa, then the pelleted samples were dried in furnace at 473-523 K, because moulding process of undried phenylene deteriorate its strength properties and lead to surface damages. The dried and pelleted dies were processed into products by the compression moulding process at temperature 593 K and under pressure of 4 MPa; the holding at this temperature was 10 minutes.

To specify physical, mechanical and tribological properties three concurrent experiments were conducted in the researches. An arithmetic mean was considered as final result.

Density (ρ, kg/m³) was determined in regard to sample mass in the air G₁ to difference between sample mass in the air G₁ and sample mass in the water G₂:

\[ \rho = \frac{G_1}{(G_1 - G_2)} \]  \hspace{1cm} (1)

Impact strength (aₙ, kJ/m²) was determined by to the Charpy impact test, according to GOST 4647-80 on pendulum hummer KM-0.4, at temperature 296±2 K and relative degree of humidity 50±5 %. The principle of method consisted in experiment, whereby a sample lying on two supports (the distance between two supports was 40 mm), was destroyed on impact with pendulum. The impact hardness of samples was determined by the following formula:

\[ a_n = \frac{A_n}{b \cdot s \cdot 10^3} \]  \hspace{1cm} (2)

where An - impact energy, used for destroying of a sample without undercut, J; b – a sample width (on center), mm; h - a sample thickness (on center), mm.

The metal-polymer microstructure was studied with the help of optical microscope NEOFOT 32, the microstructure of organoplastics was studied by scanning electron microscope of high resolution SERIES JEOL JSM-6460 LV. Increase x 100.
3. CONSIDERATION OF RESULTS

The correct and reasonable selection of a material for friction-type bearings of plate chains indissolubly relates to in-depth study of friction and wear. The researches of indicated composite materials properties were conducted both under conditions of unlubricated friction and also in lubrication with oil «Industrial-50» on machine SMC-2.

While selection of friction testing machine and its working regime one can be motivated by possibility to obtain more important and essential results, which would allow to discover the essence of friction and wear. According to data from B.I. Kostetsky, the operation of crank journals and crank pins of the crankshafts, ball and rolling bearings and also of other details proceed under conditions of corrosive wear which is usually observed at relatively low slip velocity of friction pairs relative movement (0.05 - 2.5 m/s), in load range from 2.5 to 20 MPa [3]. These conditions can be totally achieved on friction machine SSC-2, which was used before.

Tribological properties in the friction regime without lubrication were determined by scheme disk-stock at unit load - 0.6 MPa [4]. Way of friction counted 1000 m, velocity of friction - 0.3 m/s. In the friction-sliding regime with lubrication «Industrial-50» oil, the load was 5 MPa, way of friction - 1000 m, velocity of friction - 1-1.3 m/s. As part of study, friction moment, rotational speed, impact strength, sample mass and operation cycles numbers were registered. The disc made of steel 45 (GOST 1050-88) was used as counter-body, its steel was heat-treated to hardness 45-48 HRC.

The samples wear was determined by gravimetric method on analytical balances WRL - 200 (GOST 24104-88) with an accuracy to 0.0002 g. The intensity of linear wear Ih was considered as the main engineer characteristic of the wear process:

\[ \text{Ih} = \lambda \cdot \frac{dG}{\rho T \cdot Aa \cdot dLT}, \]  

where: \( G \) - weight wear; \( LT \) - way of friction; \( Aa \) - nominal contact area; \( \rho T \) - abraded material density; \( \lambda = Aa / AT \), \( AT \) - nominal friction area (in the calculation \( \lambda \) was considered equal to 1, i.e. it was analysed body wear where all friction surfaces were in permanent contact).

Due to an innovative method of composite mixture it was possible to obtain perfect allocation of fillers in the polymeric matrix (Fig. 1), which led to improvement of their physical properties.

![Figure 1. Allocation fillers of small-disperse powder (a) and organic fiber (b).](image)

In the course of in-depth study of composites based on phenylone was discovered that materials with 15 mass. % of disperse filler or 5 mass % of fiber filler have the most optimal package of physical properties [5, 6]. In the following stage were performed comparative tests of friction-type bearings of plate chains made of serial and developed materials (Fig. 2).

By analyzing data is showed, that composites based on phenylone exceed serially released materials: by wear-resistance without lubrication - approximately in 7 times; by simultaneous decrease of friction coefficient on 20-30 %; by lubrication - in 8 - 19 times and in decreasing of F on 70 %; by impact
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hardness in 3-4 times, and by density decrease of products on 82-84 %. Thus lead to significant reduction of their mass.

![Figure 2](image.png)

Figure 2. Comparative material properties.

By results of researches, experimental lots of plugs of plate chains were made of the developed materials which successfully passed performance tests and recommended for use in a serial production; that means possibility of further usage of phenylene-based materials.

4. CONCLUSIONS

By results of the carried-out tests of the plates completed with sliding bearings from developed materials and in lots produced serially Romanite and bearing bronze Бп О5Ц5С5, it was established that operational characteristics of composites 5F and 15Ti considerably exceed indicators their analogues.

The advantages consist in less values of casting wear and friction coefficient, especially in 7-19 times and in 20-70 % correspondingly.

REFERENCES