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THE IMPACT OF BORON CARBIDE ON THE INDEX OF ABRASIVE WEAR OF PHENYLONE AROMATIC POLYAMIDE

The use of parts made of polymer composites instead of serial materials (bronze, kapron, babbitt) allows get the economic effect by reducing maintenance and repair costs. Disperse fillers (copper, aluminum, iron, bronze, tin, silver, lead, zinc, carbides, shungite, vermiculite, etc.) have become widespread for the creation of PCM with a high rate of wear resistance. Taking into account the above, the development and research of new wear-resistant PCM filled with dispersed fillers with improved properties is an actual scientific and technical task. The impact of boron carbide powder on the index of abrasive wear of aromatic polyamide phenylone C-2 is considered in the article. It is found that the introduction of the filler improves initial characteristics of polymer matrix: abrasive wear resistance of phenylone increases10 times. It is discovered that the effective content of the filler is 15 mass%. The study of the friction surface of the unfilled polymer showed that deep grooves are formed on its surface; and with the introduction of the filler they decrease by 75% because the appearance of boron carbide strengthens the polymer matrix, the modulus of elasticity and hardness increase by 40 and 12%. This improvement in physical and mechanical characteristics is probably due to the effect of interstructural filling, when finely dispersed particles of the polymer matrix under the influence of chemical and physical interaction form an interfacial layer on the surface of carbide particles with new improved properties. Based on the obtained results, a composite with an effective filler content (15 mass%) can be recommended for the manufacture of parts of automotive, road and agricultural machinery operating under the influence of abrasive particles.

Key words: *aromatic polyamide, phenylone, index of abrasive wear, polymer composite*

Introduction. Every year the amount of polymer composite materials (PCM) of tribotechnical purpose [1] based on thermoplastic binders grows up on the world market. It is due to their technological properties. The use of these composites allows to get the details with simplified manufacturing technology (the formation of product finishes in one cycle) and assembly, low weight, increased wear resistance to different factors, resistance to dynamic and vibroacoustic loads, corrosion damage and aggressive environments [2-4].

The determination of the task. One of the important tasks of materials science is to increase the reliability, increase the labour force and service life of modern equipment that in turn are closely related to the problem of wear resistance of parts of the friction units of machines and mechanisms. Because tribological joints of agricultural and automotive equipment work in conditions of high dust and dirt particles content and are vulnerable to abrasive wear [5]. The use of parts made of polymer composites instead of serial materials (bronze, kapron, babbitt) allows to solve this problem and get the economic effect by reducing maintenance and repair costs [6]. Disperse fillers (copper, aluminum, iron, bronze, tin, silver, lead, zinc, carbides, shungite, vermiculite, etc.) have become widespread for the creation of PCM with a high rate of wear resistance [7]. Taking into account the above, the development and research of

new wear-resistant PCM filled with dispersed fillers with improved properties is an actual scientific and technical task.

Goal of the work: the study of tribotechnical polymer composite materials based on aromatic polyamide phenylone C- 2 filled with boron carbide powder.

Objects and methods of the researches. Aromatic polyamide phenylone C-2 (APP) was chosen as a polymer matrix to create wear-resistant PCM. APP C-2 is characterized by high temperatures of long-term (up to 533 K) and short-term operation (up to 573 K), chemical and radiation resistance [8].

Boron carbide that is characterized by such high technical characteristics like microhardness (49.1 GPa), high wear resistance and modulus of elasticity was selected as a filler [9].

Preparation of phenylone C-2 compositions containing 5-20 mass% of the filler was carried out by the method of dry mixing in an apparatus with a rotating electromagnetic field (0.12 T) using ferromagnetic particles that were removed from the prepared composition by the method magnetic separation. Then the finished mixtures were tableted at room temperature and under a pressure of 25 MPa. The tablets were loaded into a mold heated to 523 K and heated them to 598 K and kept at this temperature for 5 minutes without pressure and 5 minutes under a pressure of 40 MPa. Next, the finished mixture was tableted at room temperature and a pressure of 25 MPa.

The study of materials for abrasive wear by fixed abrasive particles (sandpaper dispersion was 40-60 μm) was performed according to GOST (State Standard) 11012-69 on a Hecker test machine. The index of abrasive wear (V_i, mm^3/m) was determined according to the method described in the work [10].

The main indicators of compressive strength such as yield stress (σ_y.) and modulus of elasticity (E) in compression were determined on a universal FR-100 research machine in accordance with GOST (State Standard) 4651-78. Samples of cylindrical shape (Ø was 10 ± 0.5 mm and height was 15 ± 0.5 mm) were used for the study [10]. The hardness of PCM on the Vickers scale was determined using dynamic TD-42 hardness tester.

The study of the morphology of the friction surfaces of unfilled polymer and PCM based on it was performed using NEOPHOT-32 optical microscope.

The discuss of the results. The results of tribological studies of PCM under the conditions of friction on rigidly fixed abrasive particles are presented on fig.1. The analysis of the results of tribotechnical characteristics of the developed composites shows that the use of boron carbide as a filler is a promising way to reduce the abrasive wear of polymer matrix (reduces by 1.5-10 times). This conclusion is based on a significant reduction in ploughing furrows in comparison with APP C-2. The study of the friction surface of the unfilled polymer (fig. 2, *a*) showed that deep grooves are formed on its surface; and with the introduction of 15 mass% of the filler (fig. 2, *b*) they decrease by 75% because the appearance of boron carbide strengthens the polymer matrix (the modulus of elasticity and hardness increase by 40 and 12% (table 1)), and inhibits the development of cracks on the surface of the composite that increases the wear resistance of the systems [11].

This improvement in physical and mechanical characteristics is probably due to the effect of interstructural filling [12], when finely dispersed particles of the polymer matrix under the influence of chemical and physical interaction form an interfacial

layer on the surface of carbide particles with new improved properties. The greatest improvement in tribotechnical and physico-mechanical characteristics is observed at a filler content of 5-15 mass%; with further increase in the amount of boron carbide in the polymer matrix, their reduction is observed.

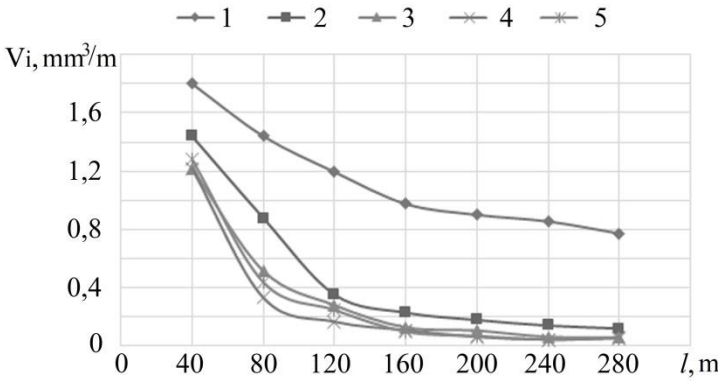

Fig. 1. The dependence of the index of abrasive wear of aromatic polyamide (1) and composites based on it containing 5 (2), 10 (3), 15 (4), 20 (5) mass% on the friction path

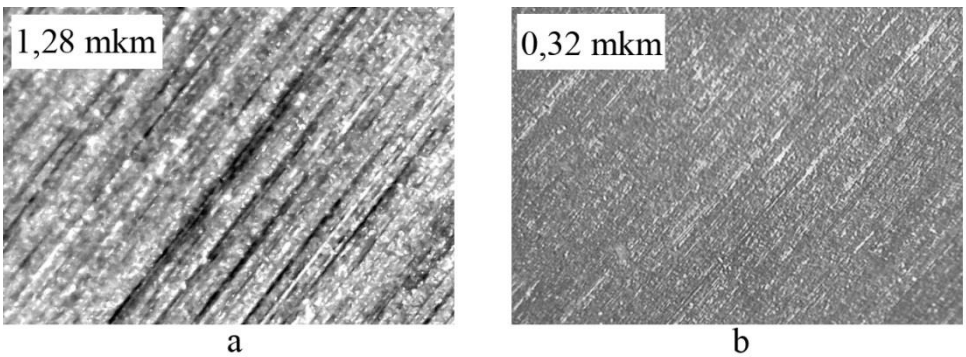

Fig.2. The morphology of the friction surface of phenylone C-2 (a) and composite based on it with a filler content of 15 (b) mass% of carbide alloy (× 100)

Table 1

Physico-mechanical characteristics of the composites filled with boron carbide

Index	Content of the filler, mass%				
	–	5	10	15	20
Modulus of elasticity, *E*, MPa	2749	3360	3410	3846	3170
yield stress ($\sigma_{y.}$) in compression, σ_y, MPa	212	216	218	225	216
Vickers hardness, *HV*, hardness unit	375	400	415	430	390

The obtained results can be explained by the fact that when the mass fraction of carbide increases to 20 mass%, it becomes more difficult to achieve its uniform distribution in the volume of the polymer matrix that leads to the formation of agglomerates of filler particles. As a result, insufficient wetting occurs between the binder and the filler that does not allow, firstly, to form interfacial layer on the surface of the filler particles, which is characterized by high tribological and physico-mechanical indicators; secondly, an uneven structure is formed that is a stress concentrator and reduces the strength of composite. The uneven distribution of the filler can be confirmed by comparing the experimental and cal-

culated density of PCM. At a mass fraction of carbide of 5-15 mass% hydrostatic density is greater than the additive, that is, the process of ordering the binder prevails over the process of disordering on the "phenylone-filler" bound; and an opposite situation occurs at the filler content of 20 mass% (see fig. 3).

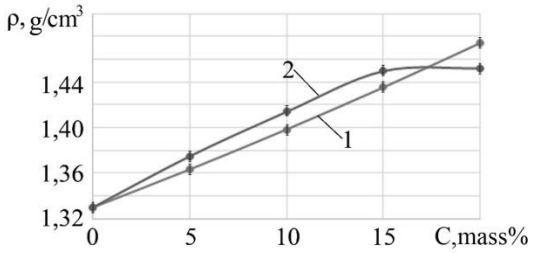

Fig.3. The dependence of the calculated (1) and experimental (2) density of phenylone on the content of boron carbide

Conclusions. The analysis of the results of tribotechnical characteristics of polymer composites showed that the use of boron carbide as a filler for phenylone C- 2 aromatic polyamide is an effective way to reduce its abrasive wear by almost 10 times. The increase in the wear resistance of the polymer matrix is due to the formation of the interfacial layer with new improved properties on the surface of carbide particles. Based on the obtained results, a composite with an effective filler content (15 mass%) can be recommended for the manufacture of parts of automotive, road and agricultural machinery operating under the influence of abrasive particles.

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А. – М. В. ТОМІНА, О. І. БУРЯ, Є. О. НАБЕРЕЖНИЙ

ВПЛИВ КАРБІДУ БОРА НА ПОКАЗНИК АБРАЗИВНОГО СТИРАННЯ АРОМАТИЧНОГО ПОЛІАМІДУ ФЕНІЛОН

Використання деталей виготовлених із зносостійких полімерних композитів натомість серійним матеріалам триботехнічного призначення (бронзі, капрону, бабіту) дозволяє отримати економічний ефект за рахунок зменшення витрат на технічне обслуговування та ремонт. Загального поширення для створення полімерних композиційних матеріалів із високим показником зносостійкості набули дисперсні наповнювачі (мідь, алюміній, залізо, бронза, олово, срібло, свинець, цинк, карбіди, шунгіт, вермикуліт тощо). Враховуючи зазначене, розробка та дослідження нових зносостійких полімерних композиційних матеріалів наповнених дисперсними наповнювачами з покращеними властивостями є актуальним науково-технічним заданням. У статті розглянуто вплив порошку карбіду бора на показник абразивного стирання ароматичного поліаміду фенілон марки С-2. Встановлено, що введення наповнювача покращує вихідні характеристики полімерної матриці: абразивна зносостійкість фенілону підвищується у 10 разів.. Виявлено, що ефективний вміст наповнювача в полімерному в'яжучому становить 15 мас.%. Дослідження поверхні тертя ненаповненого полімеру показало, що на його поверхні утворюються глибокі борозни, а при введенні наповнювача вони зменшуються на 75 %, оскільки поява карбіду бора зміцнює полімерну матрицю, модуль пружності та твердість збільшуються на 40 та 12 %. Дане покращення експлуатаційних характеристик імовірно обумовлено ефектом міжструктурного наповнення, коли дрібнодисперсні частки полімерної матриці під впливом хімічної та фізичної взаємодії формують на поверхні часток карбіду міжфазний шар із новими покращеними властивостями. На основі отриманих результатів композит із ефективним вмістом наповнювача (15 мас.% карбіду бора) можна рекомендувати для виготовлення деталей автомобільної, дорожньої та сільськогосподарської техніки працюючої під впливом часток абразиву.

Ключові слова: ароматичний поліамід, фенілон, показник абразивного стирання, полімерний композит

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