Problems of Tribology, V. 29, No 2/112-2024, 74-78

Problems of Tribology
Website: http://tribology.khnu.km.ua/index.php/ProbTrib
E-mail: tribosenator@gmail.com

DOI: https://doi.org/10.31891/2079-1372-2024-112-2-74-78

The influence of boron carbide clad with a nickel-based alloy on the abrasive wear rate of aromatic polyamide phenylon

K.A. Yeromina, A.-M.V. Tomina, Ya.E. Yarovyi

Dniprovsk State Technical University, Kamyanske, Ukraine
E-mail: an.mtomina@gmail.com

Received: 25 April 2024: Revised 25 May 2024: Accept 05 June 2024

Abstract

The paper presents the results of the development of new composite materials based on aromatic polyamide phenylon, filled with dispersed boron carbide and clad with PKHN-15 alloy. The influence of the percentage content of the filler on the abrasion rate under the conditions of friction with rigidly fixed abrasive particles was studied. It is shown that the degree of filling determines the rate of abrasive wear of composites, which reaches a minimum at a filler content of 25 wt.%. The introduction of boron carbide clad with the PKHN-15 alloy leads to a decrease in the abrasion rate of the aromatic polyamide phenylon by 6.2-9 times, which correlates with the strength indicators. The roughness of the composites is almost at the same level, from which we can conclude that the amount of filler affects their wear mechanism. An increase in microhardness at the boundary of the "polymer-filler" separation was noted, which may indicate the presence of interaction between the polymer and the filler. It is shown that the abrasive wear rate for composites containing 10-15 wt.% filler is more stable than for composites with a larger amount of filler. Developed composites are recommended for work in friction units operating in abrasive conditions, or as working bodies of grain harvesting machines and mechanisms that are in constant contact with grain which acts as an abrasive for working surfaces.

Keywords: aromatic polyamide phenylon, clad PKHN-15 alloy, abrasive wear rate, microhardness

Introduction

Today, one of the main reasons for reducing the service life of systems and units of transport vehicles equipped with serial metal parts is the abrasive wear of the working surfaces of tribological joint parts [1]. More than 30% of the world's energy costs fall on the elimination of the consequences caused by abrasive wear. Therefore, the development and introduction of new materials with high indicators of abrasive wear resistance into production is an urgent task for materials science. A promising way to solve this problem is the use of polymer composite materials (PCMs). Thanks to their high self-lubricating ability, PCMs allow us to abandon the use of lubricating and cooling fluids and high-performance oils in the operation of tribological units, which in turn leads to a reduction in financial costs for equipment maintenance. As the analysis of literary sources [2, 3] showed, PCMs are superior to carbon steels and non-ferrous metals in terms of functional properties. The use of PCMs in the tribological joint parts of the seeding complex and cultivators for processing agricultural crops, manure-removing scraper conveyors, plate chains of tow trucks increased their working life up to 5 times while simultaneously reducing labor costs for maintenance. It is important to note that the production of PCMs parts (even of complex configuration) leads to the formation of 10-30% of waste, which is much less compared to parts made of high-strength aluminum and titanium alloys. In the agricultural and metallurgical industry, waste from the production of such metal parts can exceed the weight of the product by 4-12 times. At the same time, the waste generated during the production of PCMs parts can be recycled, which is why PCM is considered an ecological material.

Dispersed powders of metals and carbides are one of the effective fillers for creating wear-resistant PCMs. The use of powders of copper (Cu), aluminum (Al), nickel (Ni), PR-N65 H25S3R3 self-fluxing alloy, boron carbide, titanium-tantalum-tungsten-cobalt (TTC) alloy allows to create PCM characterized by high indicators of thermal conductivity, wear resistance under the influence of abrasive particles, high self-lubricating properties in conditions of high-speed sliding, resistance to the influence of dynamic and fatigue loads [3, 4-6].

The purpose of the work

Considering the above, this work is aimed at the development and research of new PCMs with high indicators of wear resistance.

Objects and methods of research

C-1 aromatic polyamide phenylon (APP) was chosen as a polymer matrix for creating wear-resistant PCMs. Among the large number of engineering and technical materials, polyamides and composites based on them continue to occupy one of the important places in many branches of modern industry due to high indicators of functional properties and the possibility of forming products by many methods (die casting, compression pressing and 3D printing). It is known [3] that APP is characterized by high temperatures of long-term and short-term operation, low wear, increased radiation, corrosion and chemical resistance. Thanks to this, APP is mainly used for the production of parts that work in harsh operating modes.

Dispersed powder of PKHN-15 alloy with an average particle size of 40-100 μm based on chromium carbide clad with 15% of nickel was chosen as a FL. The use of clad alloys, which are characterized by a complex of unique properties and have an active surface, leads to a change in the interaction between the polymer and the FL, and, as a result, to an increase in adhesion between them. Thus, it is possible to expect an increase in the physical and mechanical characteristics of compositions containing clad alloys as a filler. Production of new PCMs based on APP was carried out according to the method given in the paper [7].

The study of the resistance of the developed PCMs and pure PA to the influence of hard-fastened abrasive particles (dispersion is 100 μm) was carried out using a HECKERT test machine. Before the start of the experiment, each test sample underwent a preliminary run-in in the usual mode until its surface was in full contact with the abrasive skin. The load on the sample was 10 N, and the length of the friction path for one test cycle was 40 meters. A comparison of the morphology of the friction surfaces of APP and PCMs based on it was carried out using a BIOLAM-M microscope at a magnification of 200. Microhardness at the boundary of the "polymer-filler" separation was determined using a PMT-3M device. Hardness was determined on a hardness tester 2074 ТПР.

Results

The analysis of the results of the friction of composites carried out using rigidly fixed abrasive particles (see Table 1) showed that the degree of filling directly affects the abrasive wear rate of composites. This indicator reaches its minimum value at a filler content of 25 wt.%. The introduction of harder filler into the polyamide matrix contributes to the strengthening of the composite material and inhibits the development of deformation processes in the matrix during abrasion, which increases the wear resistance of the developed materials.

Table 1

Functional properties of aromatic polyamide phenylon and composites based on it

Indicator	Percentage content of PKHN-15 alloy, wt.%				
	0	10	15	20	25
Average rate of abrasive wear, V, mm^3/m	1,80	0,29	0,27	0,25	0,20
Hardness, HB, hardness units	80,00	85,00	86,00	89,00	90,00
Roughness, Ra	1,15	0,99	0,87	0,99	1
Microhardness at the boundary of the "polymer - filler" separation, HV, hardness units	-	172,0	193,5	225,6	171,7

The introduction of boron carbide clad with the PKHN-15 alloy significantly reduces the rate of abrasive wear of aromatic polyamide phenylon by 6.2-9 times. This decrease is directly correlated with an improvement in the hardness of the material. Thus, the addition of clad boron carbide not only increases the wear resistance, but also significantly increases the hardness of the composite.

It is worth noting that the surface roughness of the composites remains practically at the same level regardless of the amount of added filler. This allows us to conclude that the wear mechanism does not change with the change in the amount of filler. This is an important aspect because stable roughness ensures predictable behavior of the material in service.

In addition, there is a significant increase in microhardness at the polymer-filler interface. This indicates the possible presence of interaction between the polymer and the FL. Such an interaction can contribute to the improvement of adhesion between the components of the composite, which additionally increases its strength and wear resistance.

Studies of the dependence of the abrasive wear resistance of composites on the number of cycles are shown in fig. 1. It can be seen from the given data that with an increase in the number of cycles, the wear resistance of all investigated composites becomes practically identical. At the same time, the indicator is more stable for composites containing 10-15 wt.% FL than for composites with a larger amount of the FL. This can be explained by a decrease in the plasticity of the composite due to the appearance of a large number of FLs, due to which the filler breaks out of the surface layers of the composite under the action of abrasive particles. The voids formed as a result can be seen in fig. 2 c, d, where the friction surfaces of the studied composites are shown.

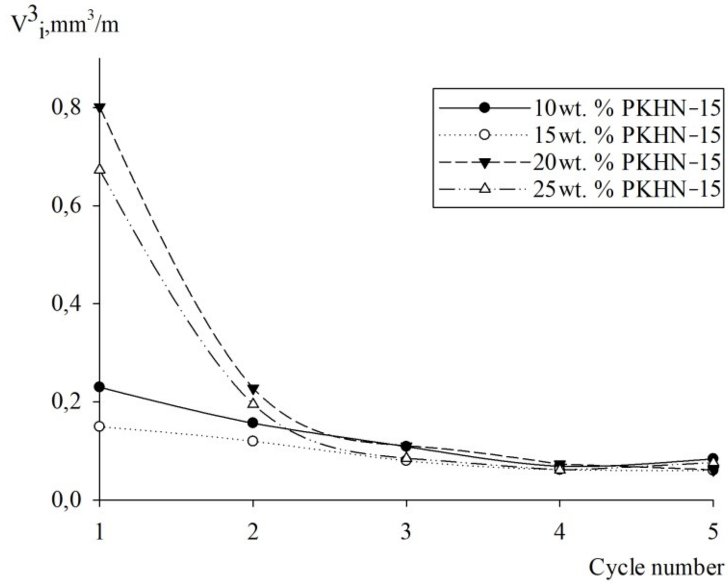

Fig. 1. Dependence of abrasive wear resistance of composites on the number of cycles

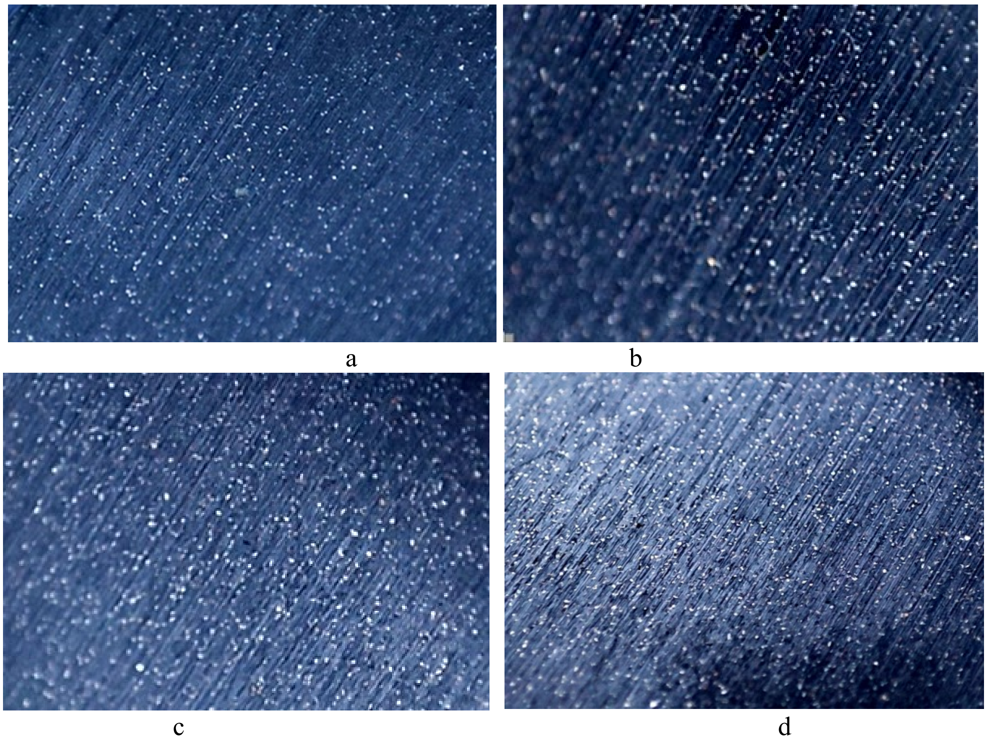

Fig. 2. Friction surfaces of composites containing: a – 10, b – 15, c – 20, d – 25 wt.% boron carbide clad with PKHN-15 alloy

The friction surfaces have a grooved structure, which is formed as a result of the ploughing process. It is important to note that no microcracks are observed on these surfaces, which is evidence that the material undergoes mainly plastic failure under the influence of sliding friction, that is, the surface layer is deformed and is more susceptible to stretching and crumpling than cracking, which leads to the formation of grooves. This type of destruction is typical for materials that are characterized by satisfactory plasticity and are capable of deformations without the formation of cracks.

The results of the conducted research indicate that the developed composites containing boron carbide clad with PKHN-15 alloy are promising materials for use in friction units operating in abrasive conditions. Boron carbide is known for its high hardness and wear resistance, making it an ideal component for materials subject to heavy wear. The PKHN-15 alloy, which is clad with boron carbide, provides additional properties, such as corrosion resistance and self-lubricating ability, which increases the overall performance of the composite.

These composites can be effectively used in various engineering and industrial applications, especially in friction units operating in abrasive conditions. For example, they can serve as working bodies of grain-harvesting machines and mechanisms that are constantly in contact with grain. The grain, which is an abrasive material, can quickly wear out the working surfaces of ordinary materials, but composites with boron carbide and PKHN-15 alloy can significantly extend the service life of such mechanisms.

The use of such composites will help reduce the frequency of replacement of worn parts, increase the reliability and efficiency of equipment, and reduce maintenance and repair costs. This is especially important in agriculture, where equipment downtime can lead to significant crop losses.

Conclusions

Summing up the results given in the article, the following conclusions can be drawn:

– New composite materials based on aromatic polyamide phenylon filled with dispersed boron carbide clad with PKHN-15 alloy were developed and can be effectively used in various engineering and industrial applications, especially in friction units operating in abrasive conditions.

– The influence of the percentage content of the filler on the abrasive wear rate under the conditions of friction with rigidly fixed abrasive particles was studied and it was shown that the rate of abrasive wear of composites reaches a minimum with a filler content of 25 wt.%.

– It is shown that the introduction of boron carbide clad with PKHN-15 alloy leads to a decrease in the abrasion index of aromatic polyamide phenylon by 6.2-9 times

– An increase in microhardness at the boundary of the "polymer-filler" separation was noted, which may indicate the presence of interaction between the polymer and the FL.

– It is shown that the rate of abrasive wear is more stable for composites containing 10-15 wt.% FL, compared to composites with a larger amount of the FL.

– Developed composites are recommended for work in friction unites operating in abrasive conditions, or as working bodies of grain harvesting machines and mechanisms that are in constant contact with grain acting as an abrasive for working surfaces.

References

1. V.V. Aulin, S.V. Lysenko, I.V. Zhilova, O.V. Verbynskyi Synergistic increase in the reliability of tribo couplings of parts of systems and aggregates of transport vehicles. "Increase of Machine and Equipment Reliability" materials of the 1st International scientific and practical conference (April 17-19, 2019, Kropyvnytskyi). Kropyvnytskyi: National Technical University, 2019. P.7.

2. O. Kabat, V. Sytar, K. Sukhyy Antifrictional polymer composites based on aromatic polyamide and carbon black Chemistry & Chemical Technology. 2018. Vol.12, No.3. P. 326–330.

3. O. Burya, Ye. Yeriomina, O. Lysenko, A. Konchits, A. Morozov, Polymer composites based on thermoplastic binders, Dnipro: Srednyak T. K. Press. 2019. 239 p.

4. O.I. Burya, A.-M.V. Tomina, Y.O. Naberezhniy The impact of boron carbide on the index of abrasive wear of phenylone aromatic polyamide. Problems of friction and wear. 2020. Vol.88, No.3. P. 47–51.

5. L.M. Yashchenko, L.O. Vorontsova, T.T. Alekseeva, T.V. Tsebrienko, L.P. Steblenko, A.M. Kurylyuk, O.O. Brovko The prospect of using Ti-containing epoxy urethane composites in solar energy Nanosistemi, Nanomateriali, Nanotehnologii, 2019. Vol.17, No.4. P. 747-760.

6. Patent 17852A Ukraine, MPK (2006.01) F16C 33/04.

7. A.-M.V. Tomina, Y.A. Yeriomina Studying the influence of HB-4 amorphous alloy on tribological properties of phenylone aromatic polyamide. Functional Materials. 2022. Vol.29, No.3. P. 388–392.

Єрьоміна К.А., Томіна А.-М.В., Яровий Я.Є. Вплив карбіду бора плакованого сплавом на основі нікелю на показник абразивного стирання ароматичного поліаміду фенілон

У роботі наведено результати розробки нових композиційних матеріалів на основі ароматичного поліаміду фенілон, наповненого дисперсним карбідом бору плакованого сплавом ПКХН-15. Досліджено вплив відсоткового вмісту наповнювача на показник абразивного стирання в умовах тертя жорсткозакріпленими абразивними частками. Показано, що ступінь наповнення визначає показник абразивного зношування композитів, який досягає мінімуму при вмісті наповнювача 25 мас.%. Введення карбіду бора плакованого сплавом ПКХН-15 призводить до зменшення показника абразивного стирання ароматичного поліаміду фенілон у 6,2 – 9 разів, що корелює з показниками міцності. Шорсткість композитів знаходиться практично на одному рівні, з чого можна зробити висновок, що кількість наповнювача на впливає на їх механізм зношування. Відзначено збільшення мікротвердості на межі поділу «полімер-наповнювач», що може свідчити про наявність взаємодії між полімером та наповнювачем. Показано, що для композитів, що містять 10 – 15 мас.% наповнювача, показник абразивного стирання більш стабільний, ніж для композитів з більшою кількістю наповнювача. Рекомендовано розроблені композити для роботи у вузлах тертя, що працюють у абразивних умовах, або як робочі органи зернозбиральних машин та механізмів, що постійно контактують із зерном, яке виступає як абразив для робочих поверхонь.

Ключові слова: ароматичний поліамід фенілон, плакований сплав ПКХН-15, показник абразивного стирання, мікротвердість