DETERMINATION OF THE TRIBOLOGICAL CHARACTERISTICS OF HEAVY LOADED FRICTIVE PAIRS BASED ON DENSITY MODIFICATIONS OF BORON NITRIDE

Volkohon V.[1], Prof. DSc., Avramchuk S.[1], PhD., Kravchuk A[1]. PhD., Neshpor O[1]. PhD.,
Antonyuk V.[2] Prof. DSc., Avramchuk K[2].I. MSc.Ing,
I.M.Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine, Kyiv. Ukraine[1]
Instrument-making Faculty, Department of Instrumentation Design and Engineering – National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine[2]
E-mail: vp@kpi.ua

Abstract**:** *In this work the constructive solution of the friction node is proposed, which provides the possibility to obtain reliable information about the tribological characteristics of the materials for work in heavy loaded slip supports. The method of determining the expediency of application in friction pairs of different materials is considered, which is based on certain shapes and sizes of the contact spot and the state of the friction track on the counter bodies. The efficiency of polycrystalline superhard materials application based on the wurtzite boron nitride in heavy loaded friction pairs due to an increase in the antifriction characteristics of the pair by the formation of graphitelike boron nitride on the surface of a thin film B_2O_2 as a result of the reverse phase transformation of dense phases (cBN + wBN) → gBN is shown.*

KEYWORDS: FRICTION NODE, SAMPLE OF POLYCRYSTALLINE SUPERHARD MATERIAL, COUNTERBODY, CONTACT SPOT, WEAR INTENSITY.

1. Introduction

For efficient functioning of heavy-duty friction pairs of machines and mechanisms, complex technological and design solutions are used to create nodes and aggregates that are operated under the influence of severe adverse factors: corrosive environments, abrasive components, temperature difference, etc.

In most cases, the given adverse factors act simultaneously, resulting in a reduction in working capacity and warranty resource for the operation of machines, mechanisms, transport systems, mining equipment.

In working junctions and nodes of machines and mechanisms, heavy-loaded friction pairs are subject to intense wear in the process of operation, especially in conditions of limited lubrication.

Such objects include shaft bits, which are widely used in boring, in the minerals exploration, during boring operations for oil and gas, as well as for the continuous boring of wells for various purposes in the mining industry and construction with the sludge cleaning by washing with liquid or using compressed air.

The resource of the bit is determined by many factors, the most important of which are mining-geological conditions (hardness, abrasiveness and rock blockage, the degree of rock mass homogeneity, its watering, etc.), and the associated conditions of operation (load on the chisel, rotation frequency, lubricating and cooling medium).

The efficiency analysis of the chisel bit in conditions of operation of the ore mining and processing plants showed that mainly the failure of the bit is observed due to the failure of the support sliding bearing (60 ... 70%), therefore, the work aimed at increasing the service life of the parts of the friction pairs of the bearings with the use of functional materials based on composite superhard materials are an effective means of reducing the efficiency of operating factors, mainly corrosion-mechanical.

2. Problem status.

Investigation of frictional characteristics and possibilities of composite material usage of the «wBN-diamond» system in heavy loaded nodes operating under axial load conditions.

The friction pair of the axial slide bearing is the tip of the pin 1 on the foot of the chassis body 2 and the support washer 3, pressed into the cavity of the shaft 4 body, located at the top of its cone (Fig. 1). During the bit operation, its support is subject to significant dynamic loads that are accompanied by heat release. To reduce the temperature in the contact area of the friction pair, a five-point purge hole is forged in a pinion with a support or solid lubricant.

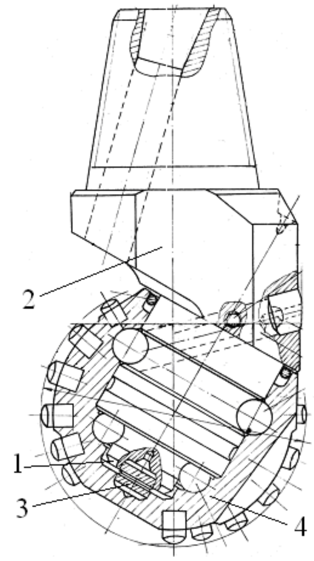

Fig. 1. *Shaft bearing design with sliding bearing: 1 - pin; 2 – bit chassis; 3 - support puck; 4 - shafters housing*

Consideration of the wear process of the contacting friction pair indicates its complex nature, which includes such phenomena as interaction in the relative displacement of friction surfaces, changes occurring in the surface layer of materials, the destruction of surfaces.

In this case, the mechanical interaction of surfaces is expressed in the mutual penetration and involvement of microniveness in combination with their collision in the case of high level of micro-rigidity, so the state of the surface of the friction pair is of great importance, and the molecular interaction is manifested in the form of adhesion and seizure. It should be noted that gripping is characteristic only of metal surfaces and differs from adhesion with more strong bonds. Changes in the friction surfaces are due to plastic deformation, temperature rise and chemical interaction with environment.

Plastic deformations lead to a change in the structure of the surface layer of the material, which at a temperature below the temperature of recrystallization, will lead to defamation and its strengthening to some depth, however, the microhardness is unchanged at the very surface.

The temperature exceeding the recrystallization threshold contributes to increased plasticity, and in some local areas, under high load conditions, the formation of tempered structures. Plastic deformations, possible high temperature gradients and structural changes cause tension in the material of the friction pair, which can affect its wear resistance. Therefore, the materials of the friction pair of bitumen are subject to high requirements. They should have high strength, hardness, heat resistance, wear resistance.

Selection of the most suitable materials for slip friction pairs can be made on a case-by-case basis only by carefully comparing the working conditions of the contacting parts, the initial properties of the materials and those changes taking place on the surfaces of friction, and also taking into account other essential circumstances.

According to, there are some following rules for the selection of friction pair materials, in accordance to which it is necessary:

- to combine hard metal with solid: such friction pairs have a high wear resistance due to the small mutual penetration of their surfaces.

- application in hard-to-reach for lubrication of structures of antifriction materials;

- application of the selective transfer mode by the selection of friction pair materials and antifriction additives.

The application of coatings to the spin improves the reliability of the pairs in the most dangerous period - at the initial stage of work, while high precision of manufacturing and assembly, considerable rigidity of construction, thorough tuning, and improved lubrication conditions significantly increase the service life of the friction pair of solid materials. This is confirmed by the use as a material of the support washer of a solid alloy BH-20, which allowed to increase the resource of friction pair in 1,5 ... 1,8 times.

3. *Experimental part.*

In this paper, the possibility of using in a friction pair of an axial slide bearing of a roller bit of a composite on the basis of dense modifications of boron nitride and diamond was studied.

Based on the recommendations of the friction pair selection, which has the maximum wear resistance for the material of the basic bit washer, composite polycrystalline superhard material (PCSM) on the basis of dense modifications of boron nitride obtained by sintering a powder of wurtzite-like boron nitride and diamonds of static or dynamic synthesis under high pressure and temperature conditions has been investigated. It can be both in a single-phase state in the form of sphalerite boron nitride (cBN), and contain wurtzite and graphite-like components.

For tribotechnical studies, a developed universal friction node was used to test materials for heavy-duty friction pairs and to perform oil or grease selection, air-emulsion environment or lubricating fluid, etc., since at this time the selection of materials for sliding pillars of roller shutters was carried out only with bench and field tests, which are relatively labor-intensive and expensive.

The use of the proposed friction unit, which provides the conditions for obtaining reliable information about the tribotechnical characteristics of materials in heavy loaded sliding supports, makes it possible to select new materials used for operation in these mechanisms. The design of the universal friction node is shown in Fig. 2.

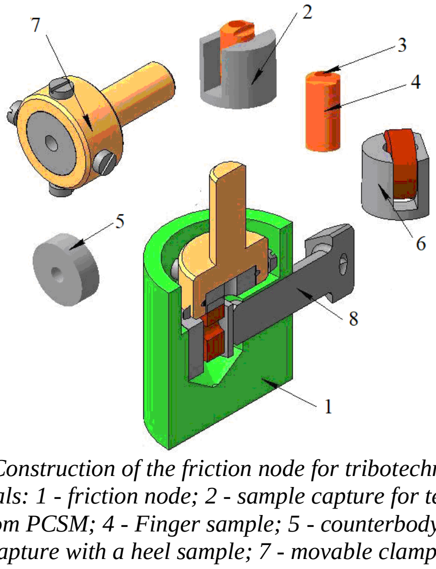

Fig. 2. *Construction of the friction node for tribotechnical test materials: 1 - friction node; 2 - sample capture for tests; 3 - sample from PCSM; 4 - Finger sample; 5 - counterbody (sample); 6 - capture with a heel sample; 7 - movable clamp with counterbody; 8 - screw-clamp.*

The dimensions of the friction unit are selected so that it can dissipate a thermal power of about 100 watts at a temperature in the friction zone of not more than 120 ºC.

The dimensions of the counterbody and the samples were determined experimentally and had dimensions - a disk (counterbody) with a diameter of $20_{-0.5}$ mm, a height of $7_{-0.5}$ mm, samples in the form of a disk of the same size with a counterbody, and those in the form of a cylinder of dimensions : diameter $10_{-0,1}$ mm and height $20_{-0,5}$ mm

Surface roughness of samples and counterbody after lapping by steel washer with boron carbide 50 micron grain powder was R_a 0,63 ... 0,32.

Friction node consists of housing (cup) 1, which is executed with step cavity, the lower part accommodates the sample holder, and the top part is designed for lubrication and moving grip with counterbody. The sample 4 is set in the grip 2 and tightened with a clamping screw (clamp) 7. After filling the shell with the oil, it is installed in the centering slot, fixed by the shpanizers on the desk of the table drill machine.

The chuck of the machine fix a clamp with a counterbody, which has the ability to move by the machine spindle, and make it contact with the sample. In this case, the contact area "counterbody-sample" with a clamp 8 is immersed in oil by 3...4 mm. On the handle of the spindle tare weight is hanged and machine is started. At the end of a given test time the machine turns off and the friction node is getting disassembled in reverse order.

For the study of the tribotechnical properties of the pair «counterbody WC10-PCSM» (counterbody WC10, a sample of composite PCSM) the following conditions of friction were adopted: a rotational speed of 1410 rpm; average slip speed of 1 m/s; lubricating oil industrial I20; duration of tests not less than 35 min; load - 50 kg.

After the tests, the shape and dimensions of contact spot on the specimens, the condition of the friction track on the counterbodies were determined. Also, calculations of the coefficient of friction, intensity of wear I_t,, and the contour pressure A_k were also performed.

To find out the effectiveness of the application of PCSM in friction pairs, comparative tests of different materials were conducted under the same conditions.

Figure 3 shows the wear and tear on the counterpart and the test specimen from a composite PCSM based on wurtzite boron nitride and diamond.

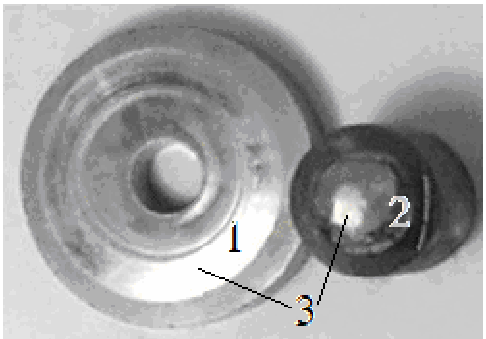

Figure 3. *The nature of the wear of the friction pair "solid alloy-PCSM" × 3: 1 - counterbody of solid alloy; 2 - sample of composite PCSM; 3- wear spots.*

Abrasion wear spot after the test has a mirror surface whose roughness is at R_a 0.16 ... 0.08 μm..

The bearing capacity of the resulting oil film in the friction pair "solid alloy - composite PCSM" reaches 1000 kg/cm^2, and the coefficient of friction is characterized by the smallest value, which in our opinion is due to the following. Composite PCSM based on wurtzite-like boron nitride is a heterogeneous high density material with a homogeneous, fine-crystalline structure having a grain size of 0.1 ... 0.3 μm.

High compressive strength (up to 4 GPa), modulus of elasticity, hardness and thermal conductivity in combination with high values of crack resistance (Table) can provide resistance to fracture at high critical loads, as indicated in the work.

Table. *Tribotechnical characteristics of friction pairs*

Materials of friction pair counterbody-sample	Slip friction coefficient	Wear intencity of the sample, I_t, μm/h	Contour pressure A_k, kg/cm^2
WC10-WC10	0,058	1,8x10^{-7}	570
WC10-WC10*	0,05	1,7x10^{-7}	600
WC10-PCSM	0,04	2,5x10^{-8}	800

* Counterbody with bronze coating

The increase of the antifriction characteristics of the friction pair "solid alloy - composite PCSM" is likely to occur both through the formation of a stable oil film and by the formation on the surface of a thin film B_2O_3 or graphite boron nitride (gBN) arising during the reverse phase transformation of dense phases (cBN+wBN)→gBN in microobjects, when contacting surfaces are interacting, when short-range flashes (10^{-7}...10^{-8}s) occur in the microcontact zone with a significant energy release and a decrease in the coefficient of friction due to the presence in the composite a high proportion of solid BNC solution and high thermophysical characteristics.

Figure 4 shows the construction of the proposed composite solid-alloy bearing equipped with composite elements with PCSM based on wurtzite boron nitride with increasing antifriction characteristics.

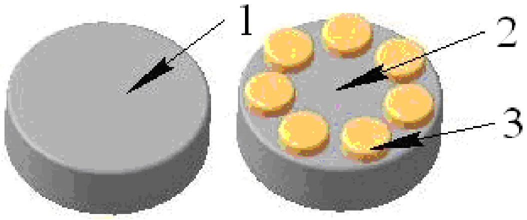

Fig. 4. *Combined support bearing: 1- heel; 2 - paternal; 3 - reinforcing elements from PCSM.*

The research carried out by the method of electronic OZE - spectroscopy of steel samples treated with cutting with the presence of shock loads, showed the presence of oxygen, as well as boron and nitrogen on their surface, which was confirmed in, where the frictional properties of materials are considered on the basis of dense modifications of boron nitride, which gives reason to assume the possibility of formation of thin antifriction films on test samples.

4. *Conclusion*.

The possibility of using in a friction pair of an axial slide bearing of a shale bit of a composite based on dense modifications of boron nitride and diamond is considered.

The method of evaluation of tribological characteristics of heavy loaded friction pairs and the design of the device for realization when selecting the most efficient materials pair is developed.

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