

POWDER COMPOSITE MATERIALS WITH CARBON NANOSTRUCTURAL FILERS FOR USE IN MACHINE FRICTION JOINTS

ПОРОШКОВЫЕ КОМПОЗИТНЫЕ МАТЕРИАЛЫ С КАРБОНОВОЙ НАНОСТРУКТУРОЙ ДЛЯ ФРИКЦИОННЫХ МУФТ СЦЕПЛЕНИЯ

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Abstract: *New wear resistance of composite materials are developed. The wear resistance of the composite materials has been tested in friction joints of harvesters DON-1500, friction joints of control mechanisms of lift-trucks «Balkankar Record», friction assemblies of mobile concrete mixers ABS-7DA with economic effect.*

KEYWORDS: *POWDER METALLURGY, ELECTROCONTACT SINTERING, CARBON NANOPARTICLES, COMPOSITE POWDER MATERIALS.*

1. Introduction

Progress in all industrial spheres is closely interrelated with the level of elaboration and assimilation of new materials with target properties that may ensure the desired reliability of machine parts and mechanisms. One of the key problems in engineering is how to attain perfect service characteristics of the products [1].

The traditional metallic and nonmetallic materials have on the main reached their design limits. There is, however, a necessity in still new, materials reliably operating in tough conditions of strain and temperature loads, in hostile media, radiation, deep vacuum and high pressures. The requirements imposed on the materials may often contradict each other, The solution lies in the use of composite materials [2].

Composite materials enable to create a given combination of diverse properties: high specific strength and rigidity, high temperature strength and wear resistance, good heat-protecting properties, and etc. It is improbable to obtain in common materials like metals and polymers traditionally employed in industry the range of properties shown by the composites. The composites make possible to create new in principle, inaccessible recently designs. Composite materials have made strong impetus on increasing engine capacity, weight reduction of machines and structures, weight ratio advantage of new transport means, aviation and space vehicles.

The composite materials on metal base manufactured by the methods of powder metallurgy are intensively used in friction units of agricultural machines, equipment and building industry. Toughening service conditions require the materials with better mechanical and triboengineering characteristics. To advanced methods of deciding these problems belongs the development of the composites containing nanometer components as antifriction and dispersion reinforcing additives. Carbon nanostructures used in composite engineering furnish a qualitatively new level of performance capabilities of the materials operating in severe conditions of dry friction via increasing their hardness, elasticity modulus, reducing friction coefficient, wear rate and surface roughness [3, 4].

We consider it unjustified to use cleaned carbon nanotubes (CNT) and onion carbon nanostructures (OCN) for the friction units of the large-sized machinery. Most promising direction in using carbon nanostructures seems to be their introduction without their preliminary separation in the form of combined carbon nanostructural fillers. This filler presents a two-component composition: 20% CNT + 80% OCN obtained by benzene pyrolysis in different temperature zones of the reaction space with CNT and OCN content not less than 95%.

2. Materials for experimental-industrial testing

The objects of the experimental-industrial testing were the composite wear resistant coatings based on copper matrix (PMS-1,

Branch Standard OST 4960-75) with 6 mass% nickel powder PNE-1 (State Standard GOST 9722-79) and 0.07 mass% of the nanostructural carbon filler.

Powder compositions for the coatings were prepared by mechanical activation of the ingredients in a pilot device for mixing and activation of powder materials during 60 min and their preheating before sintering [5, 6]. Joule's heat was used for sintering that is generated on the contacts between metal particles through which electric current is passed.

The coatings made of the powder composite materials based on a system of metal and carbon nanostructures are obtained by electrocontact sintering using a device based on a contact-welding machine MSh-3207 with roller electrodes [7]. A steel-45 tape (GOST 1050-88) was used as a metal base, the coating was made of a powder system on the base of a metal matrix and a combined carbon nanostructural filler (CCNF). The steel tape was heated in the feeding unit till 80 °C. A 60-70 µm thick layer of a gel-like flux PKG-26 is applied onto the steel tape surface and heated till 110 °C. A layer of predried till 3% humidity powder material was formed on the surface by a dispenser. The powder material was heated till 110-130 °C before application on the surface in the heated dispenser. The steel tape with a shaped powder layer was placed between two roller electrodes 200 mm in diameter and 16 mm wide, pressed together by pneumocylinders to subject the tape to rolling under a.c. passing at 50 Hz frequency as pulses described by an incomplete sinusoid, whose duration is equal to 0.75 of the sinusoidal period, while the pause makes up only 0.25 of its period. This process takes place simultaneously with pressure application. This results in sintering of the powder layer with the tape under 400 MPa pressure, 20 kA current intensity and 0.37 m/min displacement of the electrode. The required pulse duration was adjusted by a control board of the contact welding machine in relative units. Triboengineering and physico-mechanical characteristics of the developed materials are listed in the Table.

Table. Triboengineering and physico-mechanical characteristics of obtained coatings

Property	Value
Friction coefficient	0.13 – 0.14
Wear rate, µm/km	0.06 – 0.07
Ultimate strength at compression, MPa	256 – 264
Microhardness, MPa	1420 – 1515
Porosity, %	3 – 4

3 Investigation results and discussion

Wear-resistant composite materials have found application in self-lubricating friction units of agricultural machinery. These are, in particular, grain combine DON-1500 (Fig. 1), journal bearings of tubular shafts and auger conveyors.

Combine DON-1500 is equipped with a universal reel. The journals of the tubular shaft of the universal reel are rotating in rolling bearings.



Figure 1. Combine DON-1500 (Russia)

The analysis of the grain combine DON-1500 operation has shown that the journal rolling bearings in the universal reels of the reaper having 6 meters grasp width fail most often before the end of the harvesting season, which affects the technical state of the whole combine.

The causes of this failure of the rolling bearings of the reel are the following: penetration of dust particles that make the grease thicker increasing thereby the resistance to rotation of the shaft and temperature of the bearing. The dust particles in the friction zone of the rolling bearings behave like abrasive matter, which intensifies wear, and in the case of severe dusting of the bearing elements may lead to wedging of the bearing.

The auger conveyor of the reaper is designed to make the mowed stalk flow narrower and feed it to the baffle fin beater. The auger is made as a rotatable hollow cylinder to which spiral strips are welded of the left and right directions to guide the stalks into the center of the reaper. Inside the auger cylinder the disks are welded with fastened to them ball bearings of a collapsible crankshaft.

Along with above-mentioned causes of failure of the roll bearings in the crankshaft we can name the non-uniform loading because of uneven distribution of the plant stock over the field and constant vibration due to a misbalance between the rotating reaper elements and undulated surface of the soil.

It should be noted that rolling bearings as compared to plain bearings display such disadvantages as lower stiffness (since they may cause vibration of the shaft due to a rhythmic rolling of the rolling bodies across the loaded area of the support), more complex assembly, and relatively large radial dimensions.

To solve above-indicated problems we have substituted ball bearings for the self-lubricating plain bearings in which the liner is coated by a composite wear-resistant copper matrix-based material.

The developed composite materials with carbon nanostructures were field-tested in combines DON-1500. The field tests in conditions of agricultural enterprises have shown that only a negligible wear is observed on the surfaces after a harvesting season when the plain bearings are used instead of the rolling bearings in the auger conveyor crankshafts and the reaper reel journals. No worn out patches were observed on the surfaces of the plain bearing liners (Fig. 2). The total service life of the plain bearings of the auger conveyor crankshafts and the reel journals makes up above 2 harvesting seasons.

Application of the composite wear resistant materials in self-lubricating plain bearings of the reel journals and auger conveyor crankshafts in the grain combine DON-1500 has made possible to gain a considerable economic effect. The composite materials made of a system copper + CCNF + nickel were also used in self-lubricating friction joints of control gear of “Bakkancar Record DV 1792.33” and “Bakkancar Record DV 1661.33” loaders (Figure 3).

These loaders change the direction of their motion by turning the pivot arm 29 (Fig. 4), which rotates the wheel hub. The rolling bearings are used here to rotate the pivot arm hinged on the steering

axle housing. The bearing of grade 943/30 was used in the steering axle of the “Bakkancar Record DV 1792.33” and grade 943/25 in “Bakkancar Record DV 1661.33”. In the case of a single-shift work the lifetime of these bearings constitutes 3-4 months.

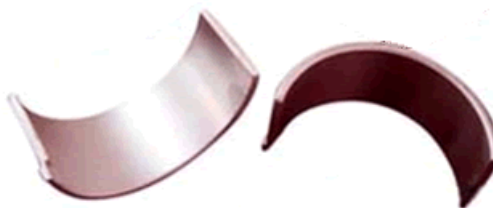


Figure 2. Plain bearing liners used in shaft bearings of the auger conveyor



Figure 3. Loaders “Bakkancar Record DV 1792.33” and “Bakkancar Record DV 1661.33”

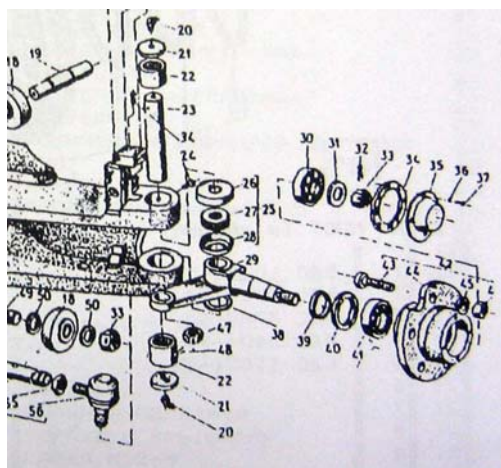


Figure 4. The mechanism of wheel turning of a steering axle of loader “Bakkancar Record DV 1792.33” (Bulgaria)

To prolong life of the bearings we have substituted the rolling bearings of named control units for self-lubricating plain bearings. The blanks for the self-lubricating plain bearings were obtained according to technical documentation for the technological process of manufacturing steel tape with a wear-resistant coating No. 40008498.01171.000095 and Techn. Spec, BY 40008498.219-2009.

Industrial testing of named bearings were carried out in friction joints of the loaders “Bakkancar Record DV 1792.33” and “Bakkancar Record DV 1661.33” in Branch 1 of “Sem Kholmov” Co. The test results have shown high reliability, service characteristics and efficiency of the bearing liners made of the developed wear-resistant material. Their service life surpassed that of the traditional rolling bearings 1.4-1.5 times.

The use of the plain bearings produced from the wear-resistant materials based on the copper mixture with nanostructural carbon in control gear of loaders Bakkancar Record at the wheel loader repair shops has also given a saving rate through increasing their durability.

Based on the results obtained, self-lubricating plain bearings from the developed composite material (Fig. 5) can be used for substitution of the imported rolling bearings and are recommended for their mass use in in friction joints of the wheel loaders.



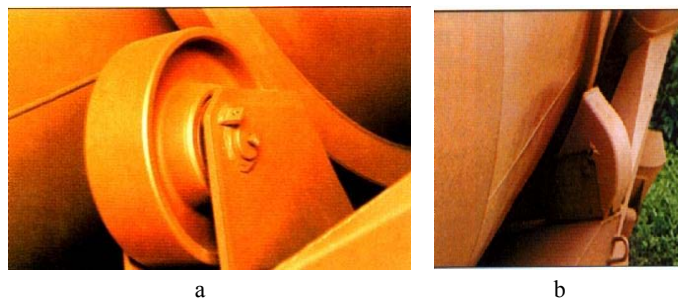
Figure 5. Plain bearings of friction joints of steering units in loaders “Bakkancar Record DV 1792.33” and “Bakkancar Record DV 1661.33”

The developed composite materials with combined carbon nanostructural fillers were also used in bearing rollers of motormixers ABC-7DA (Fig. 6) intended for carriage, ejecting to the consumer and preparation of concrete when moving.



Figure 6. Motormixer ABC-7DA (Russia)

The bearing roller (Fig. 7) of the motormixers are designed to support the mixing drum. They are made of high-strength steel with additional thermal treatment, thus showing elevated loading capacity at a relatively small mass. The roller axis is of a multiple-unit design, which enables to withstand high impact loads during motormixer motion.



a – without safety enclosure, b – with a safety enclosure

Figure 7. Bearing rollers of motormixers

To increase the overhaule period of motormixers ABC-7DA it was proposed to substitute rolling bearings for the self-lubricating plain bearings. It was expedient to use the composite wear-resistant material with nanostructural carbon fillers developed at MPRI NASB for the liners of the bearings. The liners were produced by electrocontact sintering of the initial powder components with an activated mixture following the technology elaborated at MPRI NASB.

Before their testing the liners underwent quality xontrol by measuring the seats and dimensions as well as visual observation of their integrity.

Figure 8 shows the liners of plain bearings removed from the motormixer after 1930 hours of operation.



Figure 8. Plain bearing liners of motormixer ABC-7DA bearing roller after 1920-hours operation

The usage of the plain bearing liners coated by the materials developed has made possible to prolong the technical lifetime of the motormixers ABC-7DA by 15-20% and yield affordability during service life of this type of building machinery.

5. Conclusions

The developed wear-resistant composite materials used in self-lubricating friction joints were subjected to experimental-industrial tests. The tests of the developed composite materials have proved them to be highly durable.

The composite materials based on the system metal-carbon nanostructures were use-proven in agricultural machinery. The use of the wear-resistant materials in self-lubricating plain bearings of reel journals and auger conveyor crankshaft in combines DON-1500 has given an essential efficiency in the course of operation of agricultural machines.

The developed composite materials were used in plain bearings for friction joints of control mechanisms of produced in Bulgaria loaders “Bakkancar Record DV 1792.33” and “Bakkancar Record DV 1661.33”. The usage of the plain bearings from the wear-resistant composite materials based on the copper mixture with carbon nanostructures in the control units of the loaders has shown economy through the increased technical lifespan of the loaders.

The plain bearing liners coated by the developed materials have ensured the increased technological lifespan of the motormixers ABC-7DA by 15-20% with a considerable saving rate.

The normative-technical documents have been elaborated for production of steel tapes with a wear-resistant coating (TP 40008498.01171.000095, TU BY 40008498.219-2009) used as a base for manufacture of the plain bearings.

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