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USING OF COMPOSITE MATERIALS FOR FRICTION PARTS OF PRINTING EQUIPMENT

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Abstract. *A paper summarizes the formation of new materials' structure and properties after using new making hot isostatic-pressing technology. Such technology is able to ensure the high and stable level of functional properties. The experimental results of the new composite bearing material's properties in a comparison with known nickel composite have been presented. It was shown the dense friction films were formed on the contact surfaces during tribological tests. Friction films defend contact surfaces against intensive wear and stabilize a work of friction unit in the high-speed offset printing machines.*

Development of modern technical equipment in machine-building industry has given a great importance for problem of increase the machines and mechanisms durability. There is no more important problem among tasks of new technical objects creation. Extension of useful use period for machines, mechanisms and equipment even in a small measure there is equivalent an introduction of new production capacities [1, 2].

Questions of technical evolution were continually connected with the problems of materials science development. The questions of new materials' using take a central place in the general problem of machines and equipment quality increase including materials of contact pairs such as antifriction (bearing) materials.

Among these are the bearing materials which operate with lubrication at easy operation conditions (low loadings, speeds of sliding, temperature up to 100 ºC), and especially it is important for the friction units which operate in extreme conditions - at the high loadings, aggressive environment, increased and high temperatures 200-800ºC, high speeds of rotation up to 10000 rpm. Well-known fact − 80% refuses of machines and mechanisms take place because of friction units' destruction [1, 2].

Large assortment of the cast and powder antifriction materials on the basis of iron, cast iron, copper and nickel are developed and applied for the listed too heavy working conditions [1–3]. Intensive wear and high friction coefficient have connected with imperfection of manufacturing technologies. Moreover a high cost unites these materials. And yet cast materials that use in extreme working conditions, such as, cast iron, bronze, the non-ferrous alloys are unable to combine different additives in a composition, which would form a strong matrix and contain antiscoring additives, such as sulfides, oxides, chalcogenides and fluorides.

The main task in the development of new composite bearing materials for printing machines is to increase the life of such equipment by, for example, applying lubricants to operate under conditions of high loads, temperatures or rotation speeds.

Therefore as a basis for bearings materials were selected composite nickel alloy - mark EP975 for heavy-duty conditions, such as increased loadings, air environment and rotation speeds 8000 − 10000 rpm. This choice was caused the complete absence of known alloys' operability both cast and powder on the basis of copper, iron, nickel at such operation conditions. Big number of alloy elements in the nickel matrix (more than 35 mas.%) gives an alloy EP975 high physical and physical-mechanical properties.

In the conditions of high rotation speeds any liquid lubricant is disabled because of liquid lubricant throwing out from friction zone by centrifugal forces. It is especially important to protect the friction surfaces from the increased wear and frictional seizure. Numerous studies show that using solid lubricants as a component of materials improves the tribotechnical characteristics of plain bearings [3-6]. For example, calcium fluoride CaF_2 as thermal and chemical stable substance is widely used as a solid lubricant to improve frictional contact, especially in heavy-duty conditions [1, 2, 5, 6].

Moreover, it is of theoretical and practical importance to establish an effect of making technology on structure and properties, distribution of CaF_2 over the metal matrix, and its effect on the friction behavior of nickel alloy EP975-based materials in extreme operating conditions of printing machines.

The objective of the present paper is to research bearing nickel alloy EP975-based composite materials with CaF_2 additions for heavy-duty conditions (high rotation speeds and high pressures) and to study the formation of new materials' structure and properties.

Chemical composition of materials was next, mass.% C - 0.038-0.076; W - 8.65-9.31; Cr - 7.6- 9.5; Mo - 2.28-3.04; Ti - 1.71-2.09; Al - 4.75-5.13; Nb - 1.71-2.59; Co - 9.5-11.4; Ni – basis, CaF_2 - 4.0-8.0 [7]. In our experiments we researched compositions−EP975+(4.0–8.0)% CaF_2.

Powders of the high-alloyed nickel alloy EP975 have been produced by powder spraying method of melted metal by argon stream. Dispersed metal drops are crystallized as spherical particles with dimensions from 10 to 750 μm. Usually optimum dimensions of fractions are in the range of 37–250 μm .

The hard spherical powder particles of high-alloyed nickel alloy EP975 there are a real microingot that excludes the problem of liquation at once. This problem has characterized for the cast nickel alloys obtained by traditional technology.

Traditional technology of powder metallurgy - pressing and sintering of initial mixture (EP975 + CaF_2) is unacceptable in our case because minimum porosity is already impermissible.

That is why method of hot isostatic-pressing (HIP) was used for creation of new materials. Hot isostatic pressing (or gas-static pressing) is executed on the special presses – gasostat. Hot isostatic pressing is carried out in a liquid (hydrostatical) or gas (gasostatical) environment. A working environment is forced to hermetic chamber by compressors and creates pressure of few thousand atmospheres. The isostatic pressing can combine high pressure with a high temperature that allows combining the process of forming and sintering.

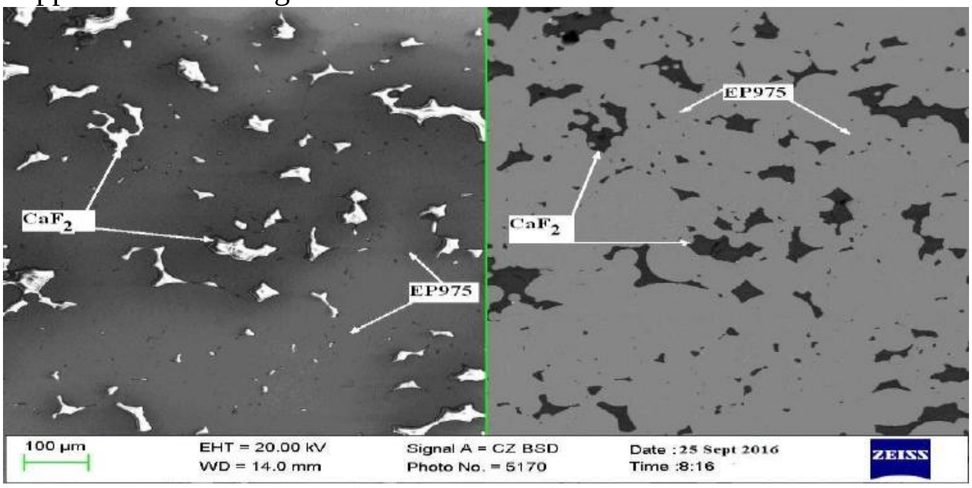
Thus, first of all – initial components of the sprayed powders of nickel alloy EP975 and solid lubricant (calcium fluoride) are mixed up during 4–6 hours. And then mixed powders are loaded to the special steel containers. The filled containers are pressurized for getting of a vacuum density. The process of hot isostatic pressing was carried out at $1210 \pm 10^{o}C$, during 4 hours, under pressure of argon up to 140 MPa. Equipment for HIP allows obtaining enough dense materials, almost without pores. The blanks had a relative density 99.9%.

Microstructure of the new composite bearing material EP975+8% CaF_2 after heat treatment is presented in figure 1.

After the hot isostatic pressing a heat treatment was carried out for optimization of dispersible phases' morphology in the structure of materials and for obtaining a necessary level of physics-mechanical and antifriction properties.

Stricture was studied using metallographic microscopy; calcium fluoride in the matrix was identified using scanning electron microscopy (SEM). Moreover, the SEM images were used for the quantitative description of CaF_2 in the composite. The physic mechanical properties of the samples were determined as well. Tribological tests were performed on a VMT-1 friction testing machine (rotation speeds V = 8000 − 10000 rpm and pressure P = 3.5 MPa), the counterface is made of R18 tool steel (HRC = 53–55); shaft–pin friction pair.

The structure of material is heterogeneous. There is a metallic matrix with inclusions of solid lubricant CaF_2. Solid lubricant CaF_2 particles were uniformly arranged [6, 7]. Presence of big number alloy elements in a nickel matrix gives new bearing materials a high level of physical-mechanical and tribotechnical properties. Tribotechnical and physical-mechanical properties of new materials have been presented tables 1, 2 in a comparison with known Ni-powder material [1], which is applied under analogue conditions.



a b

Fig. 1. Microstructure of material EP975 + 6% CaF_2 (raster electron microscope): a) image in secondary electrons; b) phase contrast image

Table 1

Strength properties of materials at room temperature

№	Composition, mas.%	Ultimate stress at tension, σ_t, MPa	Yield strength, $\sigma_{0,2}$, MPa	Extension strain, δ,%	Contraction, ψ,%
1	EP975 (cast)	1200	800	14	14
2	EP975 (powder, made by gas-static pressing technology)	1400	1120	12	15
3	EP975+6CaF_2 (powder, made by gas-static pressing technology)	1100	900	10	12

Table 2

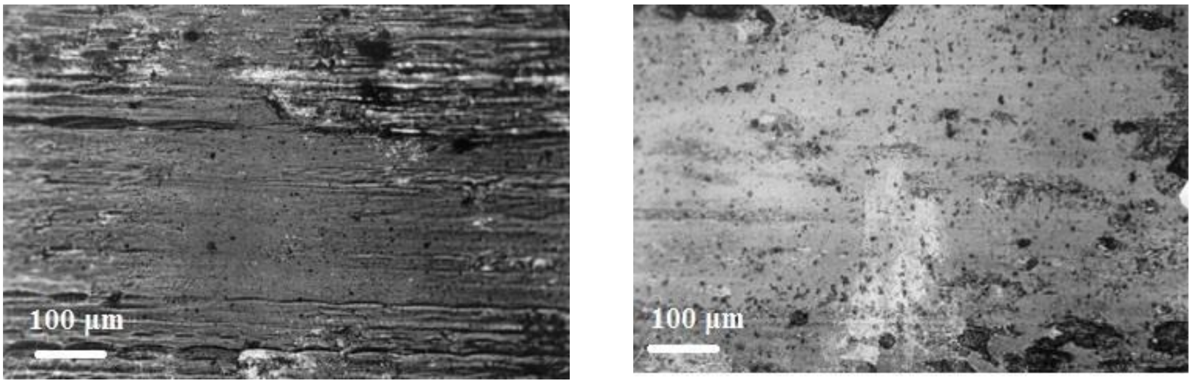
Antifriction properties of materials based on alloy EP975

№	Composition, mas.%	Friction coefficient	Wear, μ/km (V=1200 pm)	Limit load, MPa	Limit rotation speed, rpm
1	EP975+4% CaF_2	0,27	57	5	6000
2	EP975+6% CaF_2	0,26	54	5	6000
3	EP975+8% CaF_2	0,27	58	5	6000
4	Ni+(18-5%) MoB_2+ ZrB_2)+ 5%(CaF_2 or BaF_2) sintered alloy [1]	0,31	780	1,5	1500-2000

Analyzing information of tables 1, 2 evidently show, that the new high-speed bearings materials on the basis of alloy EP975 with the addition of CaF_2 have higher properties in a comparison with the known material [1] and they are able to operate at higher rotation speeds and loads.

During tribological tests the dense friction films were formed on the contact surfaces, both on the surface of examined materials and counterface (figure 2).

As it’s shown on figure 2, all friction surfaces are covered by dense antiscoring films, the so-called secondary structures. They consist of the chemical elements of bearing and counterface and solid lubricant CaF_2.



a) b)

Fig. 2. Images of friction surfaces: a) material EP975+ 6% CaF_2; b) counterface of steel R18

During friction process the different chemical reactions take place between O_2 of air and elements of researched specimen and steel R18 counterface at high rotation speeds and loads. Such chemical processes result in formation of friction films, which protect contact pair against intensive wear and stabilize a work of friction unit in printing machine.

CONCLUSION

We have developed a new effective bearing materials based on Ni alloy EP975–CaF_2 system with high physical mechanical and tribotechnical properties that performs well in more severe conditions than known sintered alloy.

The new materials have an advantageous level of tribotechnical characteristics due to the tribofilms formed on the contact surfaces by dragging of calcium fluoride to cover the entire friction area.

The full-scale industrial tests of EP975–CaF_2 bearings showed increase in wear resistance by a factor up to 10 compared with known bearings in friction units of Heidelberg Speedmaster SM-102-FPL and KBA Rapida-105 high speed printing machines.

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