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EFFECT OF MAKING TECHNOLOGY ON THE ANTIFRICTION PROPERTIES OF NEW BEARINGS FOR PRINTING MACHINES

Abstract: In a paper the results of effect the developed making technology on the antifriction properties of new bearings on the nickel alloy EP975-based composite materials with solid lubricant CaF_2 additions for high speed printing equipment have been presented. Paper summarizes the formation of new materials' structure and antifriction properties after new manufacture technology using. It was shown the efficiency of developed making technology for bearings that is confirmed by the results of industrial tests. The results of new composite material's tribotechnical properties in a comparison with known nickel composite have been presented. Full-scale industrial tests of the new composite bearing materials in friction units of printing machines have been conducted. Visual inspection and measurement of surface roughness show that the contact surfaces of bearings are not damaged, have high quality, and are usable. Industrial tests of EP975–CaF_2 bearings showed increase in wear resistance by a factor of 3.2 – 6.0 compared with known bearings.

1. Introduction

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].

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 1200 rpm. Well-known fact − 80% refuses of machines and mechanisms take place because of friction units' destruction [1].

Such phenomena are inherent for the equipment of metallurgical industry, oxygen-converter equipments, waste-smelting aggregates, heating equipment, aggregates and equipment of power engineering industry and high-speed printing equipment.

An action of high speeds, specific loadings and influence of oxidizing atmosphere - there is incomplete list of aggressive factors which accompany a work of rotary printing machines' parts and cause the intensive wear of friction units.

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.

Among antifrictional composite materials intended for severe operating conditions and incorporating solid lubricants, materials based on copper, iron, nickel, cobalt, and ceramics (Al_2O_3/TiC/CaF_2, Al_2O_3/ CaF_2/AgO/ CaF_2) are well known [1–3].

Composite materials based on iron or alloy powder steel are known to be used at speeds $V<400$ rpm and loads up to 3.0 MPa. At higher speeds ($V\geq600$ rpm) and loads up to 1.5-5.0 MPa, materials based on nickel, cobalt and copper are used [3]. This is due to their original physical properties [1].

Known powder and cast alloys on the basis of nickel (or cobalt) demonstrate unsatisfactory tribotechnical properties - high friction coefficient and wear at heavy-duty conditions of printing machines [1].

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 1000 − 1200 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 [3-5]. 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, 3].

These arguments were a reason for complex researches, which are directed for creation of new bearings materials for the wide range of loadings (3.0−5.0 MPa) and rotation speeds 1000 − 1200 rpm on the basis of the scientifically grounded material science approach with the purpose to obtain the possibility of prognostics and control of materials functional properties.

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.

2. Experimental results and discussion

Examination Techniques. 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 = 1000 − 1200 rpm and pressure P = 5.0 MPa), the counterface is made of R18 tool steel (HRC = 53–55); shaft–pin friction pair.

Chemical composition of EP975 has presented in tab. 1 [6].

Tab. 1. Chemical composition of EP975

Chemical elements, mas.%								
C	W	Cr	Mo	Ti	Al	Nb	Co	Ni
0,038-0,076	8,65-9,31	7,6-9,5	2,28-3,04	1,71-2,09	4,75-5,13	1,71-2,59	9,5-11,4	basis

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 . In our case powders of alloy EP975 there were of 50-250 μm. Spherical particles of alloy have been represented on fig. 1.

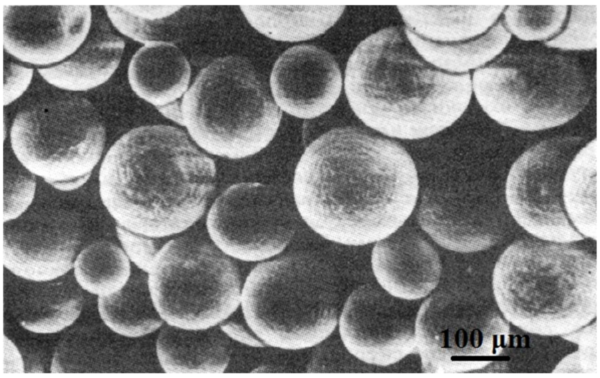

Fig. 1. Spherical particles of alloy EP975 produced by powder spraying in argon, × 100.

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 to combine 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±10 ^{o}C, during 4 hours, under pressure of argon up to 140 MPa.

Equipment for HIP allows to obtain enough dense materials, almost without pores.

The blanks had a relative density 99.9%.

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.

Heat treatment includes hardening - heat to 1240 ^{o}C during 4 hours, cooling with speed a 40 degrees/hour with a furnace to 1200 ^{o}C, then cooling on air.

After a hardening an ageing was carried out at 910 ^{o}C during 16 hours on air.

A general scheme of the technological operations for manufacture of nickel alloy EP975-based bearing materials is presented on fig. 2.

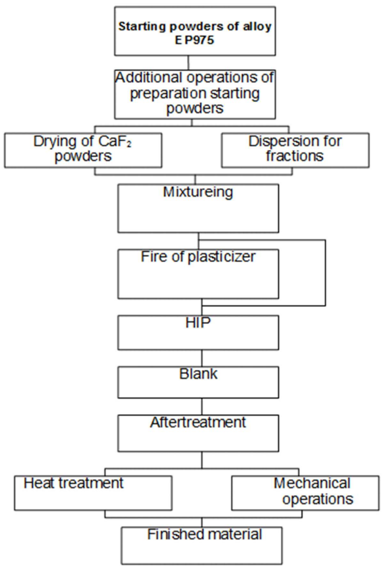

Fig. 2. Technological manufacturing scheme of the composite bearing materials EP975 + 6% CaF_2

HIP with a next aging is promoted to formation of phases in a structure, which increase physical-mechanical properties of material (combination of strength and plasticity) and improve operating reliability of a friction part.

Microstructure of composition material EP975+8% CaF_2 after heat treatment is presented on fig. 3.

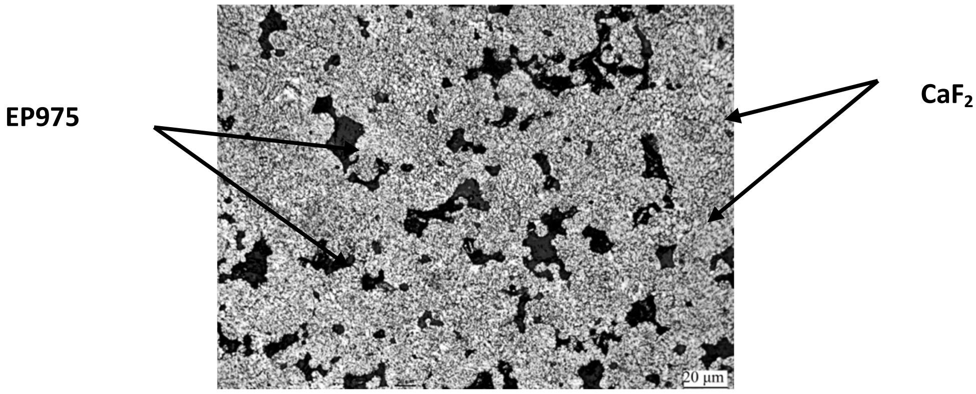

Fig. 3. Microstructure of material EP975 + 8% CaF_2 after heat treatment, etched specimen

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.

Metallic matrix is the alloyed γ-solid solution on the nickel basis with particles of alloy metal carbides and intermetallic compounds.

Presence of alloy elements big number in a nickel matrix gives a new materials high physical-mechanical and tribotechnical properties. Aluminum and titanium, and also tungsten in less degree, molybdenum and niobium make for strengthening of Ni-alloy [6] due to strengthening compounds formation.

These elements provide the increase of strength and besides Nb grinds down grains strongly. A presence of Co in an alloy positively influences for plasticity of material especially in a presence of Ti, W, Mo, Al, Cr [1].

Tribotechnical and physical-mechanical properties of new materials have been presented at tab. 2 in a comparison with known Ni-powder material [1], which is applied in analogue conditions.

Tab. 2. Antifriction properties of materials based on alloy EP975

	Composition, mas.%	Friction coefficient	Wear, µ/km (V=1200 rpm)	Limit load, MPa	Limit rotation speed, rpm
1	EP975+4% CaF_2	0,27	50	5	1300
2	EP975+6% CaF_2	0,26	30	5	1300
3	EP975+8% CaF_2	0,27	55	5	1300
4	Ni+(18-45%) MoB_2+ ZrB_2)+ 5%(CaF_2 or BaF_2) sintered alloy [1]	0,31	180	1,5	500-600

Analyzing information of tab. 2 evidently 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.

3. Conclusion

We have obtained a new effective material in the Ni alloy EP975–CaF_2 system with high antifrictional properties that performs well in more severe conditions than known sintered alloy.

The new material owes its high tribotechnical characteristics to the tribofilms formed on the contact surfaces by dragging of calcium fluoride to cover the entire friction area.

Full-scale industrial tests of the new composite bearing materials in friction units of printing machines have been conducted. Fifteen benchmark evaluations of friction units have been made. Visual inspection and measurement of surface roughness show that the contact surfaces of bearings are not damaged, have high quality, and are usable.

The full-scale tests of EP975–CaF_2 bearings showed increase in wear resistance by a factor of 3.2 – 6.0 compared with known bearings. It’s connected with using of new making technology. Such technology is able to ensure the high and stable level of functional properties.

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