УДК 621.002.3:621.89

T. Roik, Iu. Vitsiuk
National Technical University of Ukraine "Kyiv Polytechnic Institute"

EFFECT OF THE MAKING TECHNOLOGY ON THE PROPERTIES OF NICKEL COMPOSITE ANTIFRICTION MATERIALS FOR PARTS OF PRINTING MACHINES

In a paper the effect of the developed making technology on the properties of new antifriction composite materials based on powder nickel alloy EP975 with solid lubricant CaF_2 for friction parts of high speed printing equipment has been presented. In an article it has been shown the features of hot isostatic-pressing technology using. It was demonstrated the efficiency of developed making technology with the next heat treatment for new high speed bearings of printing machines Heidelberg Speedmaster SM-102-FPL and KBA Rapida-105. It is confirmed by the results of complex experimental and industrial tests.

Keywords: *making technology, powder nickel alloy, antifriction composite material, properties, friction parts, printing machines.*

Т.А. Роїк, Ю.Ю. Віцюк

ВПЛИВ ТЕХНОЛОГІЇ ВИГОТОВЛЕННЯ НА ВЛАСТИВОСТІ НІКЕЛЕВИХ КОМПОЗИЦІЙНИХ АНТИФРИКЦІЙНИХ МАТЕРІАЛІВ ДЛЯ ДРУКАРСЬКИХ МАШИН

У статті наведено результати досліджень впливу розробленої технології виготовлення на властивості нових антифрикційних композиційних матеріалів на основі порошкового нікелевого сплаву ЕП975 з твердим мастилом CaF_2 для деталей тертя високошвидкісного друкарського обладнання. Показано особливості застосування технології гарячого ізостатичного пресування. Продемонстрована ефективність розробленої технології одержання з наступною термічною обробкою для високошвидкісних підшипників друкарських машин Heidelberg Speedmaster SM-102-FPL та KBA Rapida-105, що підтверджено результатами експериментів і промислових випробувань.

Ключові слова: *технологія виготовлення, порошковий нікелевий сплав, антифрикційний композиційний матеріал, властивості, деталі тертя, друкарські машини.*

Т.А. Роик, Ю.Ю. Вицюк

ВЛИЯНИЕ ТЕХНОЛОГИИ ИЗГОТОВЛЕНИЯ НА СВОЙСТВА НИКЕЛЕВЫХ КОМПОЗИЦИОННЫХ АНТИФРИКЦИОННЫХ МАТЕРИАЛОВ ДЛЯ ПЕЧАТНЫХ МАШИН

В статье представлены результаты исследования влияния разработанной технологии изготовления на свойства новых антифрикционных композиционных материалов на основе порошкового никелевого сплава ЭП975 с твердой смазкой CaF_2 для деталей трения высокоскоростного печатного оборудования. Показаны особенности использования технологии горячего изостатического прессования. Продемонстрирована эффективность разработанной технологии получения с последующей термической обработкой для высокоскоростных подшипников печатных машин Heidelberg Speedmaster SM-102-FPL и KBA Rapida-105, что подтверждено результатами экспериментов и промышленных испытаний.

Ключевые слова: *технология изготовления, порошковый никелевый сплав, антифрикционный композиционный материал, свойства, детали трения, печатные машины*

Problem. Now existent antifriction parts (especially of cast alloys) for units of high-speed printing equipment aren't capable to satisfy the modern severe operating conditions of such equipment, for example, rotary printing machines [1−4]. It concerns the bearing materials for friction units, which are fall under influence of contact interaction different kinds. Stable work and machine life are determined by resistance of friction pairs to intensive wear at different exploitation conditions [1−4]. Most heavy operating conditions are high loading (3.0−5.0 MPa) and rotation speeds up to 10000 rpm [3]. Such conditions are characteristic of the high-speed offset printing cylinders' friction units in apparatus Heidelberg Speedmaster SM−102−FPL and KBA Rapida−105, Germany. Antifriction parts have a life cycle only near 0.5−1.5 year in friction units of these machines. It is connected with their unsatisfactory antifriction properties. This is due to the imperfections of the existing production technologies. Action of the increased loads, high speeds of rotation, influence of environment (oxygen of air) are the aggressive factors, which cause the intensive wear rate of the friction units in printing equipment [1−4].

Therefore, the problem of creating new technologies is very important for obtaining highly-effective antifriction parts for heavy operating conditions and requires the complex studies. The solution to this problem will open up opportunities to obtain highly wear-resistant friction parts for printing machines, which will significantly increase their service life.

Analysis of latest research and publications. Now the great variety of cast and composite bearing materials based on ferrous and non-ferrous alloys have been developed and used in heavy operating conditions [1−4]. Their intensive wear and high friction coefficient were connected with imperfection of manufacturing technologies. Moreover a high cost unites these materials. Also cast materials, 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 [4−6]. Therefore known antifriction parts are not able to ensure the contact surface's high quality [1−3].

At high rotation speeds of printing machines 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 [5, 6]. For instance, 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 [5, 6].

These arguments were a reason for complex researches, which were directed for studying the effect of the developed making technology on the properties of new composite materials based on powder nickel alloy EP975 with solid lubricant CaF_2 for friction parts of high-speed printing equipment.

Moreover, it is a theoretical and practical importance to establish a 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 such as loadings 3.0−5.0 MPa and rotation speeds up to 10000 rpm.

Such scientifically grounded material science approach opens the possibility of prognostics and control of materials' functional properties.

Setting targets. The ***objective*** of the present paper is to study the effect of the developed making technology on the physical mechanical and tribotechnical properties of new antifriction composite materials based on powder nickel alloy EP975 with solid lubricant CaF_2 for friction parts of high speed offset printing machines.

Presentation of the material. The subjects of study were new composite nickel alloy EP975-based materials with known solid lubricant CaF_2 additions, mas.%: powder nickel alloy EP975 + (4.0–8.0) CaF_2 [1, 8].

Examination Techniques. Structure was studied using raster electron microscope; calcium fluoride in the matrix was identified using scanning electron microscopy (SEM). The physical and mechanical properties of the samples were determined as well [9]. Tribological tests were performed on a VMT-1 friction testing machine (rotation speeds V = 7000 − 9000 rpm and pressure P = 1.5−5.0 MPa), counterface is made of EI 961 stainless steel (HRC = 52–54); shaft–pin friction pair.

Sample making. The starting powder nickel alloy EP975 has been produced by powder spraying method of melted metal by argon stream [1, 2]. Dispersed metal drops were 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. The powders of solid lubricant CaF_2 after drying at a temperature of 120°C for 1 h had a particle size of 100 μm. Chemical composition of the researched materials has been presented in table 1 [1, 8].

Table. 1.

Chemical composition of materials

Components, mas.%									
C	W	Cr	Mo	Ti	Al	Nb	Co	Ni	CaF_2
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	4.0-8.0

Thus, in our experiments we researched bearing compositions−EP975+(4.0-8.0)% CaF_2.

The hard spherical powder particles of high-alloyed nickel alloy EP975 are the real microingots that exclude the problem of liquation at once. This problem is characteristic for the cast nickel alloys obtained by traditional technology [1, 4−6].

The method of hot isostatic-pressing (HIP) was used for manufacture of new bearing materials because the traditional technology of powder metallurgy doesn't ensure minimum porosity.

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 (gas-static) environment. A working environment is forced to hermetic chamber by compressors and creates pressure of the few thousand atmospheres. The isostatic pressing can combine high pressure with a high temperature that allows combining the process of forming and sintering [1, 2].

First of all, initial components of the sprayed powders of nickel alloy ЕП975 and solid lubricant (CaF_2) are mixed up during 4-6 hours. And then mixed powders are loaded to the special steel containers. 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. Hot isostatic-pressing allows obtaining 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 physical 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, and then cooling on air. After a hardening an ageing was carried out at 910^{o}C during 16 hours on air.

HIP with a next heat treatment ensured the formation of the reinforcing phases in a structure, which increase material' physical-mechanical properties (combination of strength and plasticity) and improve a friction part's operating reliability. Microstructure of new composite bearing material EP975+8% CaF_2 after heat treatment is presented on figure 1.

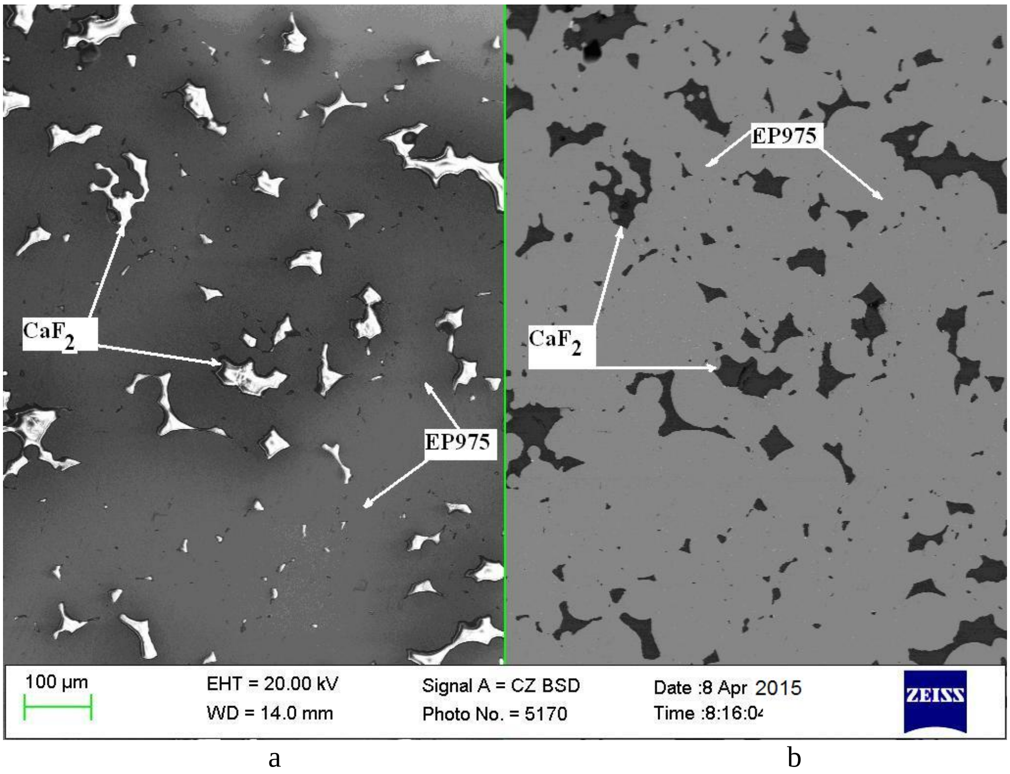


Figure 1. **Microstructure of material EP975 + 6% CaF_2 (raster electron microscope): a) image in secondary electrons; b) phase contrast image**

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 [1, 2, 8].

Presence of alloy elements big number in a nickel matrix gives new bearing materials a high level of physical and mechanical and tribotechnical properties. Physical-mechanical and antifriction properties of new materials have been presented at table 2 in a comparison with known Ni-powder material [1], which was applied in analogue conditions.

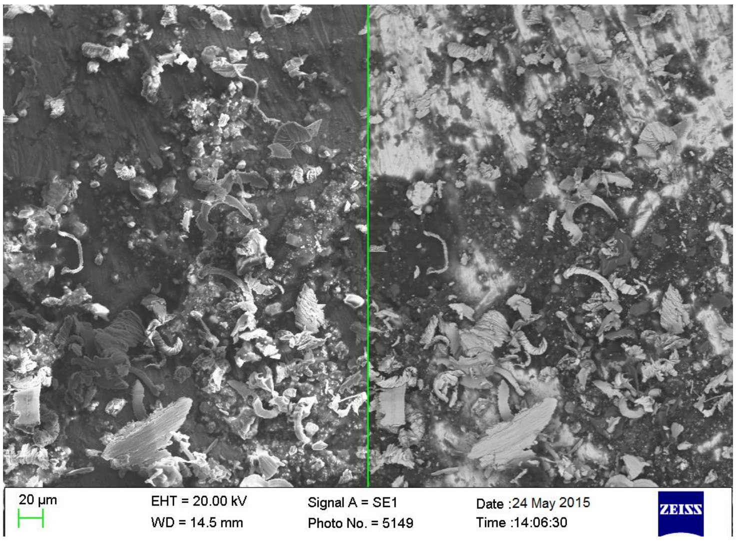
Table. 2.

New composite bearing materials' physical and mechanical and antifriction properties

Material, mass.%	Bending strength, σ_s, MPa	Impact bend KC, J/m^2	Hardness, HB, MPa	Friction coefficient	Wear, μ/km (V=9000 rpm)	Limit load, MPa	Limit rotation speed, rpm
EP975+ 4% CaF_2	540−610	600−650	2550−2600	0.26	52	5	10000
EP975+ 6% CaF_2	550−600	550−600	2500−2600	0.24	41	5	10000
EP975+ 8% CaF_2	520−570	520−550	2540−2600	0.27	54	5	10000
Ni+(18-45%) MoB_2+ZrB_2)+ 5%(CaF_2 or BaF_2) sintered alloy[1]	240−300	350−520	850−950	0.39−0.47	580−720	1.5	500−600

Analyzing table 2 evidently we can see new high-speed bearing materials based on powder 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. This is due to the differences in their manufacturing technologies.

During tribological tests the dense friction films were formed on the contact surfaces, both on the surface of researched materials and counterface (figure 2). These films are uniformly coated with the friction surfaces.



a b

Figure 2. **Friction surface of material EP975 + 6% CaF_2 (electron microscope): a) image in secondary electrons; b) phase contrast image**

The scanning electron microscopy images of the friction surfaces after tribological tests shows a presence of thin dense layer (friction film) (figure 2).

The formed friction films probably consist of the solid lubricant CaF_2, big number of alloy elements from examined material, steel counterface and oxygen of air. During friction process the different chemical reactions take place between O_2 of air, the examined specimen's elements and EI961 stainless steel counterface at high rotation speeds and loads. These films provide a high level of the friction pair's antifriction properties (table 2) due to the balance between the temps of their formation and destruction at such exploitation conditions.

Such chemical processes result to the formation of friction films, which defend contact pair against intensive wear and stabilize a work of friction unit in printing machine.

Conclusions. It was researched an effect of developed manufacturing technology on the physical mechanical and tribological properties of new composite antifriction materials based on powder nickel alloy EP975 with solid lubricant CaF_2 for friction parts of high speed offset printing machines.

New effective antifriction materials based on powder Ni-alloy EP975–CaF2 system with high physical mechanical and tribotechnical properties perform well in more severe conditions than known sintered alloy. This is due to the essential differences in their manufacturing technologies.

First of all the developed technology ensures a minimizing porosity that excludes internal oxidizing at the heavy exploitation condition, and second, new technology provides not only high density but also high properties of composite materials. This is a very essential factor to operate at high rotational speeds and loads due to high structural strength of the part.

During friction process the dense friction films are formed on the contact surfaces. Friction films consist of the chemical elements both the examined composite material and counterface of steel EI961. Solid lubricant CaF_2 and oxygen of air are very important participants in the film formation process at high rotational speeds and loads.

Formed friction films are determining factor for the trouble-free operation of bearings. They can minimize friction between bearing and shaft and ensure durability of the friction unit. It depends on the phase composition and phase combinations in formed films.

Our next steps will be directed to studying of these phases' nature and their quantitative ratio in friction films.

Also it's necessary to research friction films after tribological tests of materials under different loads, speeds of sliding, temperatures and then to identify phases that are presented in friction films and which can provide the best antifriction properties at heavy operating conditions.

Solution of these problems will allow forecasting and controlling composite materials' functional properties in wide range of loads and rotation speeds depending on the type of printing equipment.

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Name, position office, academic degree, academic status of article reviewers.

Velichko Olena Mikhailivna – Head of Reprography Department of NTUU "KPI", Professor, Doctor of Technical Sciences.

Стаття надійшла до редакції 23.03.2016.