

ANTI-FRICTION PRODUCTS FROM COMPOSITE MATERIAL BASED ON LH15 STEEL POWDER

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Abstract. The work considers the possibility of manufacturing and using sintered composite products from a metal component in the form of alloy steel powder obtained from grinding waste of bearing production. The research was carried out at optimal pressing parameters of 400...800 MPa, sintering at 1200°C for 2 hours from the moment of setting the specified temperature. The results of the first systematic studies of the strength and tribotechnical properties of sintered materials based on LH15 steel powder obtained from grinding slurries with copper and graphite additives are presented.

It was established that the tribotechnical characteristics of sintered products under conditions of medium loads mainly depend on the hardness of the composition. It has been experimentally verified that the high wear resistance and friction coefficient, which is on average 0.09, has a composition with a content of 2% graphite and 4% copper at a sliding speed of 5 m/s and a pressure of 10 MPa. It has been experimentally confirmed that the increase in the linear dependence of stress on deformation, in particular, when the strain is 8%, the stress is 1200...1400 MPa. This makes it possible to predict higher operational properties of products made from material of this composition. The resulting anti-friction products have a significantly lower cost and a higher material utilization ratio compared to traditional materials.

Keywords: Friction, Wear, Technology, Sintered products, Bearing production waste

1 Introduction

In modern technology, parts made of various anti-friction materials are used to ensure the movement of joints. Among them are sintered multi-component compositions, which have a number of advantages - better work-in in the friction process, less wear of the joint part, characterized by a stable coefficient of friction [1, 2].

The combination of several components with sharply different physical and mechanical properties allows creating sintered composite products with properties important for technology - self-lubrication, high heat resistance, good damping characteristics, etc. [3, 4].

A significant proportion of sintered antifriction products is made from materials based on powder steels. Yes, in particular, LH15 bearing steel powders are a universal material that can be used to produce parts for all operating conditions of the friction unit.

One of the methods of obtaining powder of bearing steel LH15 is its separation from grinding slurries [5]. The technological process is based on the methods of powder

metallurgy, which makes it possible to obtain new materials and products based on them with specific properties that are unique only to this method.

The efficiency of manufacturing parts from them is primarily determined by their purpose and operational properties. First of all, these are powder bearing parts of general mechanical engineering: bushings, gears, oil seal bearing, cracker, liner, etc. The use of metal waste from machine-building production makes the production of parts relatively cheap, and pays off quickly.

Therefore, it is relevant to carry out research on the manufacture of anti-friction products from composite material using as a component metal powder of steel LH15, obtained from grinding slurries.

The purpose of the work is to study the influence of the composition and technology of obtaining a composite material based on LH15 steel powder on the structure, mechanical and tribotechnical properties of sintered products.

2 Literature Review

The vast majority of modern anti-friction parts are made of composite materials. The basis of the tribotechnical antifriction composite, which contributes to the formation of certain physical and mechanical properties, is the basic material - iron, copper, nickel, aluminum, etc. [6-8].

It also includes components that regulate the size of adhesive bonds - graphite, sulfides of molybdenum, copper, zinc, boron nitrides [9-11]. In recent decades, mainly iron and copper-based powder materials have been developed [12-14]. Preference is given to iron-based sintered composites, as products from them have good physical and mechanical properties, and raw materials are not in short supply.

However, as indicated in the source [15], the introduction of copper into the composition increases the strength of the iron matrix, has a positive effect on sintering, adds thermal conductivity, creates microhardness of the material, and improves the structure and mechanical properties. An important component of the iron-based tribotechnical composite is graphite - a solid lubricant that increases the strength of the metal base.

The content of graphite in the composite is established experimentally, depending on the coefficient of friction and wear resistance [16].

Currently, the most common material with higher anti-friction properties is iron-graphite. Such a material can work in the self-lubricating mode at high sliding speeds and an operating temperature of 100–130°C [16]. Iron-graphite materials have a ferrite-pearlite structure. As noted [17], the pearlite structure is the most wear-resistant. The permissible content of the ferrite component is up to 50% and depends on the operating conditions of the material.

Antifriction compositions of iron-zinc-copper-graphite are widely used in industry. The presence of copper, in the range of 5...9%, significantly increases the properties and strength of porous iron-based antifriction materials [18]. Sintered antifriction materials also include antifriction materials based on powdered steels [19].

Recent years have been characterized by the intensive development of works on the improvement of known and creation of new methods of obtaining metal powders, which are based on the use of secondary resources of raw materials [20]. Among them are methods of obtaining powders by spraying melts and recovery methods [21].

The processes of obtaining metal powders were studied: from shavings of carbon steel, cast iron, non-ferrous metals; from waste generated as a result of spillage in metallurgical production [22-24].

Powders obtained from shavings are cheaper than powders produced by traditional technology. Nowadays, such methods of obtaining powder as grinding chips and extracting metal powder from grinding slurries are widely used [25].

The most effective is the production of powders from waste generated during the processing of alloy steels, in particular ball bearing ones [26]. In the bearing industry, among surface treatment methods, grinding occupies a significant place, and the resulting waste (grinding slurries) is a valuable raw material for obtaining metal powders. The main difficulties that prevent the wide use of sludge as a secondary raw material are, in particular, the form of metal particles.

Roik T. et al. [27] proposed the technology that includes additional processing - grinding (rolling) followed by restorative annealing. This makes it possible to achieve a more spherical shape of particles of the powder material, which increases its technological properties. In this way, a powder close in composition to the original steel is obtained, which is suitable for the manufacture of sintered products for tribotechnical purposes in [28].

Thus, after reviewing the scientific literature on this issue, we can conclude that the obtained powders from production waste can be used as a material for the manufacture of sintered products. In addition, this is the basis for the development of new resource-saving technologies and allows solving the problem of finding cheap and accessible types of raw materials.

3 Researches Methodology

The composition based on LH15 steel powder obtained by technology [27] was prepared using PMS-1 copper powders (DSTU 4960–97) and GS4 Graphite of lubricants (DSTU 8295-99). The composition of the charge of tribotechnical composite LH15 – (4 wt.%) Cu – (2 wt.%)C.

The mixture of initial powders was mixed in a mixer for 1 hour (Fig. 1). The samples were pressed at a pressure of 200...800 MPa. The samples were sintered in metal boxes filled with Al_2O_3 in a hydrogen environment in a laboratory electric furnace of continuous resistance lubricating and cooling substance. The sintering temperature is 1200°C. The sintering time was 2 hours from the moment the set temperature was set. Products were impregnated with IL - 40A Standard VG32 industrial oil.



Fig. 1. Mixer: 1 – drum; 2 – bearing; 3 – supporting frame; 4 – gear transmission; 5 – belt transmission; 6 – electric motor.

Mechanical characteristics were determined by standard methods: microt-hardness was measured on a PMT-3 microhardness tester under a load of 1 N; Vickers hardness was determined on a PT-7R-1PS hardness tester under a load of 50 N; compression tests were performed on 3 samples of a cylindrical shape with a diameter of 10 mm and a height of 12 mm on an IR5047-50 tearing machine. The loading speed is 17 $\mu\text{m/s}$. Dimensions The strength limit was determined by deformation curves in σ – ϵ coordinates. The appearance of the first cracks on the side surfaces of the sample was taken as the failure criterion.

The microstructure of the composites after sintering and tribotechnical tests was investigated by the metallographic method of the Micro-optik[®] optical software complex The structure of the sintered materials was revealed by the method of chemical etching with a 4% solution of nitric acid in ethyl alcohol.

Tribotechnical characteristics - wear and friction coefficient were determined on a laboratory test machine of the SMC-2 model. The research was carried out according to the scheme with an open kinematic circuit, when one of the samples is stationary in the modes of limit friction and without lubrication. Diagram of the shaft-tab contact. The counterbody is made of steel 45 DSTU 7809-99 with a hardness of 45 NRC. Sliding speed up to 8 m/s at contact pressure, in the friction pair, up to 15MPa.

4 Results

To evaluate the effectiveness of the anti-friction composite during friction, samples from it were compared with sintered samples from LH15 steel powder. Friction consistently decreases with an increase in nominal pressure during friction for the LH15 steel powder – copper – graphite composite compressed at 500 MPa. This dependence is similar to the dependence of the coefficient of friction of sintered steel LH15 (Fig. 2, a).

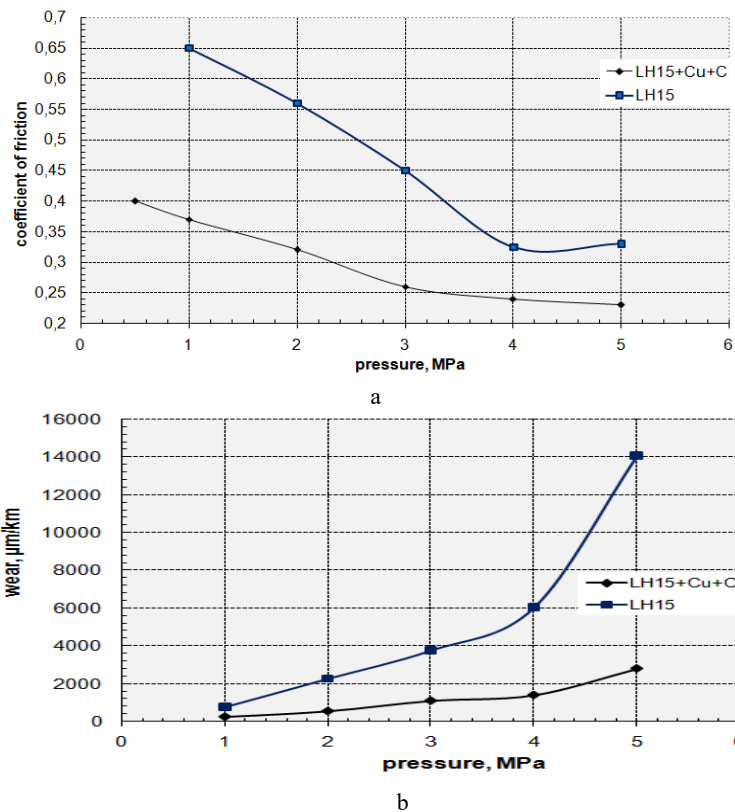


Fig. 2. Dependence of a - coefficient of friction and b - wear of powder steel LH15 and composite LH15 - Cu - C on pressure.

However, the coefficient of friction of the material LH15 - copper - graphite is lower than the coefficient of friction of sintered steel LH15 at the same pressures, due to the presence of graphite and cementite in the structure of the composite. It is the presence of these structural components that increases the wear resistance of the composite compared to the wear resistance of LH15 steel. Wear at a pressure of up to 5 MPa is not catastrophic (Fig. 2, b).

The effect of pressing pressure on the friction of the studied composite was investigated. Friction tests were performed at a pressure of 4.5 MPa. The samples were sintered at temperatures of 1100°C, 1150°C, and 1200°C. It was established that the friction coefficient is almost independent of the pressing pressure (Fig. 3, a), and the intensity of wear consistently decreases (Fig. 3,b). A higher sintering temperature slightly increases the wear resistance and practically does not affect the coefficient of friction.

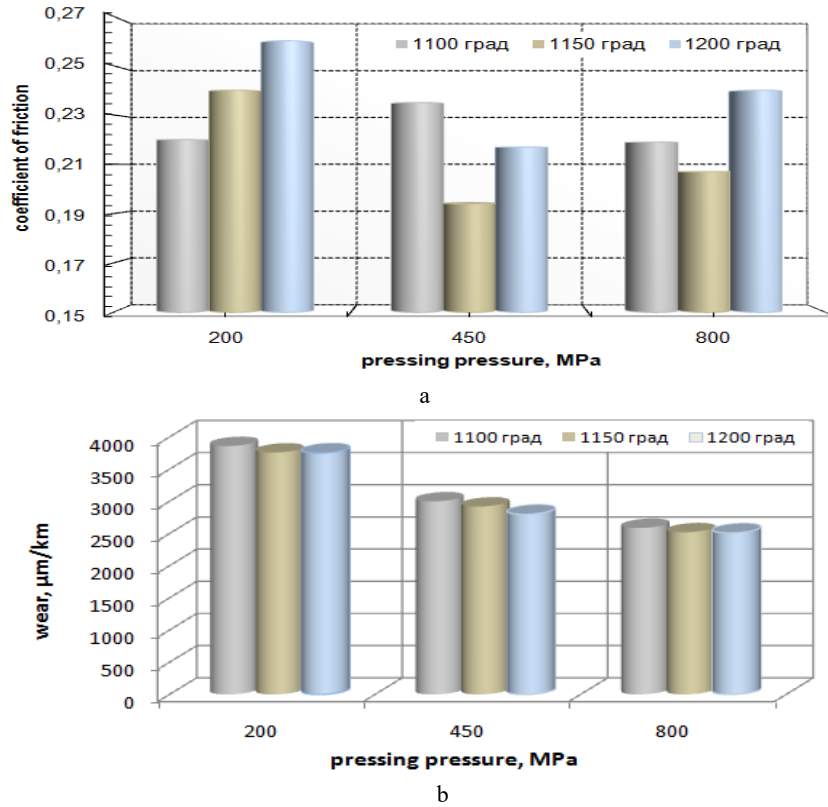


Fig. 3. Influence of pressing pressure and sintering temperature of composite LH15– Cu C: a - on the coefficient of friction and b – wear.

To increase the elastic characteristics of sintered materials, it is necessary to reduce deformation and abrasive wear. Thus, for the investigated composite at small degrees of deformation ($\approx 3\%$), the stress depends linearly on the deformation and reaches a value of ≈ 600 MPa. Further increase in load is accompanied by intense plastic deformation. The highest compressive strength limit is ≈ 3000 MPa. This is significantly higher than for samples from PJR. (Fig. 4).

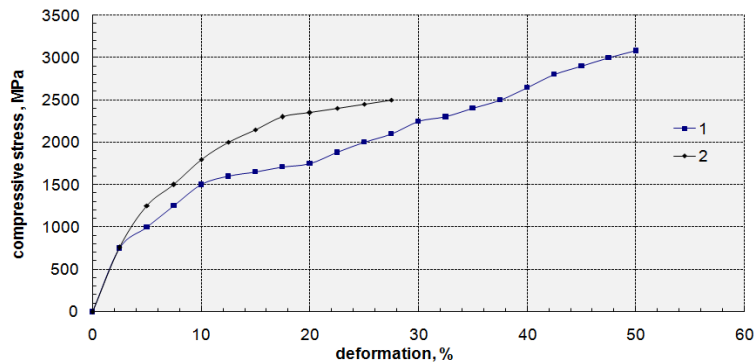


Fig. 4. Dependence of compressive stress on deformation: 1 – a sample from PJR; 2 – a sample of composite material – LH15-graphite-copper.

For a sample made of a composite material (LH15 powder - copper - graphite), the linear section of the dependence of stress on deformation increases. At a deformation of 8%, the stress is 1200...1400 MPa. This makes it possible to predict higher operational properties of products made of material of this composition.

The structure of samples from the studied composite is pearlitic (Fig. 5). An excess of carbon forms a carbide phase, which is located in the form of a grid along the boundary of pearlite grains. The hardness after sintering was $HV \approx 2100...2300$ MPa.

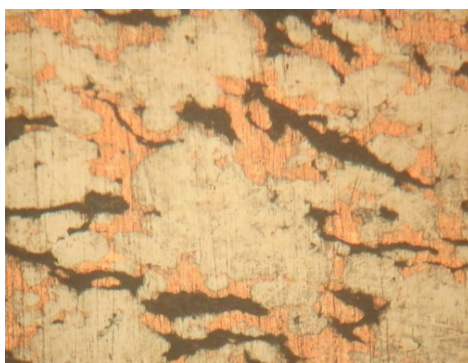


Fig. 5. The structure of the sintered composite powder steel LH15 - graphite – copper.

The tribotechnical characteristics of the obtained composites were studied on samples at a sliding speed of 5 m/s and a pressure of 10 MPa. The criterion for wear was the change in the volume of the sample depending on the friction path. The volume was measured at regular intervals. The results of wear resistance measurements are shown in Fig. 6.

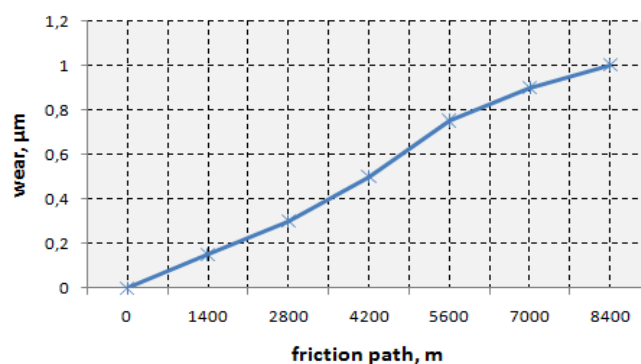


Fig. 6. Dependence of the wear of the composite material LH15 steel powder-graphite-copper on the friction path.

Samples from the studied composite have high wear resistance. This is due to the high hardness of the sintered material and the presence of a carbide mesh along the grain

boundaries. The coefficient of friction of the composite is 0.09 on average; voluminous wear $0.12 \times 10^5 \mu\text{m}^3/\text{m}$ for samples with a hardness of $\text{HV} = 2300 \text{ MPa}$.

A metallographic study of the friction surface after the study showed that the surface polishing effect is absent, and the wear is mainly abrasive in nature, which is due to the presence of a large number of wear particles. Pores during friction were smeared as a result of wear particles getting into them, as well as due to plastic deformation of the near-surface layer. Low pressure and the presence of graphite on the friction surface exclude the phenomenon of adhesion of surfaces, which is observed in the process of adhesive wear. During the increase in pressure, adhesive bonding was also not observed.

An experimental batch of guide bushings and sliding bearings was made from the composite material based on the powder obtained from the grinding slurry of LH15 (Fig. 7).



Fig. 7. Batch of guide bushings, sliding bearings.

The main characteristics of the sleeve: hardness $> 200 \text{ HB}$; porosity $< 20\%$; structure – fine-grained pearlite, graphite, pores; the sleeve is impregnated with industrial oil IL - 40A Standard VG32.

5 Conclusions

The development of a powder composite that provides high strength characteristics and wear resistance is one of the methods of increasing the reliability of loaded friction nodes. The tribotechnical characteristics of sintered powder materials based on LH15 steel powder for conditions of medium loads mainly depend on the hardness of the composition.

It was experimentally verified that the composite based on LH15 powder with a content of 2 (wt.) % graphite and 4 (wt.) % copper has high wear resistance and a small coefficient of friction, which is 0.09 on average, at a sliding speed of 5 m/s, pressure - 10 MPa. This is due to the high hardness of the sintered material $\text{HV} \approx 2300 \text{ MPa}$ and the presence of a carbide mesh along the grain boundaries. The composite material based on LH15 steel powder satisfies the tribo-technical properties, which is not inferior to the sintered iron-graphite material and has higher strength characteristics.

It can be used as an antifriction agent for dry friction conditions under moderate loads or in loaded friction units working with lubrication, and also serve as a prototype for the development of materials for various structural purposes.

According to the developed technological regimes, anti-friction products with a significantly lower cost and a higher coefficient of material utilization compared to traditional materials were obtained from a composite based on LH15 steel powder.

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