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Manufacturing Technology of Sliding Bearings from Ferro-Graphite Compositions

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Introduction. The development of modern technology imposes increasingly stringent requirements on materials operating under conditions of high pressures, speeds, deformations and aggressive media. The use of powder metallurgy methods in the creation of new materials makes it possible to provide a rational combination of production technology, structural and performance characteristics. Powder steels used in mechanical engineering are of great interest among the materials obtained by powder metallurgy. The article explores the possibility of manufacturing porous bearings made of iron powder for fan motors of domestic air conditioners instead of porous bearings made of bronze graphite.

Problem Statement. To ensure long-term operation of fan motors from metal powders, it is necessary to create porous bearings without alloying additives with the required mechanical properties. This requires a series of experimental work to determine the dependences of mechanical and technological properties on the sintering temperature, compacting pressure and the porosity of samples.

Theoretical Part. As a theoretical description, the use of a mold with an additional draining gap, which provides high bearing density at low compacting pressure, is analyzed. The effect of compacting pressure on the strength of sliding bearings under mechanical deformations depending on the sintering temperature is also considered.

Conclusions. It was established in the work that during the sintering of sliding bearings at a temperature of 800-1100°C, a significant charge carburization occurs due to the decomposition of zinc stearate in closed pores. As a result, a ferrite-pearlite structure is formed, due to which the bearings are well calibrated and have high wear resistance when paired with a steel shaft. Optimum sintering modes and compacting pressures were selected, which showed high reliability and durability of the products obtained from pure iron powder.

Keywords: sliding bearings, sintering, carbon, alloys, strength limits, yield strength, elongation, microstructure of the surface.

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Introduction. Porous sliding bearings for fan motors of household air conditioners must withstand long-term operation (15-20 thousand hours) in the following conditions: the sliding speed is 0.5 m/s; the specific load is 2 kg/cm^2; the Permavik composition is used as a lubricant, which creates a constant oil exchange in the friction unit for the entire period of operation of the electric motor (it is filled with a special cavity of the end shield). These bearings are made of non-ferrous metal powders: sprayed bronze powder of the BRO10S brand —1.5–583.8%, electrolytic copper powder of the PMS brand — 1–36% and tin powder of the PO-1 brand with a very low packed density — 4%. In addition, 1.2% graphite powder GC-3 and 1.5% zinc stearate are added to the charge. It should be noted that these materials are quite expensive. In addition, they require precise compliance with special conditions during sintering (temperature regime, composition of the gas medium in the furnace).

Currently, many varieties of porous bearings made of ferro-graphite, ferro-copper-graphite and other materials with various properties have been developed, successfully replacing porous bearings made of bronze-graphite. But these materials are less technologically advanced, since they require much more effort when pressing and calibrating bearings, which affects the performance and durability of an expensive press tool [1–4].

The **Aim** of the work is to study the technological modes of obtaining porous bearings from iron powder without alloying additives (especially carbon), as well as the development of a mold for pressing blanks with an additional drainage gap.

Problem Statement. To ensure the continuous operation of fan motors made of metal powders, it is necessary to create porous bearings without alloying additives with the required mechanical properties. To do this, it is necessary to conduct a series of experimental works to determine the dependences of mechanical and technological properties on the sintering temperature, compacting pressure and porosity of samples.

Theoretical Part. The material for the study was selected. It was iron powder of the brand PZHRV 2.200.226 with a packed density of 2.5 g/cm^3, to which 1.5% zinc stearate was added. As it is known [5-8], the increased content of zinc stearate in the charge creates additional interconnecting pores during sintering. Mixing was carried out in a V-shaped industrial mixer for 30 minutes. Cold pressing was carried out on a mechanical press with a nominal force of 50 kN according to the principle of effective removal of air from the charge through additional drainage gaps with which the mold was equipped. Due to this, at low compacting pressures (100–200MPa), a high bearing density was achieved. The possibility of additional drainage during pressing was provided by splitting the lower punch into two parts (punch in punch) (Fig. 1).

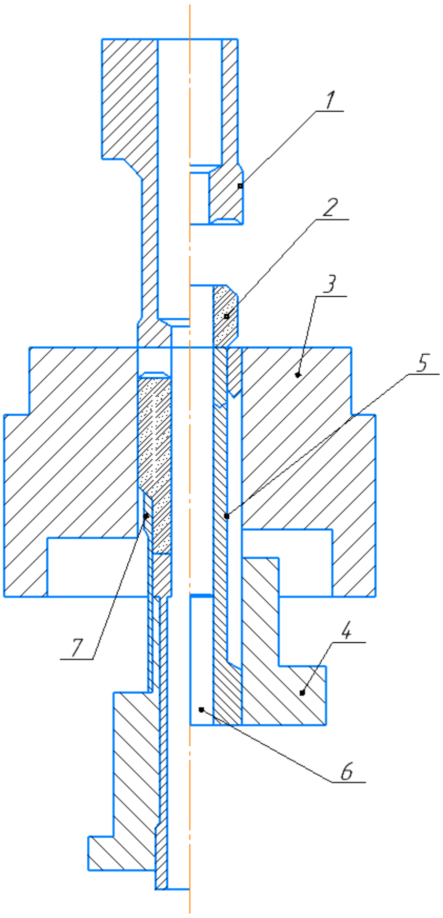
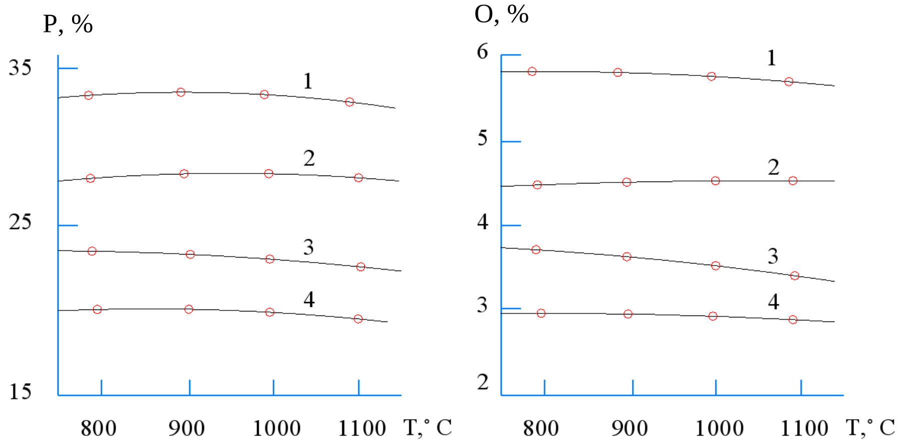


Fig. 1. Mold with additional drainage gap:1 — upper punch; 2 — porous bearing; 3 — matrix; 4 — outer lower punch; 5 — inner lower punch; 6 — rod; 7— additional drainage gap

The pressings were sintered in a continuous furnace in an endothermic gas medium (dew point temperature from +5 to +8 °C) at temperatures of 800-1100 °C for 30 minutes. Sintered bearings were calibrated with a special tool. Then the bearings were vacuum impregnated with XM-6 oil for 40 minutes at a residual pressure of 1.33 Pa.

The influence of the sintering temperature on the open porosity and oil absorption of bearings pressed at a pressure of 100-250 MPa was studied (Fig. 2). The open porosity of bearings pressed at 250 MPa decreases slightly with an increase in the sintering temperature. The difference in porosity between bearings sintered at 800 °C and 1100 °C is 1%. The porosity of bearings pressed under a pressure of 100–200MPa varies slightly with the sintering temperature. Similarly, the oil content also changes (Fig. 2b).

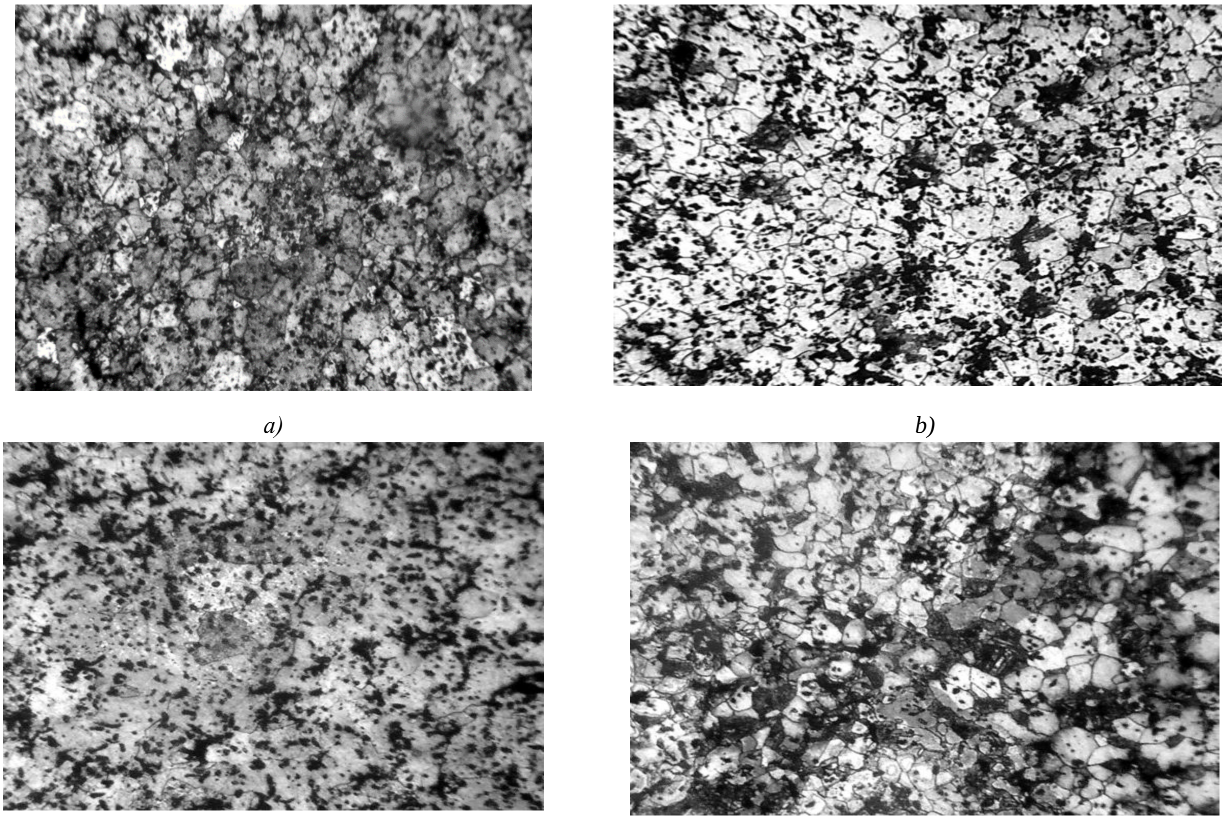


a) *b)*

Fig. 2. The results of the study of the influence of sintering temperature on: *a* — open porosity; *b* — oil absorption: 1, 2, 3, 4 — compacting pressure 100, 150, 200 and 250 MPa

With an increase in the sintering temperature, the microstructure of bearings compressed under a pressure of 150 Pa undergoes significant changes (Fig. 3). The number of small pores is reduced, and large ones become isolated. At low sintering temperatures, zinc stearate closes in closed pores, decomposes and carburizes the sintered material. In the structure of bearings sintered at 800 °C, there is much more perlite, although carbon was not introduced into the charge (Fig. 3), but with an increase in the sintering temperature, the amount of perlite decreases at 1100 °C, it is barely noticeable along the boundaries of the pores. The appearance of perlite along the boundaries of the pores confirms the fact of carburization of the material through the pores due to the decomposition of zinc stearate and exposure to a gaseous medium. During sintering, a ferritoperlite structure is formed in all considered temperature ranges.

The calibrating possibility for bearings depends on the sintering temperature (Fig. 4 *b*) to varying degrees, depending on the compacting pressure. If for bearings pressed at a pressure of 100 MPa, with an increase in sintering temperature, a smaller calibration force is required, then for bearings pressed at 150-250 MPa, a larger one is needed. Bearing sizes change during calibration mainly due to the reduction of large pores. With an increase in the compacting pressure, the porosity of the pressings decreases, the interparticle contact of the powders increases, the number of dislocations and distortions in their structure increases. Therefore, with an increase in the sintering temperature, the material of these bearings acquires greater strength and is difficult to calibrate [9–12].



a) *b)* *c)* *d)*

Fig. 3. Microstructure of porous bearings (×400) at the following sintering temperatures: *a* — 800 °C; *b* — 900 °C; *c* — 1000 °C; *d* — 1100 °C

An increase in the sintering temperature generally leads to an increase in the strength of bearings under radial compression both after sintering and after calibration (Table 1). A sharp increase in bearing strength is observed in all cases at 900 °C. Apparently, it is at elevated temperatures that the sublimation and evaporation of zinc stearate, secondary degassing of closed pores and pore channels increases. Further, diffusion processes are activated, complete recrystallization occurs: small pores disappear, and large ones are isolated. All this contributes to increasing the strength of bearings after sintering and calibration [2, 3, 10].

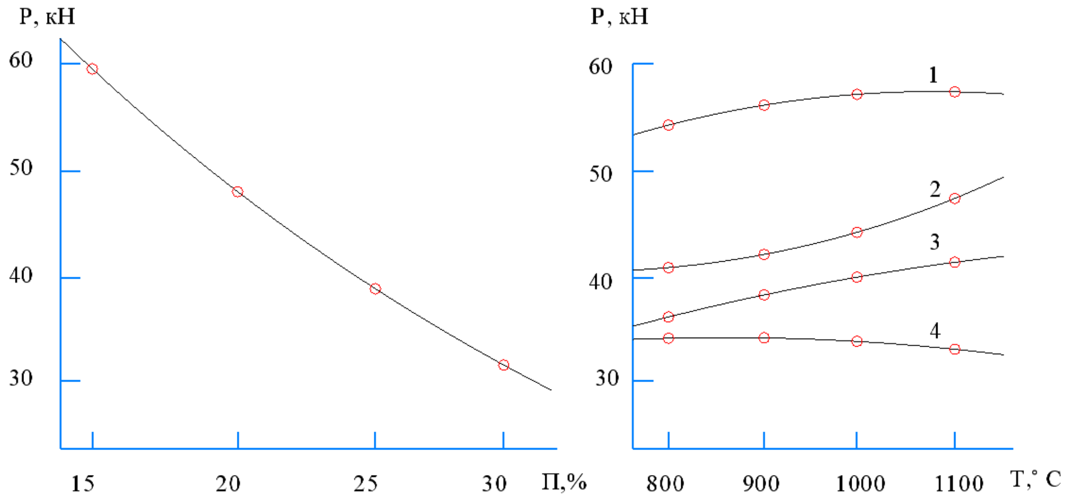
Table 1

Influence of compacting pressure and sintering temperature on the strength of bearings under radial compression

Compacting pressure P, MPa	Sintering temperature,°C	Radial compressive strength, 1×10^3 N	
		Before calibration	After calibration
1.0	800	55	62.3
	900	70	92
	1000	189	263
	1100	252	309.3
1.5	800	90	122
	900	150	178
	1000	222	288
	1100	357	417
2.0	800	221	288

Compacting pressure P, MPa	Sintering temperature,°C	Radial compressive strength, 1×10^3 N	
		Before calibration	After calibration
	900	200	250
	1000	357	457
	1100	479	547
2.5	800	160	212
	900	223	300
	1000	473	624
	1100	576	683

In accordance with the requirements of the technical specifications, bearings after sintering and calibration must have radial compression strength of at least 2.5 kN. According to Table 1, the strength of all bearings sintered at 800 °C is below this norm, regardless of the compacting pressure. Among the bearings sintered at 900 °C, those that are pressed at 200 and 250 MPa have strength of more than 2.5 kN after the calibration. Bearings pressed under a pressure of 100 MPa reach the required level of strength at a sintering temperature of 1100 °C, while other bearings — at 1000 °C.



a) *b)*

Fig. 4. Dependence of the calibration force on:
a — porosity (T = 1100 ° C, τ = 30 min); *b* — sintering temperature

With an increase in the compacting pressure in the range of 100-250 MPa, the density of both sintered and calibrated bearings increases, and the open porosity and oil absorption decreases (Fig. 5). At the same time, the nature of all curves remains unchanged.

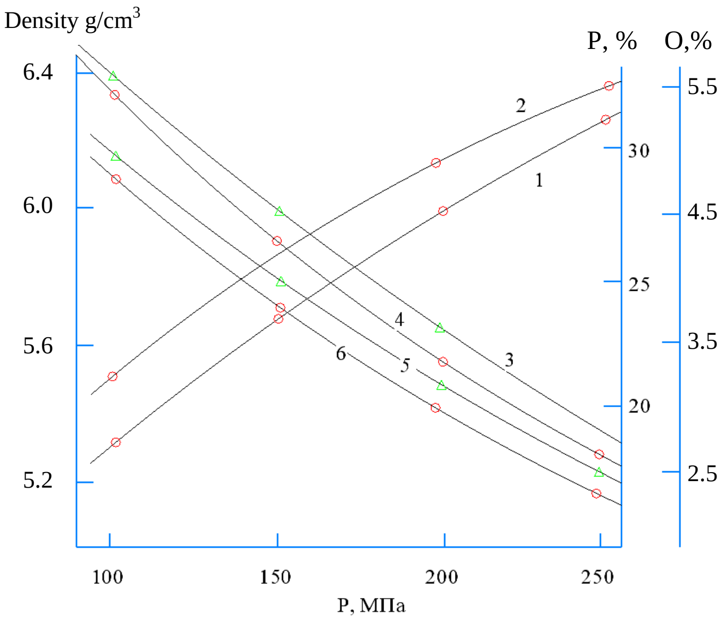


Fig. 5. Dependence of density (curves 1, 2), open porosity (curves 3, 4) and oil absorption (curves 5, 6) on compacting pressure

It should be noted that bearings pressed under a pressure of 100 MPa with high porosity and oil absorption have low strength, as a result of which they are destroyed before sintering (during installation, transportation). And bearings pressed at 250 MPa have high strength and relatively low porosity, although these parameters meet the requirements for bearings made of graphitized bronze.

Thus, the most technologically advanced bearings should be bearings pressed at a pressure of 100-150 MPa and sintered at a temperature of 1100 °C. But at all stages of their manufacture, the best properties were possessed by bearings pressed at 150 MPa and sintered at 1100 °C in an endothermic gas environment. Out of these bearings, 20 pieces of asynchronous single-phase capacitor motors of the ABT 71-115U2 type used in domestic air conditioner were assembled. Wear tests were carried out on an LG W07LC mock-up air conditioner. In accordance with the requirements of the technical specifications for this type of air conditioners, the test period was also selected — 1.5 thousand hours.

The test results have showed high reliability and durability of bearings made of pure iron powder by pressing at a pressure of 150 MPa, sintering at a temperature of 1100 °C with a calibration force of 3.8 kN and vacuum impregnation with XM-6 oil. Their wear was about the same as that of graphitized bronze bearings — about 7 microns per diameter.

Conclusions. The sintering temperature of bearings in the range of 800-1100 °C does not have a significant effect on their open porosity, oil absorption and calibrating ability.

When sintering bearings, a ferritoperlite structure is formed, which provides high wear resistance of bearings when working with a shaft made of automatic steel A-30 [13–16].

Bearings pressed under a pressure of 200 and 250 MPa and sintered at temperatures of 800-1100 °C require significant calibration effort, which dramatically reduces the durability of the press tool. Low strength of these bearings after sintering at 800-900 °C is not a factor that reduces the force of their calibration, it is inversely proportional to the porosity of the bearing.

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