FRICTION OF MATERIALS WITH ADDITIONS OF SUBSTANCES ACTING AS SOLID LUBRICANTS

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The addition to sintered antifriction materials of substances acting as solid lubricants promotes the establishment of an intermediate working layer, as a result of which the friction force and wear are reduced and seizure is prevented. Solid lubricants can be introduced into metal-powder materials by various techniques, such as by rubbing in a dry addition powder, impregnating the pores with liquid suspensions, or adding a solid lubricant to the charge before pressing and sintering. From the production point of view, the last of these techniques is the most convenient, because it eliminates the operations of impregnation, rubbing in, etc. and enables the friction surfaces to be machined. These processes are essentially used for producing sintered materials based on metals having low sintering temperatures, at which additions of substances acting as solid lubricants do not lose their properties. Bearings from such materials cannot operate at high loads or friction-zone temperatures.

In service under such conditions, iron-base sintered antifriction materials are more reliable. The relatively high sintering temperatures of these materials (1000-1200°C), however, restrict the range of solid lubricants which can be introduced into the charge before sintering. Suitable substances include zinc and iron sulfides [1], boron nitride, graphite, synthetic micas [2], etc. The comparatively small number of such substances decreases still further when sintering is to be performed in reducing environments, which aggravate the processes of thermal decomposition of substances capable of operating as solid lubricants.

The aim of the present investigation was to select solid lubricants which, when introduced into the charge of iron-base powder materials, do not lose their lubricating properties in the course of sintering in a hydrogen atmosphere and enable sintered bearings from these materials to operate at increased loads under dry-friction conditions. Zinc and iron sulfides, boron nitride, and barium and calcium fluorides were chosen for study. Some physical characteristics of these materials are listed in Table 1 [4, 5].

The test materials were prepared from PZh1M1 iron powder (fine iron powder obtained by the reduction process), to GOST 9849-61 standard, with additions of 4, 8, or 12% of the lubricating substances. Three batches of bearing inserts were made from each of these materials. Sintering was conducted in a dried-hydrogen atmosphere for 2 h, with the inserts packed in calcined alumina. The bearing-production technique has been described in more detail by Fedorchenko and coworkers [3]. Table 2 lists data on the influence of sintering on some characteristics of the materials of optimum compositions. It is clear from this table that the weight loss of the sulfide-containing materials was 3-5 times higher than that of the fluoride-containing materials, which is evidence of greater thermal stability of the latter. This is confirmed by data obtained by subjecting the surfaces of sintered bearings to x-ray diffraction analysis; the addition substance was detected only on the surface of the fluoride containing materials. The amounts of the sulfides

TABLE 1

Formula	Crystalline structure	Density g/cm^3	Melting point, °C	Heat of formation ΔH_{298}, kcal/mole
FeS	Hexagonal	4.84	1193	22.8
ZnS	Cubic	4.087	1850 (150 atm)	48.4
BaF_2	"	4.66	1290	287.7
CaF_2	"	3.18	1418	290.2
BN	Hexagonal	2.35	3000 (under N_2 pressure)	33.5

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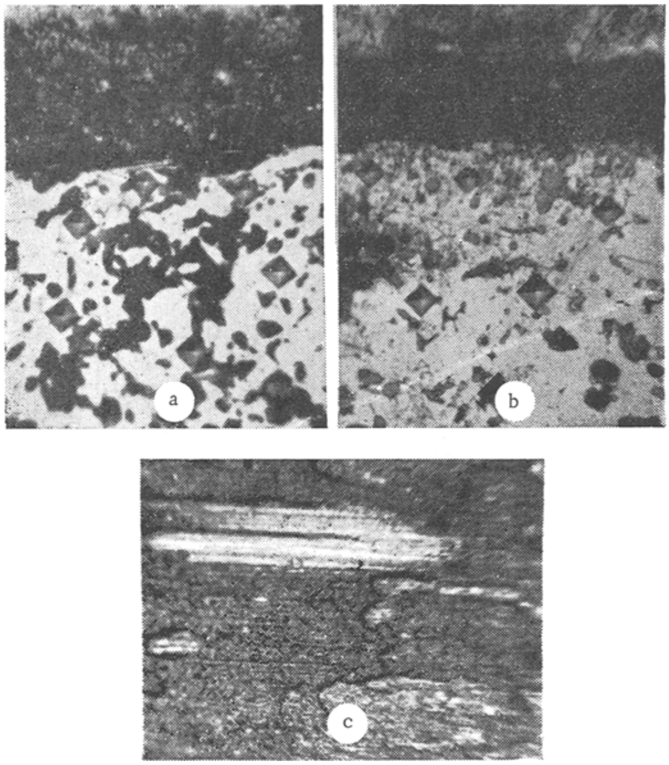

Fig. 1. Film separating friction surfaces. On surface of bearing: a) with CaF_2, ×300; b) with ZnS, ×300; c) on surface of shaft operating in bearing containing CaF_2 ×100.

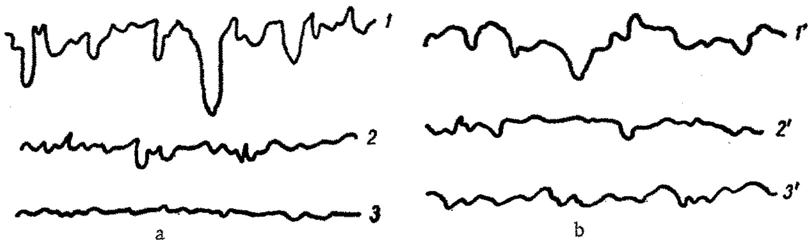

Fig. 2. Friction-surface profile charts. a) Bearing; 1) with FeS; 2) with ZnS; 3) with CaF_2. b) Shaft running in bearing containing: F) FeS; 2') ZnS; 3') CaF_2.

remaining in the surface layers of these materials after sintering were evidently outside the limits of sensitivity of x-ray diffraction analysis.

The effectiveness of additions designed to act as solid lubricants and introduced into the charge before sintering was evaluated from the antifriction properties of a friction pair operating under dry-sliding friction conditions. The friction pair was composed of a roller shaft of quenched steel 45 and a sintered segment-type bearing insert. The friction surfaces of the shafts and bearings were machined and had a Class 8 finish to GOST 2789-59 standard.

The tests were conducted on an Mi-1M friction machine under loads of 8 and 25 daN/cm^2. A constant sliding velocity of 0.28 m/sec was employed. The coefficients of friction and specific weight losses of the bearing and shaft in 4 h of operation provided criteria for evaluating materials. Each friction pair was first run-in.

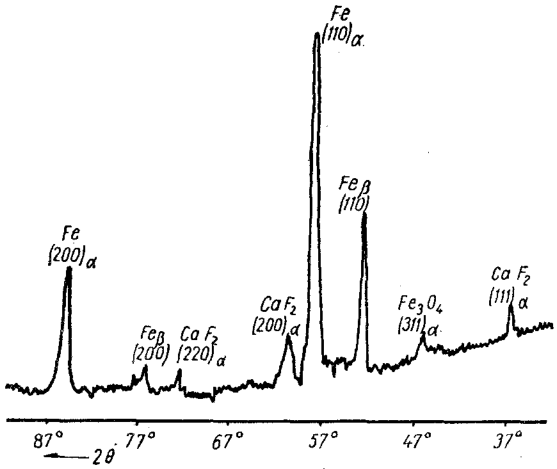

Fig. 3. Phase composition of surface film on bearing with CaF_2.

TABLE 2

Composition, vol.%	Weight loss in sintering, %	Porosity before sintering, %	Porosity after sintering, %
$Fe+12CaF_2$	0,9	13,2	12,8
$Fe+8BaF_2$	0,7	13,3	13,6
Fe+12ZnS	2,9	13,5	15,0
Fe+ 8FeS	3,8	13,0	15,2
Fe+12BN	1,0	13,0	14,9

The results of tests on materials with optimum amounts of additions are presented in Table 3. As can be seen, the least wear and coefficients of friction were recorded in tests on bearings containing calcium fluoride. The load-carrying capacity of these bearings was also significantly higher. While bearings containing calcium fluoride satisfactorily operated under the load of 25 daN/cm^2, other bearings gave good performance only under the load of 8 daN/cm^2.

Examination of the surface friction layers established that separating films had formed on the rubbing surfaces of bearings containing CaF_2 and ZnS. The film thickness in the former case was $1^1/^2$–2 times greater (Fig. 1a and b) and amounted to 40–70 μ. A similar, equally effective separating film had formed also on the surface of roller shafts operating in bearings containing CaF_2 (Fig. 1c).

The roller shafts after the tests generally exhibited an appreciable weight gain due to the transfer of the calcium fluoride onto their surface in the course of rubbing. This was confirmed by spectral analysis of the roller-shaft friction surfaces before and after testing.

A comparison of surface-profile graphs obtained for the friction surfaces of bearing after tests shows that, in the presence of additions acting as solid lubricants and promoting the formation of surface films effectively separating the friction surfaces, the finish of the latter improves (Fig. 2).

The phase composition of the surface film on bearing containing CaF_2 was determined with a URS-55a x-ray diffraction apparatus in iron radiation. A specimen to be photographed was prepared, in the form of a cylinder of 0.3-mm diameter, from the material of the film after the latter had been stripped mechanically. Photography was performed in a standard RKD camera, using an exposure time of 18 h. The x-ray diffraction picture was subjected to photometric analysis on an MF-4 microphotometer. The results of this analysis demonstrated that, in addition to iron and its oxides, the surface film contained also CaF_2 (Fig. 3).

In the course of these tests, it was established that, with increasing load, a particularly sharp decrease in the coefficient of friction was exhibited during the operation of bearings containing calcium fluoride. This was evidently due to the fact that, as the temperature in the friction zone rose, the resistance to shear deformation of CaF_2 decreased.

TABLE 3

Bearing material	Sp. wear of roller, $mg/cm^3/h$	Sp. wear of insert, $mg/cm^3/h$	Load, daN/cm^2	Coefficient of friction
Fe+8% FeS	4.1	146.6	8	0.67
Fe+BN	Poor performance		8	
$Fe+8\% BaF_2$	0.108	68.1	8	0.56
Fe+12% ZnS	0.21	117	8	0.63
$Fe+12\% CaF_2$	Weight gain	36.25	8	0.5
$Fe+12\% CaF_2$	"	41.25	25	0.28–0.34
Fe+12% ZnS	2.8	214	25	0.43

CONCLUSIONS

1. The antifriction properties of some fluorides of alkaline-earth metals and, for comparison, of zinc and iron sulfides were evaluated.

2. It is shown that, by adding calcium fluoride to the charge, it is possible to formulate iron-base sintered materials intended for the manufacture of self-lubricating bearings operating under dry-friction conditions.

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