Behavior of a Sulfidized Iron-Graphite Material under Dry Sliding Friction Conditions

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One of the essential conditions for the satisfactory, seizure-free operation of a friction pair is that separating films should be formed and continuously regenerated on the friction surfaces, thereby preventing pure metallic areas from coming into contact with one another and subsequently welding together [1, 2]. Under dry friction conditions, such separating films must ensure that the friction pair possesses not only antiscuffing but also lubricating properties, so that the processes of formation and rupture of surface bonds occur in these films with minimum energy losses.

The object of the present work was to study the nature and conditions of formation of surface films. In addition, an attempt was to be made to discover whether friction characteristics can be controlled by varying the composition of the bearing material and subjecting the working surfaces of the bearing to special thermochemical treatment.

A sulfidized iron-graphite material, ZhGr3Tss4 (3% graphite, 4% zinc sulfide, balance iron in charge), produced by sintering under pressure, was chosen for investigation. It has been established [3, 4] that, under dry friction conditions at speeds of 6-100 m/sec, dense, dark films, whose removal leads to seizure, form on the surfaces of mating parts operating in conjunction with this material. The effect of friction conditions on film generation was studied at speeds of 6, 8, and 12 m/sec and loads of 4, 8, and 12 kg/cm².

The antifriction properties of sintered bearing materials can be effectively improved by subjecting their working surfaces to sulfidizing [1, 2] or increasing their solid lubricant content. In view of this, a study was made of the effect of sulfidizing in Sulfofrezoj* [5] and of variations in the amounts of solid lubricants in the material on friction characteristics. The amounts of graphite chosen were 0, 3, 6, 9, and 12 wt.% and those of zinc sulfide, 0, 4, and 8 wt.%

Tests were conducted on an MT-62M friction machine [6]. Specimens, with a porosity of less than 3% (produced by sintering under pressure [7]), were made to slide on mating parts in Type 45 (0.45% C) steel heat-treated to a hardness of 45-50 HRC. During the tests, the intensity of wear, the coefficient of friction, and the instant at which a film appeared on the mating part were recorded. The rate at which a film is formed on the surface of the mating part depends to a large extent on the running-in conditions. Figure 1 shows recorded curves of the coefficient of friction and wear during the running-in period under various friction conditions.

During the initial brief period of operation (at V = 6 m/sec and P = 4 kg/cm²) the coefficient of friction and wear sharply rise.

Fig. 1. Effect of running-in conditions on friction characteristics of ZhGr3Tss4 material. Running-in speeds and loads: 1) 6 m/sec and 4 kg/cm²; 2) 8 and 8; 3, 4) 12 and 10 (specimen 4 was sulfidized in Sulfofrezoj).

* A metal-machining oil containing activating sulfur compounds — Publisher.

Fig. 2. Effect of zinc sulfide additions on properties of iron-graphite material (3% graphite in charge, porosity < 3%) at \( V = 8 \text{ m/sec} \) and \( P = 4 \text{ kg/cm}^2 \).

Fig. 3. Effect of graphite on properties of iron containing zinc sulfide (4 wt.% in charge, porosity < 3%) at \( V = 8 \text{ m/sec} \) and \( P = 4 \text{ kg/cm}^2 \).

attaining maxima of \( \mu = 0.36 \) and \( I = 24 \text{ } \mu \text{/km} \), which is evidence of plastic deformation and intense wear in the surface layers. After 1–2 min, the coefficient of friction and wear begin to decrease steadily. A film appears on the surface of the mating part, and, within 5–7 min of the beginning of operation, the friction behavior becomes completely stabilized.

At a speed of 8 m/sec and a load of 8 kg/cm² (Fig. 1, curves 2), scratches are formed on the surface of the mating part and sparking is observed. The coefficient of friction and wear intensity increase (\( \mu = 0.4, I = 30 \text{ } \mu \text{/km} \)). In this case, it takes 8–9 min of operation for the film to become sufficiently strong and for the friction process to become stabilized. Running-in at a speed of 10–12 m/sec and a load of 10 kg/cm² (Fig. 1, curves 3) results in individual particles of considerable size being torn out of the material. The seizure process progressively increases in intensity and no films are formed \( (\mu = 0.45, I = 40 \text{ } \mu \text{/km}) \); in our tests, these were the critical operating conditions. Thus, for the friction pair under consideration, satisfactory operation can be ensured only by light running-in.

However, there are numerous friction units whose bearings are expected to withstand the full load as soon as the machine begins to operate (end seals, etc.). Surface sulfidizing is one of the most effective methods for improving the running-in characteristics of bearings. When Sulfofrezol is used for this purpose, the specimen surface acquires a sulfide layer about 0.1 mm thick [8], which rules out the possibility of direct metallic contact. During the running-in process, the coefficient of friction gradually increases (Fig. 1, curves 4); this is an indication that the sulfide layer has a low resistance to rupture. A film forms on the mating part at the very beginning of testing. After 2–3 min, the wear and the coefficient of friction become stabilized, and their values are almost 20% lower than those for specimens subjected to no additional sulfidizing.

Of great interest are the composition and structure of the surface films. Unfortunately, x-ray and electron diffraction studies, using both reflection photographs of friction surfaces and transmission photographs of the material of films in the form of powders, failed to supply the required information. It would appear that, as a result of texturization and deep plastic deformation, the material of the film becomes