EFFECT OF THE COEFFICIENT OF MUTUAL CONTACT OF FRICTION PAIRS ON THE WEAR RESISTANCE OF IRON–GRAPHITE MATERIALS

N. E. Ponomarenko and V. G. Dikii

In modern engineering practice, end-type glands are being increasingly used for shaft sealing. The friction pairs of such seals operate at high coefficients of mutual contact (usually $K_m = 1$), which is essential for the establishment of continuous sliding contact ensuring the required degree of gas tightness.

The results are presented below of investigations into the effect of $K_m$ on the friction and wear characteristics of the following sintered antifriction materials: a sulfidized iron-base material, ZhGr3Ts4 (3% graphite and 4% ZnS in the charge, pearlitic structure, porosity $\eta = 13\%-15\%$, Brinell hardness HB = 80–95 kg/mm$^2$) and a molybdenum-containing iron–graphite material, ZhGr3M15 (3% graphite and 15% Mo, $\eta = 15\%$, HB = 130 kg/mm$^2$). Experiments were performed in a friction machine [1] at speeds of 11, 22, and 50 m/sec. Mating parts were made of ShKh15 steel (Rockwell C hardness $R_c = 60$), and also of 1Kh18N9T steel with a coating of Stellite V3K ($R_c = 42–43$). The working surface of both the specimens and mating parts were first lapped on cast iron plates and run-in. The resulting surface microrelief, which was measured with an MI-4 microinterferometer, corresponded to Class 10–12 finishes.

The results obtained in dry-friction tests on ZhGr3Ts4–V3K and ZhGr3M15–V3K pairs under a load of 1 kg/cm$^2$ at coefficients of mutual contact of 0.15 and 1 are listed in Table 1. To obtain $K_m = 0.15$, an end-face arrangement consisting of three specimens and a disk (specimen diameter 15 mm) was employed, while in tests at $K_m = 1$ ring-shaped specimens were used (o.d. 80 mm, i.d. 65 mm). Rings of this size are employed in end-type glands of bearing units.

The test results obtained and examinations of the surface layers and microrelief of friction surfaces demonstrated that, at $K_m = 1$, there is a marked deterioration in the conditions of operation of an end-type friction pair: Galling and breakdown are observed in parts of the friction surface of the sintered material and higher temperatures are generated in the friction zone. The characteristics of a friction pair with a high coefficient of contact are improved when the sintered ring has a uniform porosity and is free from large pores and graphite inclusions [2].

With specimens of 15-mm diameter, made of the same material, and rings of 75–80-mm diameter, their structure, porosity, and pore distribution may exhibit slight variations, which will affect the friction and wear characteristics. To examine this factor, a series of tests was carried out on specimens of the same friction pair, ZhGr3Ts4–ShKh15, at various values of $K_m$. Changes in $K_m(1, 0.7, 0.3, 0.15, and 0.05)$ were produced by cutting out

<table>
<thead>
<tr>
<th>Friction pair materials</th>
<th>$K_m$</th>
<th>$v$, m/sec</th>
<th>Coeff. of friction</th>
<th>$t$, $\mu$m</th>
<th>$t$, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZhGr3Ts4–Stellite V3K</td>
<td>0.15</td>
<td>22</td>
<td>0.17–0.24</td>
<td>12</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>50</td>
<td>0.3–0.16</td>
<td>6</td>
<td>250</td>
</tr>
<tr>
<td>ZhGr3M15–Stellite V3K</td>
<td>0.15</td>
<td>22</td>
<td>0.18–0.22</td>
<td>0.6</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>50</td>
<td>0.3–0.16</td>
<td>0.8</td>
<td>140</td>
</tr>
</tbody>
</table>

*ShKh15 is a 1% C–1.5% Cr ball-bearing steel, 1Kh18N9T is a Ti-stabilized 18/9 stainless steel, and Stellite V3K is an alloy containing 58–62% Co, 1.0–1.5% C, 28–32% Cr, 4.0–5.0% W, and 1.5–3.0% Si – Translator's note.

Fig. 1. Effect of $K_m$ on temperature and coefficient of friction of ZhGr3Tss4–ShKh15 end friction pair. Dry friction, $p = 1$ kg/cm$^2$.
Sliding speed: 1) 11; 2) 22; 3) 50 m/sec.

Fig. 2. Ring with profiled operating surface.

Fig. 3. Effect of profiling of friction surface on coefficient of friction and temperature of ZhGr3Tss4–ShKh15 end-type friction pair (after oil impregnation), $V = 22$ m/sec.

Fig. 1. Effect of $K_m$ on temperature and coefficient of friction of ZhGr3Tss4–ShKh15 end friction pair. Dry friction, $p = 1$ kg/cm$^2$.
Sliding speed: 1) 11; 2) 22; 3) 50 m/sec.

Fig. 2. Ring with profiled operating surface.

The results of these tests and of examinations of friction surfaces and wear products have shown that, as the coefficient of mutual contact is increased, the temperature rises and more favorable conditions are established for the formation of films on the friction surface. The wear products (graphite, sulfides, oxides) are retained longer in the friction zone and form "shielding" films [3]. Local ruptures may occur in the material in the vicinity of pores and inclusions, resulting in the formation of wear particles 100–300 $\mu$m in size. At $K_m$ values equal to or exceeding 0.5–0.7, such particles have a strong effect on the stability and value of the coefficient of friction, promote galling and breakdown of the friction surface of the sintered specimen, and raise the temperature in the friction zone.

It will be seen from the graph that, with increasing speed, the minimum values of coefficient of friction become displaced toward lower values of coefficient of mutual contact. At very low values of $K_m$, however, conditions are established permitting instantaneous removal of wear products and solid lubricant from the friction zone and direct contact between the metallic skeleton and the surface of the mating part, which adversely affects friction characteristics. Thus, by changing the value of $K_m$, it is possible to control friction and wear characteristics at constant values of sliding speed and load. In practice, this characteristic property of friction pairs is utilized by providing the surfaces of friction components in braking units with grooves and the operating surfaces of sliders, guides, etc., with slots.

In the present work, an attempt was made to improve the conditions of operation of end-type friction pairs by employing sintered rings with a specially shaped friction surface. In these experiments, three ZhGr3Tss4 rings ($l = 14\%$) of 80-mm outside diameter ($D$), 65-mm inside diameter ($d$), and 8-mm height ($h$) were employed. After machining, each ring (Fig. 2) had the profiled operating surface A (crosshatched in the figure) on one side and the annular surface B on the other side. The area of each of these surfaces