Sliding Bearings Properties Modification by Non-typical Journal Application

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Abstract: The article presents the results of investigations into the wear of slide bearings with an non-typical bearing journal. Pairs made up of elements of different hardness operating together and journals of different design were investigated. The possibility of reducing the wear due to contaminant hard particles in the oil by a change in the journal design was pointed out.

Keywords: Sliding bearing, wear, contaminant, non-typical journal

1 INTRODUCTION

One of the most serious dangers for slide bearings is contaminant hard particles [9] that occur in oil and are responsible for premature bearing damage. Their size may even exceed 200µm [10], which means that they are much bigger than the minimum bearing interspace. The research on the effect of contaminants contained in oil on slide bearing wear began already about 90 years ago and is still conducted presently [2, 4, 5, 12]. The results have shown explicitly that the particles in oil considerably increase tribological wear. A friction pair made up of a soft sleeve and a hard journal operating with it are consequently at risk of premature loss of their functional quality. The results of the research [6] also point to the fact that increasing the hardness of the journal may result in increasing its wear and a simultaneous decrease in the bearing sleeve wear. It is so because the contaminant particles are driven into the sleeve only partially and consequently have a damaging effect on the journal [3,6,11]. They stick in fully only when the sleeve is made of such soft materials as, e.g. Teflon or Plexiglas [1].

The research conducted by the Author [7,8] demonstrates that a decrease in the sliding pair wear in the presence of contaminant hard particles in oil may be achieved through a change in the construction of the journal, which results in removing contaminants from the abrasive contact area.

2. TEST METHODOLOGY

The examination of the tribological wear in the presence of hard contaminants in oil was conducted at the ZAN stand in Gdansk Technical University. The stand is described in detail in work [7]. The bearing journals were modified in two ways. The first one consisted in the formation of a two-component, steel-copper surface layer on the journal. The layer consists of a basic material with a helical groove and a modifying material put belt-like in it. In the contact area of the materials there is a groove to extra modify tribological properties. More information on the technology of shaping new layers and their properties is found in work [7]. The other way of modifying the journal involved shaping a helical groove on it. Fig.1. shows a picture of a journal with a two-component surface layer and a picture of a journal with a helical groove. The best results obtained for the two ways investigated were presented in the paper.

Tests were conducted for the following six combinations:
- variant 1 – journal made from C45 steel (hardness 86 HB) mating with sleeve made from MB 50 alloy (79% Al, 20 % Sn, 1%Cu, hardness µHV0,1 = 600 MPa),
- variant 2 – journal made from heat treated 34CrNiMo6 steel (hardness 34 HRC) mating with sleeve made from MB 50 alloy,
- variant 3 – journal made from heat treated 34CrNiMo6 steel (hardness 34 HRC) with two-component surface layer (steel-copper) mating with sleeve made from heat treated C45 steel (hardness 30 HRC),
- variant 4 – journal made from heat treated 34CrNiMo6 steel (hardness 34 HRC) with two-component surface layer (steel-copper) mating with sleeve made from heat treated C45 steel (hardness 30 HRC),
- variant 5 – journal made from heat treated 42CrMo4 steel (hardness 52 HRC) mating with sleeve made from heat treated C45 steel (hardness 30 HRC),
- variant 6 – journal made from heat treated 42CrMo4 steel (hardness 52 HRC) with helical groove mating with sleeve made from MB 50 alloy.

The following research test conditions were adopted for the ZAN stand:

Fig. 1. Photographs of bearing journal: 1) with two-component surface layer steel- copper; 2) with helical groove.
- journal rotational speed \( n = 600 \text{ rev/min} \) (frictional speed \( v = 1.65 \text{ m/s} \)),
- nominal pressure \( p = 1.57 \text{ MPa} \),
- total test time \( t = 20 \text{ h} \) (sliding distance \( s = 120 \text{ km} \)),
- lubricating agent: fully formulated engine oil of SAE40 viscosity,
- contaminants: \( \text{Al}_2\text{O}_3 \) powder, mean grain diameter-21\( \mu \)m,
- contaminant concentration in oil - 0.5 g/l.

A basis for calculating the journal and sleeve wear was profilograms of the sliding surface in axial section. They were used to determine volumetric wear. The measurement of the mass of the bimetal sleeves before and after the test determined the extent of their wear. Their mass loss was used to compute their volumetric wear. The basis for the comparison of the properties of the variants under investigation was the wear volumetric intensity \( Z_v \), and sliding distance \( s \):

\[
I_v = \frac{Z_v}{s} \quad (1)
\]

The research results made it possible to determine the following: journal wear intensity \( I_{vJ} \), sleeve wear intensity \( I_{vS} \), and the sum wear intensity of the sliding pair \( I_v \). The test was repeated three times for each variant.

3. RESULTS AND THEIR ANALYSIS

The investigation results obtained at the ZAN stand, while applying contaminated oil as lubricant, are shown in Table 1 and Fig. 2.

The investigation results presented in Table 1 and in Fig. 3 show considerable differences in the intensity of tribological wear rate of the investigated bearing variants.

As expected, variant 1 showed the highest wear intensity, where the bearing sleeve was combined with a soft journal. An increase in the journal hardness (comparison of variants 1, 2 and 5) reduces wear. The application of the hardest of the journals investigated (variant 5) gives a sixfold sliding pair wear reduction compared with the soft journal pair (variant 1). This way of improving abrasive wear resistance is well-known and often described in the literature [1,3, 7]. The application of a two-component surface layer journal paired with an MB50 material sleeve (variant 3) produced almost a threefold \( I_v \) coefficient reduction compared with the standard journal (variant 2). The wear intensity that occurs then is similar to the wear intensity of the pair with the smooth hard journal (variant 5). The similar wears of the journal and the sleeve are also worth noticing in this respect. The reduced material loss in this situation is probably due to contaminants being effectively removed from the abrasive contact area owing to the belts of soft material and the grooves on the surface of the journal.

The pair consisting of a medium hardness journal modified with copper and a sleeve of a similar hardness (variant 4) show definitely the least wear of all the investigated variants. It is three times smaller than that in the case of a hard journal and a soft sleeve (variant 5). A modification of a hard journal by making a helical groove on it (variant 6) yields a twofold reduction in wear intensity compared with the standard variant (variant 5). However, even then the wear is higher than that in the case of a copper modified journal and a sleeve of a similar hardness (variant 4).

<table>
<thead>
<tr>
<th>Variant</th>
<th>( I_{vJ} ) [mm(^3)/km]</th>
<th>( I_{vS} ) [mm(^3)/km]</th>
<th>( I_v ) [mm(^3)/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.74</td>
<td>1.51</td>
<td>17.25</td>
</tr>
<tr>
<td>2</td>
<td>5.54</td>
<td>1.59</td>
<td>7.13</td>
</tr>
<tr>
<td>3</td>
<td>1.48</td>
<td>1.25</td>
<td>2.73</td>
</tr>
<tr>
<td>4</td>
<td>0.50</td>
<td>0.35</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>2.45</td>
<td>0.12</td>
<td>2.57</td>
</tr>
<tr>
<td>6</td>
<td>1.12</td>
<td>0.09</td>
<td>1.21</td>
</tr>
</tbody>
</table>

![Figure 2. Diagram of wear volumetric intensity for investigated bearings; 1-sleeve, 2-journal.](image-url)
The results obtained and a remarkable diversity of tribological wear for the investigated variants is due to both the processes in the contaminated oil film and the effect of contaminants on the elements working together. An increase in the journal hardness means its higher wear resistance. However, there is more danger of hard contaminant particles sticking in the sleeve. The particles do not entirely sink in the sleeve and have a damaging effect on the journal. The sleeve wear intensity decrease found during the investigation seems to confirm this.

A considerable wear reduction achieved through the two investigated journal modifications is probably the effect of the partial removing of contaminants and wear products from the abrasive contact area. That occurred owing to the helical groove on the journal. It allows placing and transport of contaminants and, at the same time, enhances the axial flow of oil [7], which also helps to remove contaminants from the journal. Moreover, pairing materials of similar hardness (variant 4) most probably limits the contaminant sticking in the operating elements. Also the belts of soft copper may contribute to the reduction of the contaminant sticking. These are most probably the key factors that explain the lowest wear intensity for variant 4. The corroboration of the above theses will be the subject of further investigation.

The above presented modifications of the sliding pairs with a view to an increase in wear resistance in the case of contaminant hard particles may be an alternative to classical solutions.

4. CONCLUSIONS

1. Modifications of a journal with a two-component surface layer or a helical groove may be an effective method of wear reduction of slide bearings in the presence of contaminant hard particles.

2. During the investigations, while using oil lubricant contaminated with Al₂O₃ particles, modification of a 34 HRC journal with copper through forming a two-component surface layer produced a threefold bearing wear intensity decrease compared with the classical variant.

3. Investigation conducted under the same conditions also showed that a helical groove of a properly selected shape and pitch on the surface of a 52HRC journal resulted in a twofold wear decrease compared with a pair with a smooth journal.

4. The lowest wear intensity of all the six investigated variants was a characteristic of the sliding pair made up of a copper- modified medium hardness (34 HRC) journal and a sleeve of similar hardness (30HRC).

5. The changes observed should be most probably caused by effective contaminant removal from the abrasive contact area and a reduction in contaminant sticking in working elements, which is due to the applied journal modifications.

REFERENCES


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