Development of Oil-impregnated Sintered Bearing of Low Wear and Corrosion Resistance

Kazuhiro KIMURA*

Recently, oil-impregnated sintered bearings, which are slipping bearings, are used for a variety of applications because their steady sliding performance can be demonstrated over a long period of time without adding oil.

In this text, we added manganese sulphide (MnS) as a solid lubricant because MnS has sliding characteristics equal to oil-impregnated sintered bearings made of steel, and we introduce an oil-impregnated sintered bearing made of stainless steel that has excellent resistance to corrosion.

1. Introduction

Generally speaking, sintered oil-retaining bearings made of bronze or iron as a base material often use graphite (C) or molybdenum disulfide (MoS2) as solid lubricant. However, bronze- and iron-based materials were found inferior in corrosion resistance in special environments (in a gasoline atmosphere, for example) causing deterioration of sliding performance.

To solve this problem, we have developed, jointly with the Nagoya Municipal Industrial Research Institute, stainless steel sintered oil-retaining bearings, made of austenite-based stainless steel which are excellent in corrosion resistance. They have a sliding characteristic equivalent to that of iron-based sintered oil-retaining bearings as a result of the selection and quality of an adequate solid lubricant.

This paper presents the materials, basic characteristics, and performance of the newly developed product.

2. Materials of the newly developed product

For bearings using stainless steel as the base metal to achieve an excellent sliding characteristic, the selection of a solid lubricant plays an important role. The solid lubricants selected to evaluate the base metal and their sliding characteristic were bismuth (Bi), boron nitride (BN), graphite (C), molybdenum disulfide (MoS2), antimony (Sb), and manganese sulfide (MnS). Table 1 shows how the solid lubricants react with the base metal under heated conditions.

Solid lubricants are required not to react below the sintering temperature (1,200°C) of the base metal. However, C, MoS2, and Sb produce compounds under this condition which tend to exhibit increased hardness; for this reason, C, MoS2, and Sb cannot be used as solid lubricants for sintered bearings.

Bi, BN, and MnS do not produce reactants below 1,200°C, the sintering temperature of stainless steel, and the wear and friction tests showed that MnS exhibits the best sliding characteristic; for this reason, manganese sulfide (MnS) was selected as the solid lubricant. Fig. 1 shows an enlarged picture of manganese sulfide (MnS) powder.

<table>
<thead>
<tr>
<th>Solid lubricant</th>
<th>Temperature</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite (C)</td>
<td>1100</td>
<td>Deposition of (Cr, Fe):C3</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>Fusion</td>
</tr>
<tr>
<td>Molybdenum disulfide</td>
<td>800</td>
<td>Production of compounds after decomposition</td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>700</td>
<td>Production of compounds</td>
</tr>
<tr>
<td>Bismuth (Bi)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boron nitride (BN)</td>
<td>1200</td>
<td>No reaction</td>
</tr>
<tr>
<td>Manganese sulfide (MnS)</td>
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<td></td>
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3. Basic characteristics of the newly developed product

3.1 Features of the newly developed product

(Features)

1. The newly developed product excels in seizure resistance and wear resistance as a result of using manganese sulfide (MnS) as solid lubricant;
2. It excels in corrosion resistance because manganese sulfide (MnS) does not hinder the formation of passive state membrane by chromium oxide in stainless steel; and
3. Its sliding characteristics excel even in special environments (gasoline atmosphere).

3.2 Corrosion resistance

Table 2 shows the chemical composition of the newly developed product. Its base metal is austenite-based stainless steel, a material excellent in corrosion resistance.

A humidity cabinet test was conducted to ascertain the corrosion resistance of the newly developed product and iron-based sintered bearings.

(Test method)

The newly developed product and iron-based sintered bearings were left alone in a thermostatic bath for 200 hours under the following conditions to observe how rust occurred:

- Temperature: 50±5˚C
- Humidity: 95±5%RH
- No protective layer of lubrication

Fig. 2 shows the appearance of the bearing after the test. Rust was observed on the surface of the iron-based sintered bearings 24 hours after the start of the test, while it was not observed on the surface of the newly developed product 200 hours after the start of the test.

Table 2 Chemical composition

<table>
<thead>
<tr>
<th>Chemical composition (%)</th>
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</thead>
<tbody>
<tr>
<td>Fe</td>
</tr>
<tr>
<td>Residue</td>
</tr>
</tbody>
</table>

3.3 Evaluation of corrosion resistance in a special environment

Excellent corrosion resistance is required of fuel pump bearings as they are used in gasoline or bio-fuel, which have been found to be highly corrosive when used around past products.

For this reason, bronze-based bearings, widely used as sintered oil-retaining bearings, and the newly developed product, both without a protect oil coating, were immersed in a sulfur-containing solution for comparison.

(Test method)

- Solution: Liquid mixture of regular gasoline, ethanol, and sulfur
- Solution temperature: 60˚C
- Test duration: 100 h
- Bearing size: Inside diameter: 6 mm; outside diameter: 12 mm; width of 6 mm

Fig. 3 shows the appearance after the test and Fig. 4 the change in dimensions due to corrosion.

After the test, discoloration was observed on the bronze-based sintered bearings, and the inside diameter, outside diameter, and width all showed changes of at least 0.1 mm, evidence of corrosion. By contrast, the newly developed product showed no change in appearance, with change in dimension being one-tenth or less than that found in bronze-based bearings.
discoloration. Fig. 5 shows the surface state and Fig. 6 the result of analysis. The manganese sulfide (MnS) surface is blackened by oxidation, while the stainless steel surface near the manganese sulfide (MnS) area does not exhibit changes. The results of the analysis before and after the test show that oxygen (O), which was not observed in the sample before the test, was detected in the sample after the test. Also, a slight amount of oxygen (O) was observed on the surface of manganese sulfide (MnS). That being said, the stainless steel surface exhibited no change, which shows that manganese sulfide (MnS) did not affect the corrosion resistance of the base metal.

3.4 Evaluation of the corrosion resistance of solid lubricant, manganese sulfide (MnS)
The humidity cabinet test was conducted to see how sulfur-containing manganese sulfide (MnS) affects the base metal, stainless steel, when the newly developed product undergoes corrosion positively.

(Test method)
- Temperature: 60°C
- Humidity: 90%Rh
- Test duration: Observation was conducted at intervals of 168 hours, and the test was to be ended when a change was observed on the surface.

After 1,176 hours of testing, the surface of the newly developed product exhibited discoloration. The test was ended in order to perform SEM/EDX-EPMA analysis on the areas of the part showing the most discoloration. Fig. 5 shows the surface state and Fig. 6 the result of analysis.

The manganese sulfide (MnS) surface is blackened by oxidation, while the stainless steel surface near the manganese sulfide (MnS) area does not exhibit changes. The results of the analysis before and after the test show that oxygen (O), which was not observed in the sample before the test, was detected in the sample after the test. Also, a slight amount of oxygen (O) was observed on the surface of manganese sulfide (MnS). That being said, the stainless steel surface exhibited no change, which shows that manganese sulfide (MnS) did not affect the corrosion resistance of the base metal.
3.5 Sliding performance of the stainless steel sintered bearing

To compare the coefficient of friction between the newly developed product and the iron-based sintered bearing, the testing machine shown in Fig. 7 was used to measure the coefficient of friction. Table 3 shows the physical property values of the newly developed product and iron-based sintered bearing.

Table 3 Basic characteristics

<table>
<thead>
<tr>
<th></th>
<th>Density g/cm³</th>
<th>Pressure ring strength MPa</th>
<th>Surface hardness HRF</th>
<th>Oil content Vol.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly developed product</td>
<td>6.5–7.0</td>
<td>150 or more</td>
<td>70 or more</td>
<td>8 or more</td>
</tr>
<tr>
<td>Iron-based sintered bearing</td>
<td>5.9–6.3</td>
<td>200 or more</td>
<td>40 or more</td>
<td>18 or more</td>
</tr>
</tbody>
</table>

Fig. 7 Test rig

(Test method)
- Peripheral speed (V): 37.7 m/min
- Contact pressure (P): 0.2–1.5 MPa
- Lubricant: Mineral oil
- Atmosphere: Room temperature

* With the peripheral speed kept constant, the PV value was varied by varying the contact pressure.

Fig. 8 shows the relationship between the PV value and the coefficient of friction. Both materials show their coefficients of friction at about 0.1, which is about the same as that of an iron-based sintered bearing.

Fig. 9 shows the initial adaptive characteristic at a peripheral speed of 37.7 m/min and a contact pressure of 1.0 MPa and the change in the coefficient of friction over a 500-hour period of time.

Like iron-based sintered bearings, the newly developed product exhibits a high coefficient of friction immediately after the start of the test, but the value of the coefficient of friction begins to decrease gradually and shows about the same value as that of iron-based sintered bearings at the end.
4. Points to notice in using stainless steel sintered bearings

In sintered bearings, generally speaking, lubricant retained in the bearing by means of impregnation seeps to the bearing surface to form oil film with the effect of preventing the contact between the shaft and bearing surfaces. For this reason, the presence of lubricant is indispensable to maintaining a good sliding characteristic; the same characteristic is true of the newly developed product\(^2\). Accordingly, the sliding performance deteriorates remarkably without lubrication or under high temperature conditions in which the lubricant cannot perform its role sufficiently. A solid lubricant (MnS) works to prevent abnormal friction, however, since there is a danger that the lubricant will lead to abnormal heating of the sliding part and abnormal wearing of the shaft and bearings, it is necessary to select a lubricant compatible with the temperature of the atmosphere.

5. Conclusion

A new sintered oil-retaining bearing with excellent corrosion resistance and low friction has been developed by means of adopting stainless steel as the base metal and manganese sulfide (MnS) as the solid lubricant. The newly developed product has a sliding characteristic equivalent to that of a conventional iron-based sintered bearing, with its corrosion resistance improved substantially. The result of this development work will contribute to further lengthening of the service life of sintered bearings under special environments.

References