Koyo has developed a high-rigidity, long-life ball bearing to satisfy the needs of lightweight, compactness and low cost. This bearing has the same boundary dimensions as those of a corresponding standard single row ball bearing, and can provide longer life and higher rigidity than the conventional single row ball bearing (e.g., four-point contact ball bearing, deep groove ball bearing), in minimizing the decline of service life compared to the double row angular contact ball bearing.

Key Words: high-rigidity, long-life ball bearing, long life, high rigidity, single row ball bearing, four-point contact bearing

1. Introduction

In today's automobile industry, demands for lightweight, compactness, low cost and high performance designs have steadily increased under the background of environmental problems and competition among carmakers both in cost and performance. Under these circumstances, similar demands are seen for rolling bearings.

In order to satisfy such demands, Koyo has developed a new single row ball bearing with the same boundary dimensions as a standard single row bearing. The developed bearing has higher rigidity and longer life than conventional single row ball bearings (4-point contact ball bearings and deep groove ball bearings) and the reduction in bearing life has been minimized compared to double row angular contact ball bearings. Results of the development are reported below.

2. Target of Development

Among applications currently using double row angular contact ball bearings, there are some cases in which these bearings cannot be replaced with single row ball bearings due to inadequate life or rigidity, though double row ball bearings have adequate life.

Therefore, the target of development was set at a bearing that has service life around halfway between double row angular contact ball bearings and conventional single row ball bearings, while maintaining a level of rigidity equivalent to double row ball bearings. Specifically, taking account of development background of products applicable in various usage, the target life of the developed bearing was set at the level both minimum 1.6 times the conventional 4-point contact ball bearings and minimum 0.7 times the double row angular contact ball bearings. Furthermore, the life goal must also match the equivalent service life of a deep groove ball bearing under pure radial load. Concerning the bearing cost, similar cost to that of corresponding deep groove ball bearings was the target (Fig. 1).

3. Structure of Developed Bearing

The developed bearing is a new 4-point contact ball bearing with bilaterally asymmetrical internal design that is different from conventional 4-point contact ball bearings. The inner and outer ring raceway curvatures and contact angles were optimized to minimize heat generation, reduce the risk of the balls riding on the raceway shoulders and to minimize the maximum contact pressure between the balls and raceway. The raceway dimensional accuracy was also improved as compared to the conventional 4-point contact ball bearings (Fig. 2).
2) Verification of Mechanism

A measurement was conducted to verify the spin occurrence in the bearing under pure radial load condition. The test method and test results are shown in Figs. 6 and 7, respectively. In this test one of the steel balls was magnetized while the coil was provided on the shaft. The electromotive force generated by rotation of the magnetized ball induces a measurable voltage in the coil, which provides evidence of spin.

Based on the obtained voltage wave pattern, it was verified that the ball spin occurred in the developed bearing, but not in the conventional 4-point contact ball bearing under pure radial load.

4. Features of Developed Bearing

4.1 Improvement of Seizure Life (Compared with Conventional 4-point Contact Ball Bearing)

1) Mechanism

The mechanism for improving the seizure life of the developed bearing under pure radial load is summarized in Fig. 3.

Since the conventional 4-point contact ball bearing has bilaterally symmetrical internal design, its rolling elements do not spin under pure radial load conditions but rotate on its C-axis. As a result, each ball keeps rolling on the same rolling track, which causes the oil film to break partially, and hence shorten the bearing life (Fig. 4). On the contrary, the developed bearing with bilaterally asymmetrical internal design has different spinning moments A and B even under pure radial load. This difference causes the balls to spin for preventing the oil film from breaking, and hence to assure long life.

A specific quantitative analysis of compound spinning moments under various offset loads was conducted. The results are shown in Fig. 5.

Whereas the conventional 4-point contact bearing shows zero compound spin moment at zero offset, the developed bearing has some spin moment under no offset load.

Fig. 2 Structure of development article

<table>
<thead>
<tr>
<th>Outer ring internal design</th>
<th>Developed bearing</th>
<th>Conventional 4-point contact ball bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left side ≠ right side</td>
<td>Left side = right side</td>
<td></td>
</tr>
<tr>
<td>Inner ring internal design</td>
<td>Left side ≠ right side</td>
<td>Left side = right side</td>
</tr>
<tr>
<td>Raceway curvature, contact angle</td>
<td>Optimized (Heat generation, contact pressure, ball riding on shoulder)</td>
<td>Standard</td>
</tr>
<tr>
<td>Raceway accuracy</td>
<td>Improved accuracy compared to conventional 4-point contact ball bearing</td>
<td>–</td>
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</tbody>
</table>

Fig. 3 Long-life mechanism under pure radial load

Fig. 4 Appearance of rolling element after test under pure radial load (conventional 4-point contact bearing)

Fig. 5 Analysis result of offset and composite spin moment
Improvement of Life under Offset Load

(1) Mechanism

The mechanism of seizure life improvement under offset load conditions is shown in Fig. 8.

Like conventional 4-point contact ball bearings, the developed bearing shows multi-point contact between the balls and the raceways in offset loading condition (radial load + moment) and hence heat generation occurs due to sliding between the balls and raceways. To prevent temperature rise, and thereby to improve bearing life, the internal design of the bearing was optimized together with improvement of the raceway accuracy.

(2) Verification of Mechanism

① Optimization of Bearing Internal Design

Analytical result of heat generation in the bearing under various offset loads is shown in Fig. 9.

It shows that the internal design of the developed bearing has less heat generation than conventional 4-point contact bearings.

② Improvement of Raceway Roughness

Figure 10 shows the relationship between the raceway roughness and measured heat generation.

Conventionally, it was difficult to apply super finishing on the raceway of 4-point contact ball bearings since their raceway profile is not a single arc. That is the reason why the raceway roughness of conventional 4-point contact ball bearings is slightly larger than that of deep groove ball bearings. Therefore, new super finishing technology has been developed in order to achieve the same roughness as that of deep groove ball bearings and to reduce the temperature rise of the bearing.

Fig. 6 Measurement method for spinning of rolling element

Fig. 7 Voltage waveform under pure radial load

4.1.2 Improvement of Life under Offset Load

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Fig. 8 Long-life mechanism under offset load
Development of High-Rigidity, Long-Life Ball Bearing

The result of comparative seizure life test is shown in Fig. 11.
Within the entire offset range, the developed bearings showed longer life than conventional 4-point contact ball bearings and, in the 0 ~ 10mm offset range, 1.7 times longer life. In the offset range less than 6mm, the developed bearings showed 0.6 ~ 0.7 times as long as the double row angular contact ball bearings. Under pure radial load, life of developed bearings was nearly the same as that of deep groove ball bearings.

**4. 2 High Capacity**
Calculated flaking life of the developed and conventional bearings under various offset values are shown in Fig. 12.
Since the developed bearing is basically a 4-point contact ball bearing, it has higher capacity than a deep groove ball bearing. In the small offset range, the developed bearing’s calculated flaking life was 0.8 times that of a double row angular contact ball bearing and 1.5 times that of deep groove ball bearings. Also, the developed bearing can accommodate twice as large moment as deep groove ball bearing without causing ball riding on the shoulder.

**4. 3 High Rigidity**
Three types of bearings, the developed bearing, double row angular contact ball bearing and deep groove ball bearing, were compared in terms of axial clearance as related to the radial clearance as well as angular clearance, as shown in Figs. 13 and 14, respectively.
The developed bearing had half the axial clearance of the deep groove ball bearing and about the same as that of the double row angular contact ball bearing. Also, the developed bearing had angular clearance approximately 1/3 of deep groove ball bearing and close to the double row angular contact ball bearing.

**4. 4 Summary**
Table 1 summarizes various features of the developed bearing in comparison with current ball bearings.
In summary, the life and rigidity performance of the developed bearing nearly satisfied the initial development target.

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**Table 1** Features of development article

<table>
<thead>
<tr>
<th>Feature</th>
<th>Performance comparison</th>
<th>Compared bearing</th>
</tr>
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<tbody>
<tr>
<td>Improved seizure life</td>
<td>Approx. 3 times</td>
<td>Conventional 4-point ball bearing</td>
</tr>
<tr>
<td></td>
<td>(under pure radial load)</td>
<td></td>
</tr>
<tr>
<td>High capacity</td>
<td>Approx. 1.7 ~ 2 times</td>
<td>Equivalent (under pure radial load)</td>
</tr>
<tr>
<td></td>
<td>(small moment range)</td>
<td>Deep groove ball bearing</td>
</tr>
<tr>
<td>High rigidity</td>
<td>Approx. 0.6 ~ 0.7 times</td>
<td>Double row angular contact ball bearing</td>
</tr>
<tr>
<td></td>
<td>(pure radial load ~ small moment range)</td>
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</tbody>
</table>

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**Fig. 11** Comparison of offset and seizure life

**Fig. 12** Comparison of offset and flaking life

**Fig. 13** Relation between radial and axial clearances

**Fig. 14** Relation between radial clearance and angular clearance
5. Conclusion

The developed bearing has the feature of longer life than conventional 4-point contact ball bearings under high-speed condition, pure radial load or moment. Compared with single row deep groove ball bearings, it showed higher capacity and higher rigidity. Therefore, the new bearing can be applied for air conditioner pulleys, idler and single row water pump bearings. It will also be possible to apply the developed bearing as a replacement of other single row ball bearings of similar size where increased capacity and rigidity are required.

References


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* Chubu Technical Center, Bearing Business Operations Headquarters