Long Life Technology of Grease for Journal Bearing

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Journal bearings are very important components of railway vehicles as they directly affect the vehicle’s running stability. Sealed type double row tapered roller bearings with grease packed are traditionally used as journal bearings. NTN Engineering tested grease packed double row tapered roller bearings to investigate the relationship between oil separation of the grease and metal to metal contact of between bearing rollers and raceways. As a result, it was observed that bearings would be kept in good lubrication conditions by using the greases which had proper oil separation performance. This paper reports the effect of lubrication condition of rolling bearing due to oil separation of utilized the grease.

1. Introduction

There are typically three types of bearings used with railroad vehicles. These include bearings for the main motors used for driving the vehicles, bearings for the drive equipment used for transmission of driving power, and journal bearings to support the wheel axles. All of these bearings require a high reliability since they are directly related to the running of the vehicles. With the requirements for longer life come requirements for longer intervals between maintenance, making extending bearing life and maintaining reliability a difficult task.

Sealed-type double-row tapered roller bearings with grease lubrication are mainly used as journal bearings for use with railroad vehicles as longer grease life is required for longer maintenance intervals.

Sealed-type double-row tapered roller bearings have a larger space between the rollers and the cage. Since sealed-type double-row tapered roller bearings have line contact between the roller and the raceway, they require increased lubrication in comparison to ball bearings, which have point contact. Therefore, longer lubrication life through improvement of the grease itself is critical.

This paper investigates the effect of different greases’ oil separation properties on journal bearing life of railroad vehicles with the intent of optimizing grease and bearing life.

2. Journal bearings

Under normal operation, journal bearings are installed in the journal box to support the wheel axle. While in operation, radial load from the vehicle weight, axial load from the vehicle movement, and vibration are applied to the journal bearings. While various bearing types were investigated, adopted, and used in the past, sealed-type rotating end cap tapered roller bearings (RCT), shown in Fig. 1, are the most prevalent design today.

Sealed-type rotating end cap tapered roller bearings consist of an inner ring, outer ring, rollers, cage, oil seal, slinger, back cover, etc. For a lubricant, a grease with a lithium soap as the thickener and mineral oil as a base oil is generally use. Grease is injected between the rollers and the cage but as the bearings rotate, grease is often pushed outward toward the (5) oil seal. Since sealed-type rotating end cap tapered roller bearings have a larger space between (3) the rollers and (5) the oil seal compared

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to other types of rolling bearings, it is necessary to pay attention to fluidity when selecting sealing grease. The rate of deterioration of grease in journal bearings is one important element for determining the maintenance intervals of the vehicles. The bearings are disassembled, inspected, and greased during the periodical maintenance.

So far, various measures have been taken to extend the maintenance intervals. Cages that in the past were made of steel were replaced with cages made of resin to reduce the metal abrasion powder, which can cause grease deterioration. In addition to this, low-heat generating seals were adopted to control degradation of grease due to temperature rise 3). Although these measures gradually extended the maintenance intervals, the requirement for further extension is still very high 4), requiring longer life of the grease itself.

3. Grease lubrication

The grease properties to be improved for long life vary depending on the use location and conditions.

Within the rolling bearings, grease itself penetrates in the rolling surface providing lubrication at the beginning of the operation; however, after some time in operation the base oil becomes the main vehicle for lubrication. Toward the end of lifecycle, seizure may be caused by shortage or deterioration of oil 5).

For cylindrical roller bearings, studies have already been conducted showing the relationship between lubrication life of bearings and oil separation property. It concluded that the optimum oil separation property would provide a longer bearing life 6).

In this paper, we investigated how the oil separation property of grease would affect lubrication of rotating end cap tapered roller bearings.

4. Oil separation property of grease

The oil separation property of grease varies depending on the type and amount of base oil and thickener, as well as the manufacturing method of the grease. For this test a total of 44 types of grease with various types and amounts of base oil and thickener were prepared to investigate the relationship between the grease composition and oil separation properties. For measuring oil separation properties, the following centrifugal oil separation testing method was used assuming that grease attached to the bearing cage would be separated from oil by centrifugal force.

4.1 Grease samples under test

Table 1 shows the composition of grease samples prepared for this test. For thickener, three types of urea compound and one type of lithium soap were selected and used with different blending amounts. For base oil, mineral oil and synthesized hydrocarbon oil were used.

4.2 Centrifugal oil separation test

The oil separation property of the grease samples was investigated using the centrifugal separator. After rotating the centrifugal tube with 1.0 ± 0.1 g of grease sample under 3.9 × 10^4 G for 1 h, the weight of the separated oil within the centrifugal tube was measured, as shown in Fig.2. The centrifugal oil separation ratio was calculated as the ratio of the weight of separated oil against original grease using the following equation (1).

\[
\text{Centrifugal oil separation ratio (\%) = \frac{\text{Amount of separated oil in the test (g)}}{\text{Original amount of grease (g)}} \times 100 \quad \ldots (1)
\]

Fig. 3 and 4 show the measurement results as the centrifugal oil separation ratio. The centrifugal oil separation ratio decreases when the thickener is increased in any grease sample. When compared with the same amount of thickener, the centrifugal oil separation ratio varies depending on the type of thickener or base oil.

Table 1 Composition of test grease

<table>
<thead>
<tr>
<th>Group</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickener</td>
<td>Aliphatic urea</td>
<td>Aliphatic urea</td>
<td>Alicyclic urea</td>
<td>Aromatic urea</td>
<td>Li soap</td>
<td>Aliphatic urea</td>
<td>Alicyclic urea</td>
<td>Aromatic urea</td>
</tr>
<tr>
<td>Amount of thickener wt%</td>
<td>7~13</td>
<td>7~10</td>
<td>16~15</td>
<td>9~15</td>
<td>11~14</td>
<td>17~26</td>
<td>22~41</td>
<td>16~34</td>
</tr>
<tr>
<td>Base oil</td>
<td>Mineral oil</td>
<td>Synthesized hydrocarbon oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity of base oil mm²/s (40°C)</td>
<td>100</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
With mineral oil as base oil, as shown in Fig. 3, when aromatic urea (M3) is used as thickener, centrifugal oil separation ratio tended to be higher; however, no significant difference was observed among thickeners other than aromatic urea. When synthesized hydrocarbon oil was used as base oil, as shown in Fig. 4, the centrifugal oil separation ratio tended to be higher than when compared the cases where mineral oil was used as base oil. When aromatic urea was used as thickener, the centrifugal oil separation ratio tended to be higher too.

As a result, it is determined that the type and blending ratio of thickener as well as the type of base oil affect the centrifugal oil separation ratio.

5. Grease endurance test using rolling bearings

5.1 Test method

Five types of grease with different centrifugal oil separation ratio, M1-12% (expressed in group-amount of thickener), S2-17%, S3-22%, S4-16%, and S4-31% were sealed between the cage and inner ring of roller bearings. For this endurance test, 20g of grease was used in each bearing. Fig. 5 shows the overview of the test equipment and Table 2 shows the test conditions.

<table>
<thead>
<tr>
<th>Bearing</th>
<th>Tapered roller bearing ((\phi 70 \times \phi 110 \times 31))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bearings</td>
<td>Two (back to back)</td>
</tr>
<tr>
<td>Radial load (per 2 bearings)</td>
<td>10.78kN</td>
</tr>
<tr>
<td>Rotational speed</td>
<td>3000 min(^{-1})</td>
</tr>
<tr>
<td>Temperature</td>
<td>Room temperature</td>
</tr>
<tr>
<td>Test duration</td>
<td>2000–10000 h</td>
</tr>
</tbody>
</table>

Table 2 Endurance test condition

![Fig. 2 Schematic diagram of centrifugal oil separation test](image)

![Fig. 3 Oil separation of test grease (M1 to M4)](image)

![Fig. 4 Oil separation of test grease (S1 to S4)](image)

![Fig. 5 Endurance test equipment](image)
conditions. For bearings under test, two units of rotating end cap tapered roller bearings (φ70 × φ110 × 31) were used. The bearings were rotated at a speed of 3000 min⁻¹ with an applied radial load of 10.78 kN. During the test, the metal contact ratio between the inner and outer rings of the rolling bearings was measured using the electric resistance method. The test equipment was stopped after a predetermined duration and the oil reduction ratio of the grease measured. The calculation method of metal contact ratio and the oil reduction is shown in equations (2) and (3), respectively.

\[
\text{Metal contact ratio} (\%) = \left( \frac{\text{Voltage when insulated} (V) - \text{Voltage under operation} (V)}{\text{Voltage when insulated} (V)} \right) \times 100 \quad \ldots (2)
\]

\[
\text{Oil reduction ratio} (\%) = \left( 1 - \frac{\text{Amount of thickener in the grease after operation} (\%)}{\text{Initial amount of thickener in grease} (\%)} \right) \times 100 \quad \ldots (3)
\]

5.2 Status change of the grease after test

Fig. 6 shows the behavior of S4-16% grease during the endurance test. At the beginning of the operation, 100% of grease is inside the bearings. Some grease moves to the sealed area as the bearings start to operate (shown in Fig. 7). It was observed that the grease mostly remained after 2000 h of operation.

Fig. 8 shows the oil reduction ratio of the grease remaining inside the bearings and the grease attached to the sealed area. Since the oil reduction ratio of the grease remaining inside the bearings continues to increase after 2000 h, it is understood that the lubrication of the raceways is maintained using only the oil separated from the grease that remained inside the bearings.

Fig. 9 shows the relationship between the oil reduction ratio of the grease inside the bearings and the centrifugal oil separation ratio. There is an exponential correlation between the two. The oil separation of the grease inside the bearings in this test is assumed to be caused by the centrifugal force.
5.3 Oil reduction ratio of the grease after test

Fig. 10 to 14 show the temperature of the outer ring of the bearings and metal contact ratio between the inner/outer rings measured for the bearings with the five types of grease. S4-16% grease shown in Fig. 10 became unstable by both metal contact ratio and bearing temperature specifications after 3000 h of test. M1-12% grease in Fig. 11 and S4-31% grease in Fig. 14 had high metal contact ratio and bearing temperature from the beginning; therefore, the tests were terminated in 2000 h and 5000 h, respectively. In contrast, S2-17% grease in Fig. 12 and S3-22% grease in Fig. 13 were stable over 7500 h of operation.
Table 3 summarizes the relationship between the centrifugal oil separation ratio and lubrication status measured as the metal contact ratio during the bearing endurance test. It was observed that the greases with a high or extremely low centrifugal oil separation ratio caused unstable bearing lubrication when used in tapered roller bearings under these operating conditions.

Grease with a high centrifugal oil separation ratio delivers a large amount of lubrication oil to the raceway early in terms of the life of the grease. It is assumed that this lubrication oil is depleted after some operation causing ill lubrication for longer term operating. Grease with an extremely low centrifugal oil separation ratio does not sufficiently deliver lubrication oil to the raceway; therefore, the lubrication is not good from the beginning of operation.

On the other hand, it is assumed that grease with the appropriate centrifugal oil separation ratio continues to deliver lubrication oil to the raceway throughout the operation, without depletion, maintaining a good lubrication state for a long time.

Table 3 | Centrifugal separation ratio and metal contact ratio of grease

<table>
<thead>
<tr>
<th>Grease code</th>
<th>Centrifugal oil separation ratio wt%</th>
<th>Metal contact ratio during bearing operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4-16</td>
<td>38.0</td>
<td>△</td>
</tr>
<tr>
<td>S3-22</td>
<td>34.0</td>
<td>○</td>
</tr>
<tr>
<td>S2-17</td>
<td>22.0</td>
<td>◯</td>
</tr>
<tr>
<td>S4-31</td>
<td>4.2</td>
<td>×</td>
</tr>
<tr>
<td>M1-12</td>
<td>3.6</td>
<td>×</td>
</tr>
</tbody>
</table>

Better Judgment (metal contact ratio) ➔ Worse

6. Conclusion

The impact that the oil separation property of grease on lubrication of bearings was investigated by testing and comparing the durability of tapered roller bearings with grease types of different oil separation properties. The study was completed with the purpose of pursuing grease with long life for journal bearings of railroad vehicles. The following findings were obtained:

1) Grease with a centrifugal oil separation ratio close to 40% shows good lubrication at the beginning; however, the lubrication performance degrades as the operation continues for a longer time.

2) Grease with an extremely low centrifugal oil separation ratio of 5% or less has low oil delivery capability; therefore, the state of lubrication is not good from the beginning.

3) Greases with centrifugal oil separation ratio of 20–35% show good lubrication for long periods time.

4) For improving the grease life of tapered roller bearings used in wheel axles, controlling the oil separation property of the utilized grease is one of the important factors.

We have studied the grease composition that contributes to extending life of journal bearings for railroad vehicles considering that the centrifugal oil separation property is one of the important factors for extending grease life for journal bearings. Based on the findings obtained in this study, we would like to conduct tests under closer operating conditions to the actual vehicles to verify the grease composition of appropriate oil separation properties in an effort to contribute to longer life and reliability improvement for journal bearings of railroad vehicles.

Reference

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