1. Introduction

Off-Highway Trucks in mines are generally used under very severe conditions of continuous operation for 24 hours per day, in dusty natural environment of sand and particles. In addition, “productivity/high efficiency,” is valued by the transported loads per hour; “durability/reliability” by supporting this productivity for a long period of time and “safety/comfort” for the workers is also required.

In order to address these market needs, NTN has developed new products shown in Fig. 1 with high-functionality for wheel bearings, which are the critical components of these trucks and is actively proposing them to the market. In this paper, NTN new product features and specifications are introduced.

2. Filter seal integrated large-sized bearing

Wheel bearings for off-highway trucks require special measures against severe operating environment and improved reliability in addition to long life and maintenance-free operation. However, damage due to denting on the bearing raceways caused by contamination from dust and particles into lubricant and metal abrasion powder from the gears around bearings is very common in only a short time of operation.

Filter seal integrated large-sized bearing developed by NTN (Fig. 2) does not allow foreign objects in the lubricant to enter into bearings, thus resulting in longer life; therefore, it is expected that the intervals for replacing the bearings will be extended. The following are the features and test results of these bearings.
2.1 Features
(1) Extending bearing replacing cycles
Denting on the bearing raceways can be prevented by the filter seal equipped with mesh that prevents foreign objects in the oil from entering into the bearings without blocking the flow of lubricant oil.
(2) Compact design
Existing bearings can be replaced as the filter seal is attached without changing key dimensions (inner diameter/outer diameter/width) of the bearings.
(3) Operable under vibration
They can be used with vibration acceleration of 10 G.

2.2 Rotational test under the condition of foreign objects in the lubricant

<Test condition>
Test machine: NTN outer ring rotational test machine for large sized bearings (Fig. 3)
Bearings under test: Tapered roller inch bearings, back-to-back combination
Rotational speed: 50 min⁻¹
Lubricant oil: Diesel engine oil ISO VG100
Foreign objects (Fig. 4): Size: max. 0.7 mm
Hardness: HRC 56 to 60
Amount: 2000 mg/L

<Test results>
The control effect of denting by the filter seal was confirmed by observing dents on the inner ring raceway after the test, as shown in Fig. 5. As a result, no dents were observed on the inner ring raceway when the filter seal was attached. Thus, it was confirmed that the foreign objects were blocked.
2.3 Summary

Filter seal integrated large-sized bearing blocks foreign objects in the lubricant oil entering into the bearing, and therefore, it is expected that the actual life of the bearing will be extended.

3. IC tag integrated bearings

Off-highway trucks are periodically inspected and repaired. For critical components such as bearings, maintenance records such as inspection date and operating hours are managed and kept. As bearings are used for a long time it is challenging to simplify the management and to secure inspection records against loss. Thus, management by IC tags (RFID: Radio Frequency Identification) was seen with high expectation. However, the existing IC tags do not allow reading or writing while embedded in metal and use of non-magnetic material for enabling read/write operation makes the tag size too large; therefore, IC tags have not been practical.

NTN has developed IC tag integrated bearings so that the quality information and operation history can be directly recorded on the bearings (Fig. 6). It is possible to read/write information on IC tag embedded directly in the bearings and to set management information for each user. In addition, bearing quality information including inspection records can be confirmed. The features, specifications, and the examples of usage are discussed in the following:

3.1 Features

(1) Quality information can be read directly from the actual bearings
Quality information of the bearings at factory shipment such as accuracy of dimension for inner diameter, outer diameter and width, space information, and serial number can be read out.

(2) Operating history of the bearings can be written and read out by the users
The inspection information can be directly written/read from the bearings.

(3) Management items can be freely set
Management items can be set according to the users’ needs.

3.2 Specifications

Tables 1 and 2 show the specifications of the IC tag and the reader/writer and Fig. 7 and 8 show their appearance.

<table>
<thead>
<tr>
<th>Table 1 Specification of IC Tag</th>
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<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>Memory capacity</td>
</tr>
<tr>
<td>Carrier frequency</td>
</tr>
<tr>
<td>Compliance standard</td>
</tr>
<tr>
<td>Transmission distance</td>
</tr>
<tr>
<td>Maximum operating temperature</td>
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<tr>
<td>Dimension</td>
</tr>
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<table>
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<tr>
<th>Table 2 Specification of reader and writer (PDA※1 type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>Carrier frequency</td>
</tr>
<tr>
<td>Compliance standard</td>
</tr>
<tr>
<td>Operating temperature range</td>
</tr>
<tr>
<td>Dimension</td>
</tr>
<tr>
<td>Weight</td>
</tr>
</tbody>
</table>

1: PDA: Personal Digital Assistant

Fig. 6 IC Tag integrated bearing

Fig. 7 IC Tag (Embed in bearing side face)

Fig. 8 Reader and Writer (PDA Type)
3.3 Examples of usage
(1) Read the bearing data from the factory shipment and compare it with the user data at periodical inspections.

(2) Periodically write the bearing management information and manage the change of the recorded data.

(3) Store the bearing history data as electronic data on a PC and manage all the information related to the bearings of the entire machine.

- Examples of management items
  1. Bearing quality information
     Fig. 9 shows an example of data that NTN records at the factory shipment.
  2. User management information
     Fig. 10 shows an example of data that users can write, in addition, for the maintenance.

3.4 Summary
IC tag integrated bearings allow necessary information to be read/written directly from the bearings; therefore, the management of information can be simplified even in operating conditions where long-time reliability is required.

4. Integrated rotation sensor large-sized bearing
As the off-highway trucks are driven on unpaved roads in the mines, slippage of wheels may cause accidents. As a countermeasure to avoid slippage trucks are equipped with, anti-lock brakes and traction control systems. These systems detect the rotation of the wheels to control them. The wheel rotation detection sensors are usually installed separately from the wheel bearings. In order to accurately detect the rotation speed, position adjustment is required for associated rotation sensor components.

NTN has developed an integrated rotation sensor large-sized bearing with a pulse detection sensor on the stationary inner ring, and a pulsar ring on the rotating outer ring, (Fig. 11).

By integrating the rotation sensor and bearings, sensor positioning adjustment is not required and the number of components is reduced. In addition, a disconnection prevention mechanism is adopted for sensor wiring so that even when slippage occurs between the axle and bearing inner ring, (called creep), rotational speed or direction can be detected without causing damage or errors to the sensor. The following are the features and specifications of an integrated rotation sensor large-sized bearing:

4.1 Features
(1) Integration of rotational sensor and bearings
   Reduced installation work, reduced number of components, and reduced size of peripherals.

(2) Mechanism of preventing disconnection of wiring even if creep (slippage) occurs between the axle and inner ring is adopted
   Rotation speed can be detected even when the creep occurs at the inner ring.

(3) Operable in oil
   No errors for rotational speed detection when immersed in the engine oil (oil temperature 120°C × 2000 h) \(^*2\)
   \(^*2\): May be affected depending on the oil or additive types.

(4) Usable under vibration
   No errors in rotational speed detection under vibration acceleration of 10 G.

4.2 Structure
Fig. 11 shows an example of the structure of tapered roller bearings used in rotational outer ring.
4.3 Specification of a rotational sensor and an example of output

Table 3 shows the specification of a rotational sensor and Fig. 12 shows an example of output waveform.

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor type</td>
<td>Back magnet type Hall IC</td>
</tr>
<tr>
<td>Resolution</td>
<td>192 pulses/rotation *3</td>
</tr>
<tr>
<td>Output phases</td>
<td>Single phase *4</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>4~24V (DC)</td>
</tr>
<tr>
<td>Output waveform</td>
<td>Open collector (square wave)</td>
</tr>
<tr>
<td>Response frequency</td>
<td>12 kHz</td>
</tr>
<tr>
<td>Sink current</td>
<td>25 mA or less</td>
</tr>
<tr>
<td>Maximum operating temperature</td>
<td>120˚C</td>
</tr>
</tbody>
</table>

*3: Resolution when bearing outer diameter is Φ 420
*4: Two-phase output when detection specification is on the rotational direction

Fig. 12 Example of output style

4.4 Summary

Integrated rotation sensor large-sized bearing does not require position adjustment associated with assembly of sensor components, as the bearing and the sensor are integrated. This brings a reduced number of components and promises cost reduction.

5. Conclusion

In this paper, three new products that NTN developed are discussed as the high-functionality version of wheel bearings for off-highway trucks used in mines.

The demand for mineral resources continues to expand against a backdrop of population growth and urbanization in the emerging countries, and the mining development is expected to continue in the future.

NTN will continue developing products that respond to the requirements of productivity, reliability, and safety for mining machines such as off-highway trucks.

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