Development of the Lubricating Oil Supply Unit with Self-generating Power Supply

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For the purpose of life time extension of the grease lubricated bearing for machine tool spindle, NTN developed a lubricating oil supply unit with the self-generating power supply. This lubricating oil supply unit, which includes a self-generating power supply, pump, and lubricating oil, is built into the outer ring spacer. Testing on angular contact ball bearings confirmed that it is possible to supply adequate lubrication by using a standalone lubrication supply unit.

1. Introduction

For bearings with grease lubrication, maintaining an oil film for a long time with minimum grease is a critical task. NTN has been developing a “New grease lubrication system, MQGS (Minimum Quantity base oil of Grease Supply lubrication),” 1) which supplies a small quantity of grease base oil while maintaining oil films.

Based on the minimum oil supply technology we have cultivated, we have added an electronic application technology to develop a lubrication supply unit with a self-generating power supply which supplies grease lubrication to the bearings.

This unit lubricates itself without any external power supply or external control. In this paper, we will discuss this lubricating oil supply unit with self-power generation (hereafter referred to as the “lubricating oil supply unit”).

2. Configuration

2.1 Overall structure

Fig. 1 shows the external view of the lubricating oil supply unit with self-generating power supply. The lubricating oil supply unit is installed on the inside of the outer ring fixed spacer and can be separated from the bearings, as shown in Fig. 2 (a). Also, as shown in Fig. 2 (b), power generator (thermoelectric converter), power supply/controller, pump, and lubrication oil tank are built-in inside of the unit to draw lubrication oil out with the pump and supply oil to the bearing raceway through the nozzle using the generated power.

The nozzle is installed near the bearing outer ring raceway, as shown in Fig. 2 (a). Fig. 3 shows the nozzle hole and (a) and (b) show the status before and after discharge of lubricating oil.

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(a) Section view of lubricating oil supply unit and bearing

(b) Inside of lubricating oil supply unit

Fig. 2 Schematic structure of lubricating oil supply unit with self-power generator

Fig. 3 Discharge of lubricating oil

(a) before discharge  (b) after discharge

Nozzle hole  Lubrication oil (colored red)
2.2 Power generator and power generation method

The electrical control block of this unit is shown in Fig. 4. A power generation method to obtain sufficient energy for powering the control devices and charging the electric storage device is necessary.

In general, heat, vibration, magnetism (electromagnetic induction) are used for power generation. This lubricating oil supply unit adopts a method of converting differences in the temperature between the inner and outer rings (thermal energy) generated by the rotation of bearings into electrical energy by using a thermoelectric converter.

The thermoelectric converter used in this unit is the Peltier module, which generates electricity when there is temperature difference between side A and side B in Fig. 5. Since the Peltier module is small, it can be installed between the inner ring spacer and the outer ring spacer of the bearings.

2.3 Controller

The amount and interval of lubricating oil supplied to the bearings are controlled by the program of the controller.

2.4 Electric storage device

The electric storage device stores power generated by the Peltier module and ensure the pump operates consistently by maintaining a constant voltage.

3. Features

1. No external power or lubrication is necessary since the self-generating power supply and lubrication reservoir are built-in.
2. Same configuration of bearings and spacers as the conventional unit.
3. Lubricant supply is minimized by utilizing microcomputer control to disperse the optimum amount of lubricant at the appropriate intervals.

4. Performance evaluation

4.1 Power generation characteristics

By installing the power generator in the spindle shown in Fig. 6, the relationship between charging voltage and charging time from power generated using the difference in temperature between the inner/outer rings of the bearings was verified. The bearing specification of this test is shown in Table 1 and the power generation test conditions are shown in Table 2. A double layer capacitor was used as the electric storage device and the time needed to reach an arbitrary charging voltage target was evaluated.

![Fig. 6 Spindle for test](image)

![Fig. 5 Structure of peltier module](image)

Table 1 Specifications of test bearing

<table>
<thead>
<tr>
<th>Test bearings</th>
<th>φ100×φ150×24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact angle</td>
<td>20°</td>
</tr>
<tr>
<td>Rolling element material</td>
<td>Si3N4</td>
</tr>
<tr>
<td>Cage material</td>
<td>Laminated phenolic resin</td>
</tr>
<tr>
<td>Sealed bearing grease</td>
<td>MP-1 (9g contained)</td>
</tr>
</tbody>
</table>

Table 2 Conditions of power generator

<table>
<thead>
<tr>
<th>Attitude of axis</th>
<th>Horizontal axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure when incorporated into bearings</td>
<td>100 N (pressure at fixed position)</td>
</tr>
<tr>
<td>Rotational speed</td>
<td>10,000min⁻¹, 15,000min⁻¹</td>
</tr>
<tr>
<td>Outer cylinder cooling temperature</td>
<td>Room temperature ±1°C</td>
</tr>
<tr>
<td>Electric storage device</td>
<td>Electrical double layer capacitor (rated 0.1 F)</td>
</tr>
</tbody>
</table>
Fig. 7 shows the power generation characteristics. It can be seen that the charging time is reduced when the temperature difference between the inner and outer rings is larger.

![Characteristic of power generation](chart)

Fig. 7 Characteristic of power generation

4.2 Dispenser operation

In order to verify the diffusion of the lubricating oil, the oil was colored red and the dispenser was installed in the spindle shown in Fig. 6. The test conditions are shown in Table 3.

Fig. 8 (a) shows the grease condition before dispensing lubricating oil and (b) shows the grease condition after lubricating oil is dispensed. It was verified that the grease became red overall after lubricating oil was dispensed. The lubricating oil supply unit was verified to operate correctly as the oil was uniformly diffused in the grease reservoir close to the bearing raceway indicated in Fig. 2 (a).

![Before and After Dispensing](images)

(a) Before lubricating oil discharge  (b) After lubricating oil discharge

Fig. 8 State of grease before and after discharge

4.3 Durability evaluation

Bearings for machine tool main spindles with grease lubrication are required to have a durability of 20,000 hours or more. Therefore, we are currently continuing a durability test based on conditions listed in Tables 4 and 5, setting the optimum amount and interval of lubricating oil supply.

<table>
<thead>
<tr>
<th>Test bearings</th>
<th>φ 100x φ 150x 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact angle</td>
<td>20˚</td>
</tr>
<tr>
<td>Rolling element material</td>
<td>Steel</td>
</tr>
<tr>
<td>Cage material</td>
<td>Laminated phenolic resin</td>
</tr>
<tr>
<td>Sealed bearing grease</td>
<td>MP-1 (9 g contained)</td>
</tr>
<tr>
<td>Supply lubrication oil</td>
<td>MP-1 base oil</td>
</tr>
<tr>
<td>Amount and interval of supply oil</td>
<td>Automatically adjusted depending on the bearing conditions.</td>
</tr>
</tbody>
</table>

Table 4 Specifications of test bearing and lubricating oil supply unit

<table>
<thead>
<tr>
<th>Attitude of axis</th>
<th>Horizontal axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure when incorporated into bearings</td>
<td>100 N (pressure at fixed position)</td>
</tr>
<tr>
<td>Rotational speed</td>
<td>15,000min⁻¹</td>
</tr>
<tr>
<td>Outer cylinder cooling temperature</td>
<td>Room temperature ± 1˚C</td>
</tr>
</tbody>
</table>

Table 5 Conditions of endurance test

5. Summary

In this paper, we have discussed the lubricating oil supply unit with self-generating power supply that operates using the difference in temperature between the inner and outer rings in the bearings. Traditionally, with grease lubrication, it was difficult to maintain a long and optimum lubrication environment; however, we have solved this issue with the developed lubricating oil supply unit. We will extend this technology to general industrial machines for energy saving and reduction of environmental load.

Reference


Photo of authors

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