Development of Grease-Lubricated Spindle for Machining Center

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JTEKT has developed a grease-lubricated spindle for machining centers. The developed spindle has improved high-speed performance, grease life, and prevention of coolant intrusion, all of which have been problems attributed to grease-lubricated spindles, and has enabled the replacement of conventional oil/air lubricated spindles. It has become possible to reduce the amount of consumption of factory air and lubricating oil, resulting in a reduction of environmental burden from machining centers.

Key Words: *machining center, spindle, grease lubrication, high speed, long life, sealing*

1. Introduction

Recent years have seen a rapid surge in industrial development and, in accordance, a deepening of associated problems such as environmental pollution and the depletion of resources. In response, JTEKT develops machine tools which are environmentally considerate and engages in activities that help conserve the planet environment. The main element of machining centers which cause environmental burden is the consumption of power, factory air, oil and so on. **Figure 1** shows the power consumption rate by converting factory air consumption of individual machining center components. **Figure 2** gives the consumption rate of oil used in machining centers. **Figure 1** and **2** combined demonstrate that spindle lubrication accounts for a significant portion of environmental burden.

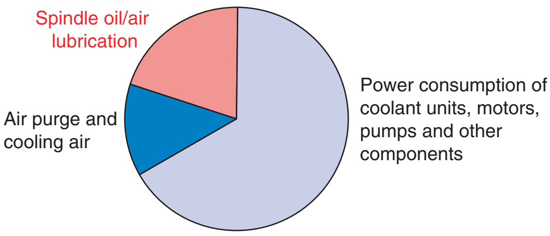

Fig. 1 Rate of energy consumption

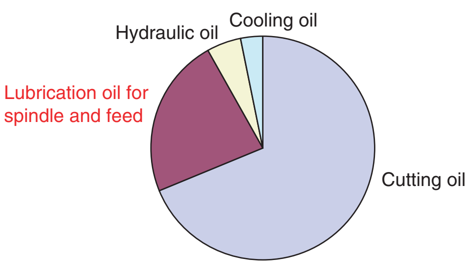

Fig. 2 Rate of oil consumption

2. Development Aims

The main lubrication methods of spindles are oil/air lubrication and grease lubrication. Oil/air lubrication was widely used on conventional machining centers as it was suitable to high speed rotation which made coolant intrusion difficult. However, the oil/air lubrication method constantly consumes factory air and lubricating oil, and as such is comparatively more burdening on the environment. In contrast, the grease lubrication method is less burdening on the environment as it does not consume factory air and lubricating oil when the machine is operating. JTEKT has changed the lubrication method of high speed spindles from the oil/air method to the grease method in order to alleviate the environmental burden caused by machining centers.

3. Grease Lubrication Issues

Compared with oil/air lubrication, grease lubrication is advantageous as far as being less burdening on the environment is concerned, however, it is disadvantageous in regards to high speed, lubricating oil life and coolant intrusion. As such, the following issues can be raised.

Issue 1 High speed spindles and long life of grease

- If the spindle is rotated at high speed, the temperature of the bearing increases and grease life shortens. Therefore, one issue is how to achieve both high speed spindles and the long life of grease.

Issue 2 Reduction of air consumption and preservation of coolant sealing performance

- Increasing air purge is one way in which to prevent the intrusion of coolant within the bearing. However, this method opposes the aim of this development of reducing air consumption therefore another issue is how to both reduce air consumption and preserve coolant sealing performance.

4. Outline of the Developed Spindle

In this development, it was possible to solve the issues of grease lubricant by the technologies mentioned hereinafter and extend the application area of grease lubrication to parts which conventionally used oil/air lubrication as shown in **Fig. 3**. **Figure 4** shows the overall structure of the developed spindle. This spindle has a diameter of 80mm, a maximum speed of 12 000 min^{-1}, and a grease life of more than 20 000 hours. (The grease life of 20 000 hours was calculated based on acceleration tests of the spindle in isolation).

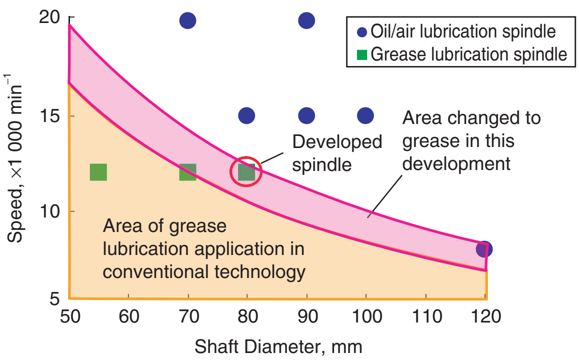

Fig. 3 Applicable range of grease lubrication

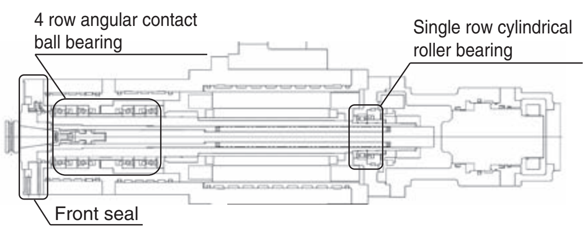

Fig. 4 Spindle structure

4. 1 Grease Lubrication Bearing

Ceramic bearings with seals from JTEKT's High Ability® bearing series for machine tools were adopted for this development as they are suited to high speed. It is possible to avoid reducing grease life by suppressing coolant intrusion and grease leaks with the provided seal. Moreover, ceramic bearings have relatively low temperature increase and do not seize easily even if the lubrication conditions are poor, therefore advantageous in extending grease life.

4. 2 Grease

Different high speed spindle greases by various manufacturers were investigated by rotating the spindle in isolation and the grease with low temperature increase was investigated. **Figure 5** shows the results of this rotation test. Grease B was adopted for this development as it had the lowest temperature rise and had a higher speed limit compared with Grease A, which has conventionally been used widely.

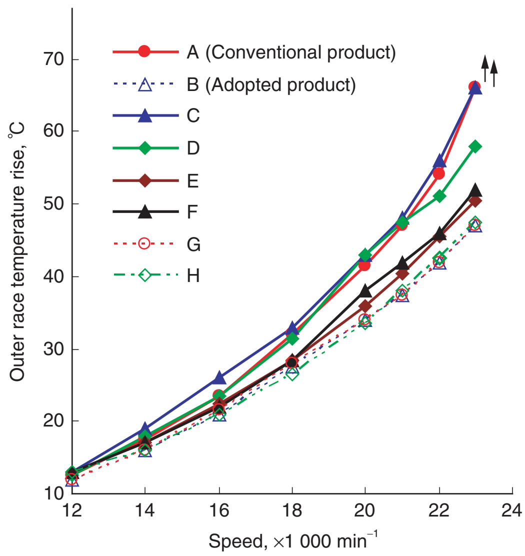

Fig. 5 Grease evaluation test

4. 3 Grease Reservoir

If grease lubricant bearings are used for a long period of time, the base oil separates from the grease (syneresis), negatively effecting lubrication performance. This is one of the factors behind reduction of grease life. To countermeasure this issue, as shown in **Fig. 6**, a collar was positioned next to the bearing and a grease reservoir created, inside which grease is collected. Due to the base oil oozing from the grease reservoir into the grease inside the bearing, deterioration is alleviated and the life of the grease is extended. After measuring the amount of base oil which was able to ooze out of grease reservoirs of various different shapes, it was discovered that an annular groove grease reservoir allowed a stable supply of base oil to the bearing, therefore this shape was adopted. An endurance test of the spindle in isolation was carried out to confirm how effective using this grease reservoir was on extending grease life. As a result, it was confirmed that the grease reservoir extended grease life by 2.3 times normal (**Fig. 7**).

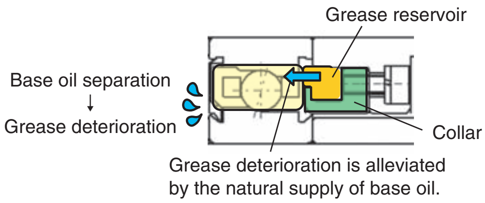

Fig. 6 Grease reservoir (annular groove)

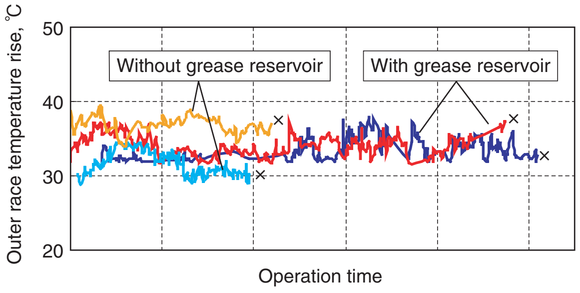

Fig. 7 Bearing durability test

4. 4 Coolant Intrusion Countermeasure

As **Fig. 8** shows, the seal structure of conventional oil/air-lubricated spindles was a linear gap seal, with any coolant that intruded inside the spindle being drained out together with the oil/air lubricating oil. In grease lubrication, air is not used for lubrication therefore it is not as strong against coolant intrusion as oil/air lubrication. Increasing air purge is one way of improving sealing performance however this conflicts with the aim of this development. Hence, the authors revised seal structure, as shown in **Fig. 9** and were able to maintain sealing performance while reducing air purge amount. The seal structure evaluation equipment shown in **Fig. 10** was fabricated and an evaluation performed. Results of the evaluation showed that the improved seal consumed 70% less air than the conventional method and at the same time was able to prevent coolant intrusion.

4. 5 Cooling of Bearings

Grease life is significantly affected by the temperature increase of bearings. Therefore, as shown in **Fig. 11**, a groove was made in the housing periphery into which cooling oil was poured in order to control temperature. **Figure 12** shows the measurement results of the bearing temperature rise upon rotation of the developed spindle. The temperature rise for each bearing at an Speed of 12 000 min^{-1} was approximately 4℃, achieving our target of below 7℃.

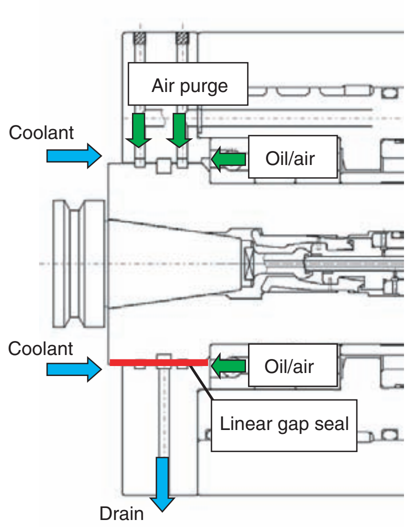

Fig. 8 Seal structure for oil/air lubrication

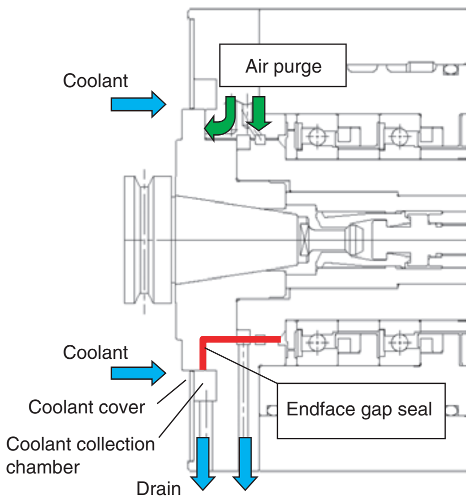

Fig. 9 Seal structure for grease lubrication

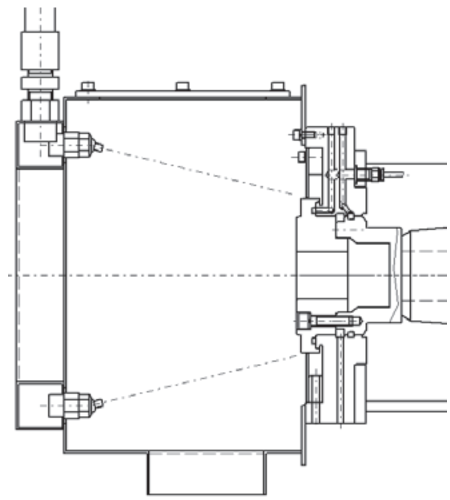

Fig. 10 Seal structure evaluation equipment

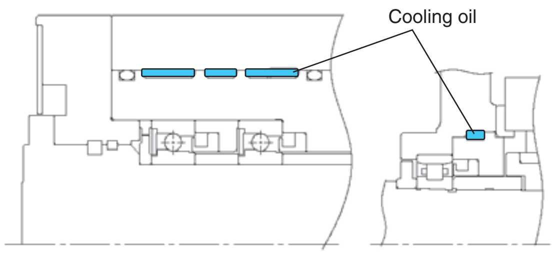

Fig. 11 Cooling of bearings

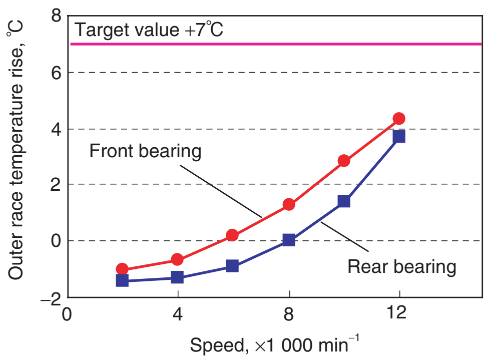

Fig. 12 Bearing temperature rise

5. Conclusion

The demand for energy and resource saving measures is predicted to continue increasing, making the transition to grease lubrication for machining center spindles imperative. JTEKT will strive to reduce the environmental burden of machining centers by widening the scope of grease-lubricated spindles through the developed high speed grease-lubricated spindle and grease lubrication of heavy-cutting spindles.

References

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