[New Product]

Minimum Quantity and Cooling Jet Lubricated Angular Contact Ball Bearings for Machine Tool

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Minimum Quantity and Cooling Jet (MQCJ) angular contact bearings feature a unique jet lubrication system. The design incorporates a special inner ring design, with a cooling groove combined with special geometry for directing lubricant to allow an optimally small amount of lubricant to reach the raceway, in order to minimize power losses from friction torque. It was developed in response to market demands for machine tool spindles with increased speed capability coupled with high rigidity. Its practical use has been demonstrated by having achieved a $d_m n$ 3.6 million with fixed-position preloading. This technical review paper is intended as an overview of its development and design.

1. Introduction

Needs have been mounting for faster machine tool main spindles. This trend is even more apparent with the main spindles of machining centers for machining dies because of the desire to realize machine tools that are capable of providing higher quality finished surfaces of workpieces and to improve machining efficiency. To address these needs, attempts to develop higher speed main spindles by using air-oil lubrication and oil-mist lubrication have been undertaken. In 2004, **NTN** developed a novel jet lubrication mechanism that shoots lubricating oil to a scoop formed on the inner ring end face, realizing both high-speed operation at 5 million $d_m n$ with a constant pressure preloading system for angular contact ball bearings and low power loss that is comparable to the power loss with air-oil lubrication. To satisfy market needs for higher bearing speed, we have recently developed angular contact ball bearings based on a fixed-position preloading system, and the newly developed bearings have realized high speed operation of 3.6 million $d_m n$ while ensuring preloading at the initial stage of bearing operation. This report describes the features of these bearings, and the results of evaluation testing.

The author has named this novel jet lubrication system MQCJ (**M**inimum **Q**uantity and **C**ooling **J**et) lubrication.

2. Features of the MQCJ Lubrication Mechanism

2.1 Jet lubrication for the inner ring

The construction of an MQCJ-lubricated angular contact ball bearing is illustrated in **Fig. 1**. When the main spindle runs at a higher speed, the preload increases because of expansion on the inner ring due to centrifugal force as well as because of temperature differences across the inner ring and outer ring due to heat generation on the bearing. If jacket cooling is provided, the outer-ring side is actively cooled. However, because the inner-ring side is disadvantageous in terms of heat radiation compared to the outer-ring side, the temperature on the inner-ring side is higher than that on the outer-ring side, and the thermal expansion on the inner-ring side becomes greater. As a result, the preload on the bearing increases unavoidably. The author's lubrication mechanism is characterized in that lubricating oil is first shot to the scoop formed on the inner-ring end face to actively cool the inner ring in order to inhibit preload buildup.

2.2 Application of the minimum quantity of lubrication mechanism to the rolling contact surface

Conventional jet lubrication arrangements have the drawback that their power loss is greater due to

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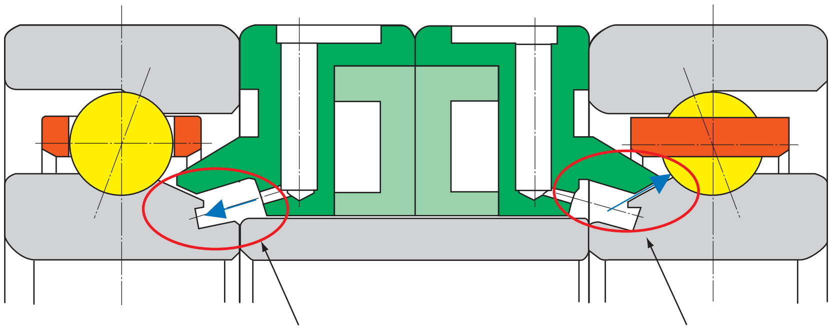

Fig. 1 Bearing and spacer design

greater stirring resistance when a bearing runs at a higher speed because a greater amount of lubricating oil flows inside the bearing. With the author's lubricating system, the lubricating oil shot at the scoop deposits on the scoop inner surface, then centrifugal force and surface tension caused it to move to the conical surface on the inner-ring outer circumference, thereby only a minimal amount of lubricating oil is fed into the bearing.

Because the amount of lubricating oil entering the bearing is controlled by the gap between the conical surface and the outer ring spacer, most of the lubricating oil contributes to cooling the inner ring while a very limited amount of it flows through the bearing. Thus, the author's bearing arrangement boasts lower power loss.

2.3 Bearing lubricating oil serves as jacket cooling oil

The author's lubricating system is schematically illustrated in **Fig. 2**. In many air-oil lubrication and oil-mist lubrication systems for machine tool main spindles, the bearing is lubricated by a lubricating oil supply system and the jacket is cooled by a cooling oil supply system. In contrast, with the author's lubrication mechanism, one common oil supply system feeds oil to both the bearing section and the jacket cooling section, and the used oil is recovered by a scavenge pump. Since the jacket cooling oil also serves as the bearing lubricating oil, the necessary accessory equipment can be of simpler construction.

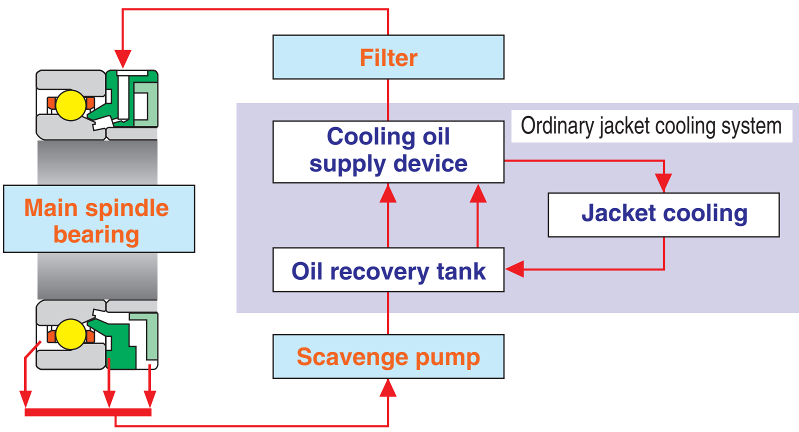

Fig. 2 MQCJ lubrication system

3. Test Result

The test conditions used are summarized in **Table 1**, while the construction of the test rig is illustrated in **Fig. 3**. Because of dimensional limitations, only the front side bearing (lower section) in the test rig incorporated the MQCJ lubrication mechanism (the rear side is provided with air-oil lubrication). The measurements of temperature increase on the outer ring at varied lubricating oil feed rates are graphically plotted in **Fig. 4**, and the resultant power losses are given in **Fig. 5**. When the spindle was arranged vertically and the as-mounted preload was set to 0 N (zero axial clearance), the author's bearing was capable of stable operation at 3.6 million d_mn and higher, the outer ring temperature was lower than 50˚C and the resultant power loss was not greater than 8 kW.

The outer ring temperature increases measured at initial preloads of 0 N and 150 N are plotted in **Fig. 6**. Though the temperature increase with the initial preload of 150 N is somewhat significant compared to that with the preload of 0 N, when the d_mn exceeded 3.6 million, the outer ring temperature was less than 50˚C. Therefore, the author's bearing arrangement seems to be capable of practical use. The measurements of temperature increases on the outer rings of vertically and horizontally arranged spindles are illustrated in

Fig. 7. Regardless of the spindle attitude, the temperature increase profiles are virtually same, so the author's bearing arrangement can be used for practical applications in both vertical and horizontal arrangements.

Table 1 Test condition

Test bearing	ID 70 x OD 110 x 20 mm width
Contact angle	20˚
Preload system	Definite position preloading
Initial preload	0，150 N
Spindle attitude	Vertical, horizontal
Lubricating oil/cooling oil	ISO VG1.5
Rate of oil feed to bearing	0.8，1.5，3.0 L／min
Jacket cooling	Only for the motor section
Jacket cooling oil temperature	20˚C
Bearing ring material	Special cemented steel
Rolling element material	Ceramic Si_3N_4
Cage material	Phenol resin

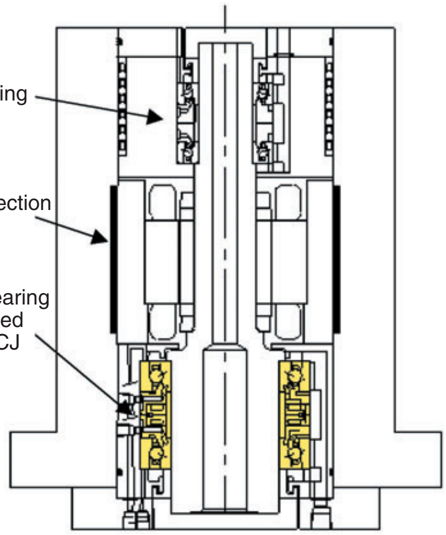

Fig. 3 Schematic construction of test spindle

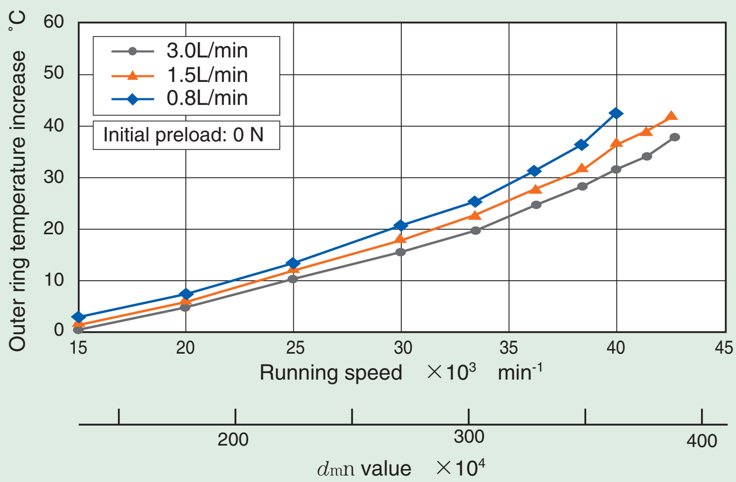

Fig. 4 Affect of amount of lubricant on outer race temperature

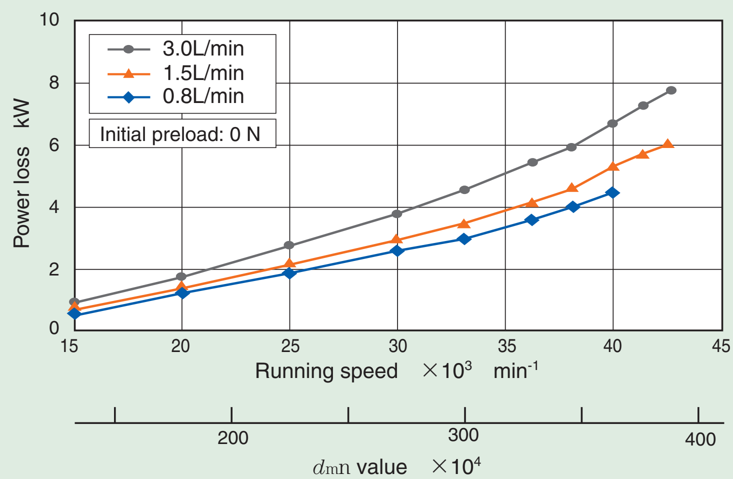

Fig. 5 Affect of amount of lubricant on power loss

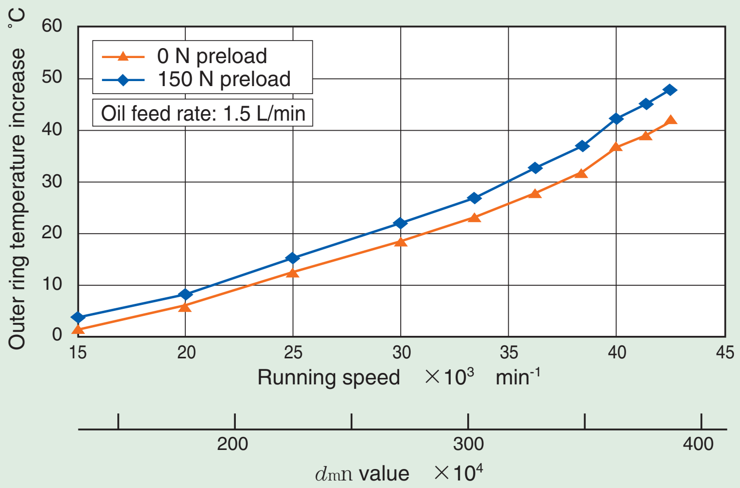

Fig. 6 Initial preload after mounted with DB set on outer race temperature

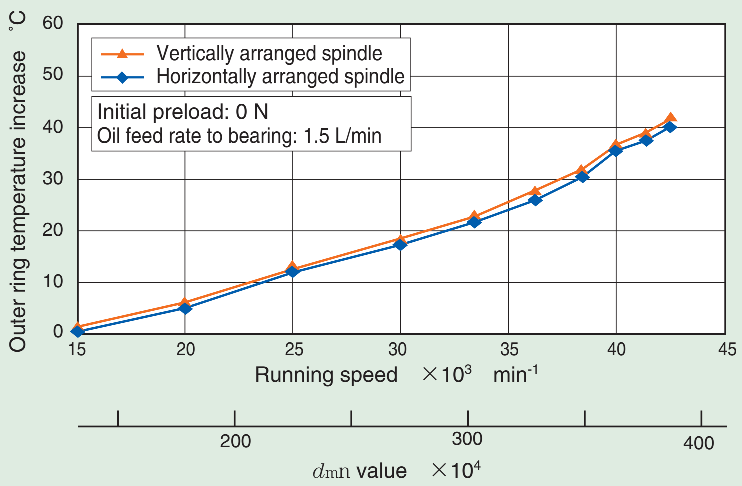

Fig. 7 Main spindle orientation on outer race temperature

4. Conclusion

The author has demonstrated that a combination of an angular contact ball bearing and a definite position preloading system is capable of high-speed operation at 3.6 million d_mn by adopting MQCJ lubrication. The author believes that this novel technique will greatly contribute to higher speed, greater rigidity and higher precision with machine tool main spindle bearings.

References

1) Y. Akamatsu, M. Mori: Development of Eco-friendly Oil Jet Lubricated Angular Contact Ball Bearings for Machine Tool, **NTN** Technical Review No. 72 (2004) p. 6.

Photo of author

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