High-speed Angular Contact Ball Bearings
New 9 Series for Machine Tool

1. Introduction

In order to shorten lead time by addition of process integration capability, an increasing number of machine tool models have recently been adopting unique main spindles whose angle can be varied during machining operation, and examples of such main spindles include milling main spindles on 5-axis machine tools and combined machine tools.

Main spindles on these machines swing to change their angle, and a sufficiently large space is needed on these machine tools to accommodate the motion of main spindles. Therefore, any main spindle in these machines needs to be compact in size, and the main spindle bearing also needs to be compact in size. For this reason, 9 series bearings are used because of their low cross-sectional heights and smaller width.

This article hereunder describes the features and performance of the NTN’s newly developed “high-speed angular contact ball bearing 9 series” products.

2. Advantages of 9 Series bearings

Fig. 1 provides information that helps clarify the advantages of 9 series bearings in comparison with 0 series bearings. Because of lower cross-sectional height, 9 series bearings have the following advantages over 0 series bearings:

- **When main spindle diameter (bearing bore diameter) is same with both series (Fig. 1a)**: for a given main spindle diameter, a bearing product of smaller outside diameter may be used. Thus, a more compact gearbox design is possible, which leads to size reduction for main spindle.
- **When bearing outside diameter is same with both series (Fig. 1b)**: In an application where there is limitation on the bearing outside diameter dimension, use of a 9 series bearing can lead to larger main spindle diameter. This feature will allow a main spindle design that provides greater shaft rigidity.

Many 9 series angular contact ball bearings are used for the main spindles of machine tools in Europe. However, demand for them has risen also in Japan recently. We improved the current design and developed new 9 series high-performance angular contact ball bearings.

We introduce the features and the performance test data of these new 9 series high-speed angular contact ball bearings in this report.
On the disadvantage side, having balls smaller than those of 0 series, 9 series bearings are inferior to 0 series bearings in terms of their radial load capacity and maximum allowable axial load. To eliminate this problem, NTN has developed 9 series bearing variants that boast greater load capacity.

3. Improved functions on New 9 Series products

3.1 Load rating and allowable axial load

Our newly developed high-speed angular contact ball bearing products—new 9 series—feature improved internal design that include rolling elements of increased diameter as shown in Fig. 2, thereby the load rating has been improved by a maximum of 50% and the allowable axial load has been increased by 20% (Fig. 3). Consequently, the new 9 series bearing products boast longer life and increased allowance against axial load that occurs during tool change process on machine tools; thus, these bearings will be used in a larger scope of applications.

Fig. 4 provides axial rigidity graph and radial rigidity graph with high-speed angular contact ball bearings (new design and old design), internal bore diameter 100 mm, with constant pressure preload (GN preload).

3.2 Result of operation test

The result of operation test with the high-speed angular contact ball bearings (new design and old design) is described below.

Fig. 5 schematically illustrates the construction of the test rig (main spindle type test rig) used for the test. Fig. 6 summarizes a result of temperature rise test on the new and old bearing design variants with ceramic balls, air-oil lubricated, and with fixed position preload.

The pattern of heat rise on the outer ring of our new design, up to $d_{mn} = 1.45 \times 10^6$ (12,000 min$^{-1}$) is identical to that of the old design. However, at higher speed range, the temperature with the new design is somewhat higher (1 to 2°C). A possible cause is a larger ball size, which leads to greater $P/V$ value (contact surface pressure x slip velocity).
Fig. 7 graphically plots the variation in bearing preload in this test: the diagram shows that the new design helps reduce possible increase in preload by approximately 15% compared with the old design. To sum up, the temperature on outer ring on our new design is somewhat higher compared with the old design: nevertheless, our new design boasts improved anti-seizure property because temperature difference across its inner ring and outer ring is smaller, minimizing the increase in preload.

Fig. 8 illustrates test result with constant pressure preload type bearing specimens.

The temperature on the outer ring of our new design is higher by 1°C compared with the old design: nevertheless, our new design is capable of stable operation up to ultrahigh-speed region of $d_{nm} = 2.40 \times 10^6$ (20,000 min$^{-1}$).
Fig. 9 summarizes test result with grease-lubricated specimens having steel balls, with fixed position preload setting. Even under these conditions, heat rise on the outer ring of the new bearing design remains low up to $d_{\text{mn}} = 1.44 \times 10^6$ (12,000 min$^{-1}$).

4. Conclusion

Compared with old products, our newly developed high-speed angular contact ball bearing 9 series products boast greater radial load capacity and allowable axial load, and longer life and increased load capacity during tool change process on machine tools.

In terms of functions, the bearing temperature on our new design is 1 to 2°C higher compared with old design. Nevertheless, the temperature gradient across the inner ring and outer ring on our new design is low and increase in preload in high-speed bearing operation is also low. Thus, our new design excels in anti-seizure property.

NTN will add its “high-speed angular contact ball bearing new 9 series” products, which boast compact size and enhanced functionality, to its ULTAGE Series line of products, and will actively market these novel products.

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