Technical Trend of Machine Tool Bearings

1. Introduction

Machining efficiency and machining quality are two criteria historically common to the machine tool industry. Current economic times call for additional criteria, those being reduced machining cost and a decrease on environmental impacts. To address these challenges, bearing manufacturers are committed to the development of improved materials and the optimization of bearing internal design. As a result, the performance of main spindles and feed systems will improve due to higher speeds, higher rigidity, improved lubrication, and better overall accuracy.

This paper will present the recent engineering trends of machine tool bearings and introduce products NTN has developed to meet these requirements.

2. Recent engineering trends of machine tools and machine tool bearings

Though there are signs of recovery from the 2008 global recession, worldwide demand in the machine tool market remains sluggish. China, whose manufacturing output was largest in the world in 2009, is rapidly improving their machine tool industry and will soon equal the technology of Japanese and European machine tool industry.

Due to the slow recovery and the increased impact of the Chinese market, machine tool development in Japan has been divided in two directions. The first being high-end machines featuring improved machining efficiency and accuracy as well as the capability of processing larger parts. The second option is for lower-cost general purpose machines accomplished through utilization of common components, lower machining accuracy, and limited part size capability. NTN has designed machine tool bearings for both the high-end and general purpose markets.

NTN has been developing machine tool bearings focusing on attaining both high speed performance and higher rigidity (two conflicting requirements), as well as higher accuracy and eco-friendliness. In this context, NTN has been developing unique machine tool bearings to support further sophistication of functionality for 5-axis machine tools and CNC turning centers.

As for the increased interest in general purpose machine tools, NTN has been helping reduce both the cost and size of main spindles by developing various technology, including grease-lubricated bearings that do not need an additional lubricating oil supply system.

3. Engineering trend of NTN’s machine tool bearings

For machine tool bearings, high-speed, high rigidity and high accuracy are important. Recently, reducing environmental impacts and costs have also become important. This paper gives an overview of technical trends for machine tool bearings and explains current machine tools.

Fig. 1 illustrates engineering improvements in NTN’s precision bearings for machine tools.

3.1 Engineering trend of NTN’s angular contact ball bearings

In the 1980s, need for high-speed main spindles began, resulting in the development of high-speed angular contact ball bearings. NTN’s efforts in
developing high speed angular contact ball bearings began with HSA bearings that are similar to standard types but feature smaller diameter rolling elements. Around 1990, NTN developed “HSB bearings” that were improved HSA bearings featuring limited heat generation, as well as “HSBxxxCAEX1 bearings” that are capable of even higher speed. In 2000, NTN released “ULTAGE Series high-speed angular contact ball bearings”—also known as HSE Bearings—that utilize bearing rings made from special bearing steel featuring excellent wear resistance and anti-seizure quality. Thanks to use of special bearing steel, HSE bearings are capable of greater mounted preload compared with conventional bearings. Thus, they feature both high-speed performance and greater rigidity, helping greatly enhance functionality of the machine tool main spindles they support.

Furthermore, NTN marketed “HSF bearings” in 2002. Compared with the HSE bearings, the diameter of their rolling elements is much smaller. NTN developed this new series of bearing products as air-oil lubricated constant preload bearings for ultra-high speed main spindles on machine tools such as die machining machines.

Main spindle bearings allowing for higher speed helped improve the efficiency of machining and the quality of machined surfaces. Recently, need for higher speeds with these bearings have decreased as the demands for die machining machines have been sluggish. Instead, there has been an increase in the needs for cost reduction and size reduction of machine tools.

To address this market trend, NTN has recently developed the “New 9-Series High-Speed Angular Contact Ball Bearings (HSE9xxU)” and “Ball Screw Supporting Double Row Angular Contact Ball Bearings (BSTU)”. These two product lines will be later described in further detail in Sec. 4 “Introduction to NTN’s Newly Developed Bearings”.

3.2 Engineering trend of NTN’s cylindrical roller bearings

Single-row cylindrical roller bearings are often used to support machine tool equipment main spindles. As a result of creating high-speed angular contact ball bearings for machine tools, it was now required to increase the speed capabilities of the supporting cylindrical roller bearings. To address this challenge, NTN developed the “N10xxxHS bearings” that feature a smaller roller diameter verses that of the
standard NTN single row cylindrical roller bearings. In 2000, NTN developed the ULTAGE Series “N10xxHSRT6 Bearings” that incorporate a PEEK resin cage which allow an even higher speed when used with main spindle bearings. In 2004, a similar modification was made to double-row cylindrical roller bearings NN30xx often used to support turning center main spindles. This resulted in the high-speed double row cylindrical roller bearings “NN30xxxHSRT6 bearings” that incorporate PEEK resin cage.

3.3. NTN’s technology for improving bearing accuracy

There are JIS accuracy classes, equivalent to those specified in a corresponding ISO standard. Machine tool main spindles often use bearings of JIS accuracy class 4. Applications that need particularly high bearing accuracy employ bearing of JIS accuracy class 2.

As stated previously, there are additional needs in the machine tool bearing market including: bearing users who want both high accuracy and low cost, bearings of special accuracy, or those satisfying both JIS accuracy class 2 in terms of running accuracy and JIS accuracy class 4 in terms of dimensional accuracy. To meet these needs, NTN added a unique line of products whose accuracy class is categorized into “P42” as standard bearings to the “Sealed Standard Angular Contact Ball Bearings 7xxCD/ADLLB Bearings” series products that were developed for use on rotary tools.

Main spindles attaining much higher accuracy employ unique bearings whose NRRO (Non-Repetitive RunOut) has been decreased by limiting variation in the diameter of rolling elements and regulating bearing ring roundness.

NTN offers angular contact ball bearings in two levels of NRRO—0.3 mm or smaller, and 0.1 mm or smaller. These angular contact ball bearings are used in main spindles of high-precision machining and turning equipment.

3.4 NTN’s eco-friendly bearing technology

Around 2000, machine tool manufacturers started their efforts reducing environmental impacts, lowering power consumption, and improving work environments.

On the basis of its ULTAGE Series bearings, NTN has established new lines of eco-friendly bearing products illustrated in Fig. 2: the “HSL bearings” that are based on the HSE bearings, the “HSFL bearings” that derive from the HSF bearings, and the “N10xxHSLT6 bearings” that are essentially improved N10xxHSRT bearings. These eco-friendly bearings are unique in that lubricating oil is fed through a special nozzle into the bearing, thus helping reduce consumption of compressed air and oil 50% to 75% compared with those of conventional bearings. At the same time, noise level of the bearing is reduced by limiting the flow of compressed air interfering with
the rolling elements, thereby these air-oil lubricated, eco-friendly machine tool bearings contribute to reduction in consumption of energy and resources as well as improved work environments.

Use of grease-lubricated bearings can also contribute to reduction in consumption of compressed air, oil, and electricity. Since 2000, NTN has been developing the “BNS/BNFS bearing” products shown in Fig. 3. These bearings feature grease chambers on the outer ring rolling surfaces, a non-contact seal, and high-speed long-life grease “SE-1”, all of which contribute to the improved reliability of grease-lubricated machine tool bearings.

Thanks to these improvements, higher speed is also now possible with grease-lubricated bearings. In other words, air-oil lubricated bearings typically used in higher speed machine tool applications can be replaced with grease-lubricated bearings.

NTN made another innovation in 2008—the “MQGS Lubrication Bearings \( \left( d_m = 1.9 \times 10^6 \right) \)”, schematically illustrated in Fig. 4. This bearing design features a unique spacer that delivers a minimum amount of base oil to the outer ring rolling surface in order to help extend grease life and improve the high-speed capability of the bearing.

4. NTN’s newly developed machine tool bearings

4.1 New 9 series high speed angular contact roller bearings

As shown in Fig. 5, the cross-sectional area of 9 series angular contact ball bearings (often used in the European market) is smaller compared with 0 series angular contact ball bearings (commonly used in Japan). As a result, the same size spindle can be used in a more compact housing, or alternately, a larger, more rigid spindle can be used in an equivalent sized housing.

One disadvantage is that the load capacity of the 9 series bearings are smaller compared with the 0 series bearings due to their smaller cross-sectional area.

To address this drawback, NTN has developed the “HSE9xxU bearings” that feature the high-speed performance of the HSE9 series bearings. Optimal specifications for bearing internal design have led to 50% increase in dynamic load rating and 20% increase in axial load rating relative to conventional similar bearing products.

Thanks to this engineering development, it is now possible to design compact, high-speed, high-rigidity main spindles employing 9 series angular contact ball bearings.

Detailed information about the high-speed angular contact bearings—9 series HSE9xxU bearings will be provided in a separate article within this technical review.

4.2 Ball screw supporting bearings

In the Asian machine tool industry, ball screw supports employ duplex angular contact ball bearings. In the same application, European machine tool industries use double-row angular contact ball bearings whose outer rings have mounting holes. The advantages of this bearing type include a simpler mounting procedure, a decreased number of parts since the bearing can be mounted directly to the bearing housing, and no need to match bearing pairs.

To its ULTAGE series of bearing product, NTN has added the “double row angular contact ball bearings BSTU for supporting ball screws” schematically illustrated in Fig. 6. This bearing type is essentially double-row angular contact ball bearing with the outer ring having mounting holes mentioned above, except that the BSTU bearing has a uniquely shaped seal. Features of this bearing include high-load capacity, low contact pressure and low torque, as well as long-life grease.

Detailed information about the double-row angular contact ball bearings BSTU bearings will be provided in a separate article within this technical review.

Fig. 5 High-speed angular contact bearings new 9 series
5. Conclusion

With its unique ULTAGE series of bearings, NTN has been helping machine tool manufacturers satisfy the ever demanding engineering needs for their machine tool products.

Machine tool manufacturers have experienced a dramatic change in engineering trends for machine tools—from higher functionality to reduction in cost and size. We believe that the most challenging needs in the machine tool industry may vary as the market demands will vary. Typical examples of engineering challenges include eco-friendly technology, higher functionality, and cost reduction.

In order to address the ever changing engineering trends in bearing industry and to contribute to the engineering development of machine tools, NTN will continue to be committed to the development and improvement of its bearing technology.