# Introduction of 3D Electronic Catalog for Precision Machine Tool Bearings

1. Introduction

Having been developed as precision bearings for machine tools, NTN ULTAGE Series bearing products are used in various areas on main spindles and feed systems of machine tools. Their high precision and advanced functionality have been highly appreciated by machine tool manufacturers. The term “ULTAGE” was created from a combination of “ULTIMATE” (meaning last in progression) and “STAGE”. This name is meant to convey NTN’s goal that this series of products are unsurpassed in a range of applications. In order to meet this target, the ULTAGE Series bearing products are being produced in a wide range of sizes.

Recently, NTN developed a 3D Electronic Catalog of ULTAGE Series Bearing Products for Machine Tools (3D CAD Data) and has started providing it to machine tool manufacturers (reported in the Nikkei Sangyo Shimbun on p. 15 of the April 22, 2008 issue).

3D CAD helps customers clearly understand bearing design features. This allows design, manufacturing and sales to easily communicate and collaborate during the development phase. For this reason, 3D CAD systems are being adopted by an increasing number of manufacturers.

Additionally, 3D CAD data can be used to provide information for thermal analysis, stress analysis, structural analysis and other types of analysis. 3D CAD data also allows designers to analyze various areas on main spindles and associated structures, thereby resulting in a decrease in the expected number of prototype bearings required.

This paper presents the configuration of NTN’s 3D electronic catalog that was recently released, and provides example applications for using the 3D data.

2. 3D Electronic catalog interface

The 3D electronic catalog is provided to users in the form of a CD-ROM that includes: ① 2D and 3D CAD data, ② a user’s guide for the CAD data, ③ a precision rolling bearings catalog (in PDF format), ④ access to “mt-tecnos” (a web site dedicated to precision bearings technology for machine tools), ⑤ a user’s guide for “mt-tecnos” and ⑥ access to NTN’s home page. Fig. 1 below shows the starting screen that appears on the computer screen after installation of the CD-ROM.

![Activation screen for CD-ROM](image)

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For detailed information about these features, refer to user’s guides 2 and 5 on the CD-ROM.

(1) Structure of 3D CAD data

The “3D Electronic Catalog for Precision Machine Tool Bearing Products” contains data for angular contact ball bearings and cylindrical roller bearings used on main spindles and feed systems of machine tools. The CD-ROM has 3D CAD data for a total of 1329 bearing base sizes that include 1039 angular contact ball bearings (including those with ceramic balls), 212 cylindrical roller bearings and 78 ball screw support bearings.

Table 1 summarizes all bearing series stored on the CD-ROM.

The CAD data is displayed on the computer screen in the file structure format shown in Fig. 2.

Table 1  Bearing series stored on CD-ROM

<table>
<thead>
<tr>
<th>Angular contact ball bearings: 1039 base sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
</tr>
<tr>
<td>7805C<del>7834C, 7900U</del>7934U</td>
</tr>
<tr>
<td>7000U<del>7040U, 7200C</del>7226C</td>
</tr>
<tr>
<td>High-speed</td>
</tr>
<tr>
<td>HSE910<del>HSE934, HSE010</del>034</td>
</tr>
<tr>
<td>Axial load carrying</td>
</tr>
<tr>
<td>HTA920U~HTA964U</td>
</tr>
<tr>
<td>HTA010U~HTA064U</td>
</tr>
<tr>
<td>For grinding machines</td>
</tr>
<tr>
<td>BNT900<del>BNT913, BNT000</del>BNT014</td>
</tr>
<tr>
<td>BNT200~BNT216</td>
</tr>
<tr>
<td>Sealed standard</td>
</tr>
<tr>
<td>7900~7910LLB</td>
</tr>
<tr>
<td>7000~7010LLB</td>
</tr>
<tr>
<td>Sealed high-speed</td>
</tr>
<tr>
<td>BNS910~BNS920LLB</td>
</tr>
<tr>
<td>BNS009~BNS020LLB</td>
</tr>
<tr>
<td>Ball screw support bearings: 78 base sizes</td>
</tr>
<tr>
<td>Ball screw support bearings</td>
</tr>
<tr>
<td>BST17x47~BST60x120</td>
</tr>
<tr>
<td>7000HT<del>7002HT, 7203HT</del>7208HT</td>
</tr>
<tr>
<td>Cylindrical roller bearings: 212 base sizes</td>
</tr>
<tr>
<td>Standard double-row</td>
</tr>
<tr>
<td>NN3005~NN3036</td>
</tr>
<tr>
<td>Standard single-row</td>
</tr>
<tr>
<td>N1006~N1032</td>
</tr>
<tr>
<td>High-speed double-row</td>
</tr>
<tr>
<td>NN3005HS~NN3026HS</td>
</tr>
<tr>
<td>High-speed single-row</td>
</tr>
<tr>
<td>N1011HSRT6~N1020HSRT6</td>
</tr>
</tbody>
</table>

Figs 3, 4 and 5 show examples of screens displaying different levels of the CAD data file structure.

By clicking on the icon for a particular bearing series, the user can access the corresponding 3D CAD data.

Fig. 3  Top screen

Click.

Fig. 4  Precision bearing screen

Click.

Select a bearing type, and then click.

Fig. 5  Precision bearings icons
(2) Accessing 3D CAD data

After selecting the appropriate bearing icon, corresponding bearing part numbers can be selected to access their 3D CAD data. An example of this process is illustrated in Fig. 6 through Fig. 10.

For example, suppose data is required for the standard angular contact ball bearing base sizes 7015US (ID $75 \text{ mm}$ $\times$ OD $115 \text{ mm}$ $\times$ W $20 \text{ mm}$).

After clicking on the appropriate icons, the monitor will eventually display the bearing data as shown in Fig. 9.

Once a bearing base sizes is selected, then the screen will show:
1. Bearing boundary dimensions (section A)
2. 3D CAD data (section B)
3. Bearing bill of materials (section C)

The 3D CAD data shown in item 2 is saved to the CD-ROM so it can be downloaded to the user’s computer. The different formats available on the 3D Electronic Catalog are listed in Fig. 10.

The available file formats (SAT, STEP, IGES, DXF, etc.) are used to import the data into various CAD systems (Solidworks, Inventor, OneSpaceModeling, Solid Edge, etc.).

When saving these files, the user will obtain the CAD data complete with constraint conditions, i.e. the relationships between parts and assemblies are maintained. The user should be sure to select the file format that works best with the CAD software currently being used.
Also, for information about the software in a specific language, NTN Engineering should be contacted for technical assistance.

3. Typical applications

A 3D CAD image helps everyone easily visualize and understand the bearing design. Thus, 3D CAD imaging is expected to reduce the design time for a new product as well as the workload for the whole development process through commercialization of the product (see items ① - ④ below);

① Design Confirmation
② Application to Analysis
③ Reduction in Prototype Cost
④ Data Management

It is getting more common to check for possible interference and perform other various analysis to optimize the design prior to prototype fabrication. As a result, both time and cost have been reduced for prototypes and testing.

Examples of activities NTN is undertaking associated with items ① and ② are described below.

(1) Design Confirmation

One major objective of 3D CAD is to assist the designer in detecting potential interference between adjacent components in order to prevent a deficient design.

By reviewing the 3D CAD data provided on the CD-ROM, the dimensional issues described below can be checked when the bearing is being specified for an application:

① Verification of appropriate shoulder height for bearing inner and outer ring when compared to the dimensions of the shaft and spacer.
② Confirmation that the oil nozzle on the spacer lines up with the oil feed/drain piping in the housing.
③ Ensure proper bearing position with respect to the lubricating oil jet ejected by the nozzle.

Fig. 11 shows a typical 2D arrangement of an angular contact ball bearing and a bearing spacer with an oil feed nozzle. A 3D model allows the user to view the bearing from various angles and confirm the proper position of the nozzle tip with respect to the oil hole/drain hole (see Fig. 12).

(2) Application to Analysis

Higher precision bearings are being made to endure with applications running at higher speeds. Also, to reduce the number of sample test runs, thermal analysis, stress analysis and structural analysis are now being performed during the design phase.

By performing stress analysis and thermal analysis by loading graphic data into analysis softwareNOTE), it is possible to predict potential issues and develop countermeasures to increase bearing life.

NOTE): Analysis software is not included on this electronic catalog CD-ROM.

Example of Mode Analysis

An example of the simplest analysis using 3D graphic data for a bearing is calculation of its natural frequencies.

Fig. 13 illustrates deep groove ball bearing part number 6208 (ID ø 40 × OD ø 80 × W 18 mm). Table 3 summarizes the natural frequencies of this bearing.

Table 3 shows the fundamental frequencies for the inner and outer rings from the first harmonic through the fifth harmonic. When reviewing the calculated values only, it is extremely difficult to imagine the mode diagram for a particular harmonic. In contrast, with a 3D image for a given harmonic, it dramatically helps visualization of the mode image.

For example, 6208 mode diagrams for the first
harmonic to third harmonic of the inner ring are shown in Table 4. By reviewing these diagrams, it is clear that the pattern of the first harmonic is a simple oval shape; the pattern of the second harmonic is wavy in the axial direction; and the pattern of the third harmonic exhibits a basic triangular shape.

**Structural Analysis Example**

Structural 3D analysis is often used to investigate the stress and displacement that occur when an external load and rotation-induced centrifugal force are applied to a bearing. An example of this analysis is described below, referencing the structure shown in Fig. 14. This structure is comprised of a rhomboidal bearing housing with a self-aligning roller bearing installed into its bore. For simplicity, the diagram shows the bearing outer ring only (light blue portion).

An axial load $F_a$ is applied to the bearing and bearing housing via the main spindle, and a radial load $F_r$ is applied to the upper portion of the housing. As a result, the load is transferred to the bearing housing via the main spindle, inner ring, rolling elements and outer ring.

The stress analysis of this bearing and housing assembly is described below.

First of all, it should be mentioned that for the loads acting on the outer ring and housing, the loading of each rolling element (spherical rollers: 30 rollers/row × 2 rows) was calculated in advance. Using these calculated loads, structural analysis for the outer ring was performed.

(When planning to perform a detailed investigation as shown in this example, NTN should be contacted for the calculation results on rolling element loading and the spring constant of the rolling elements.)
**Fig. 15** illustrates the stress distribution of the bearing housing.

The red portions of this diagram indicate the highest stresses. By optimizing the shape and wall thickness of the housing flange sections, the calculated stress levels of these portions is reduced.

**Fig. 16** shows a view of the housing from underneath: this diagram reveals the stress caused by individual rollers (see arrows) on the housing bore surface.

**Figs. 17 and 18** exhibit the amount of deformation of the bearing and housing.

The amount of bearing and housing deformation does not pose a problem. However, the stress distribution does need to be studied carefully for an extreme case. When a sleeve is mounted to the inner ring, it can be deformed and displaced by the applied load and centrifugal force, causing it to come in contact with the housing bore surface.

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**Thermal Analysis Example**

Finally, an example of thermal analysis is presented below.

When the temperature distribution on and around a shaft is relatively constant, 2D thermal analysis is often used.

For the following example, 2D thermal analysis was performed on an NTN high-speed test rig, and the analysis result was been compared with the test data from an NTN bearing.

(For more detail, refer to the “Heat Transfer Analysis of Machine Tool Main Spindle” section in this Technical Review Manual.)

The horizontal bearing test rig shown in **Fig. 19** features the internal construction show **Fig. 20**.

The test rig features a simple structure: both ends of the main spindle have an angular contact ball bearing, a spacer is situated in the middle of the rig and the bearing housing is surrounded by a cooling jacket.

In order to obtain an array of bearing test data, this
rig is capable of testing a range of bearing and spacer dimensions and can vary its operating conditions (e.g., running speed, lubrication conditions and jacket cooling capacity).

Fig. 21 shows an example of thermal analysis.
When a bearing is running at a high speed, thermal analysis demonstrates how the heat is transmitted and how the resultant heat gradient appears.

During an early stage of this test, the results of the test rig thermal analysis were compared with the actual test data (temperature data from 14 test points shown in Fig. 20). In certain cases, the difference between these two results exceeded 5˚C.

To minimize this difference, a tuning technique can be utilized to reduce the average error. After this tuning technique is applied, the average difference between the thermal analysis and actual test data falls in a range of ±1˚C. (Tuning for a case in Fig. 21 is primarily intended for thermal conductivity.)

The acquisition of basic data using a test rig as shown in Fig. 19 involves a lot of equipment set-up time, and the corresponding data acquisition also requires many man-hours.

Currently, it is difficult to achieve perfectly accurate temperature estimation by thermal analysis only (i.e., without performing an actual test). Nevertheless, NTN will further accumulate theoretical data and improve its thermal analysis technique to achieve better approximation of the estimated temperature and develop improved techniques with other test rigs.
4. Conclusion

One of recent trends of machine tool manufacturers is the increased use of 3D CAD-based design and development. For this reason, there have been increasing requests for 3D CAD data for bearings used in machine tool applications (including main spindles, feed axis and table axis).

In response to numerous inquiries from machine tool manufacturers, NTN has started supplying 3D CAD data (in the form of an electronic catalog) for the most popular precision bearings from the ULTAGE Series. Included in this new electronic catalog are angular contact ball bearings and cylindrical roller bearings (a total of 1329 bearing base part numbers).

By using 3D CAD data, all customer personnel can more easily interpret the information listed on bearing drawings. Thus, every detail of the bearing design can be confirmed and be clearly understood. Furthermore, by importing the 3D CAD data into stress analysis and thermal analysis, the application can be analyzed even further to ensure that the bearing design is optimized.

This report presented some examples of NTN’s analysis techniques. Incidentally, machine tool manufacturers have been utilizing various analysis methods to facilitate higher precision requirements, more severe application conditions and a shorter development period for new machine tool bearings. Consequently, NTN believes that machine tool manufacturers will ultimately develop new machines that make use of these advanced analysis techniques.

NTN hopes that its new 3D CAD Data Electronic Catalog will help develop the machine tools of the future.