5. Bearing Arrangements and Structures of Bearings for Main Spindles

Bearing Arrangement for Main Spindles

Typical examples of bearing arrangements for main spindles of machine tools are summarized in Table 5.1. An optimal bearing arrangement must be determined through considerations about the properties required of a main spindle in question (maximum speed, radial and axial rigidities, main spindle size, required accuracies, lubrication system, etc.). Recently, an increasing number of new machine tool models incorporate built-in motor type main spindles. However, heat generation on a built-in motor can affect the accuracies of main spindle and performance of lubricant, a bearing for a main spindle should be selected very carefully.

Table 5.1 Typical examples of bearing arrangements for main spindles

<table>
<thead>
<tr>
<th>Bearing arrangement for main spindle</th>
<th>Bearing type</th>
<th>Typical applications</th>
</tr>
</thead>
</table>
| Gear-driven configuration           | [Type I]  
Tapered roller bearing +  
Tapered roller bearing +  
(Double-row cylindrical roller bearing) | Large turning machine  
(Oil country lathe)  
General-purpose turning machine  
Typical lubrication  
<Grease lubrication> |
| Belt-driven configuration            | [Type II]  
Double-row cylindrical roller bearing +  
Double-direction angular contract thrust ball bearing +  
Double-row cylindrical roller bearing | CNC turning machine  
Machining center  
Boring machine  
Milling machine  
Typical lubrication  
<Grease lubrication> |
| Belt-driven configuration            | [Type III]  
Double-row cylindrical roller bearing +  
High-speed duplex angular contact ball bearing for axial load +  
Single-row cylindrical roller bearing  
NOTE: high-speed variant of type II | CNC turning machine  
Machining center  
Milling machine  
Typical lubrication  
<Grease lubrication> |
| Belt-driven configuration            | [Type IV]  
Duplex angular contact ball bearing (DBT arrangement) +  
Double-row cylindrical roller bearing  
NOTE: high-speed variant of type II or III | CNC turning machine  
Machining center  
Milling machine  
Typical lubrication  
<Grease lubrication> |
| Belt-driven configuration            | [Type V]  
Double-row cylindrical roller bearing +  
High-speed duplex angular contact ball bearing for axial load +  
Single-row cylindrical roller bearing  
NOTE: high-speed variant of type II with built-in motor-driven configuration | CNC turning machine  
Machining center  
Milling machine  
Typical lubrication  
<Grease lubrication>  
<Air-oil lubrication> |
<table>
<thead>
<tr>
<th>Bearing arrangement for main spindle</th>
<th>Bearing type</th>
<th>Typical applications</th>
</tr>
</thead>
</table>
| ![Built-in motor-driven configuration](image1) | [Type VI] Single-row cylindrical roller bearing + High-speed duplex angular contact ball bearing for axial load + Single-row cylindrical roller bearing  
NOTE: high-speed variant of type V | CNC turning machine  
Machining center  
Typical lubrication  
<Grease lubrication>  
<Air-oil lubrication> |
| ![Built-in motor-driven configuration](image2) | [Type VII] Duplex angular contact ball bearing (DTBT arrangement) + Single-row angular contact roller bearing (w/ ball slide)  
NOTE: super high-speed variant | Machining center <vertical>  
Typical lubrication  
<Grease lubrication>  
<Air-oil lubrication> |
| ![Built-in motor-driven configuration](image3) | [Type VIII] Duplex angular contact ball bearing (DTBT arrangement) + Duplex angular contact roller bearing (w/ ball slide)  
NOTE: super high-speed variant | Machining center <vertical>  
Typical lubrication  
<Grease lubrication>  
<Air-oil lubrication> |
| ![Built-in motor-driven configuration](image4) | [Type IX] Duplex angular contact ball bearing (DTBT arrangement) + Single-row cylindrical roller bearing  
NOTE: super high-speed variant | Machining center  
Typical lubrication  
<Grease lubrication>  
<Air-oil lubrication> |
| ![Built-in motor-driven configuration](image5) | [Type X] Adjustable preload bearing unit + Duplex angular contact ball bearing (DBT arrangement) + Single-row cylindrical roller bearing  
NOTE: high-rigidity/super high-speed variant | Machining center  
Typical lubrication  
<Air-oil lubrication> |
| ![Built-in motor-driven configuration](image6) | [Type XI] Duplex angular contact ball bearing (DT arrangement) + Duplex angular contact ball bearing (DT arrangement) | Small turning machine  
Grinding machine  
Typical lubrication  
<Grease lubrication>  
<Air-oil lubrication> |
| ![Belt-driven configuration](image7) | [Type XII] Duplex angular contact ball bearing (DT arrangement) + Duplex angular contact ball bearing (DT arrangement) | Grinding machine  
Typical lubrication  
<Grease lubrication>  
<Air-oil lubrication>  
<Oil-mist lubrication> |
### Technical Data

An optimal bearing product that best suits your application is selected by referring to the bearing selection table in Table 5.2 that contains the possible bearing arrangements for main spindles.

- The free side and fix side are designated.
- The bearing arrangement type (I to XII) on the free or fix side is selected.

#### Table 5.2 Bearing selection table

<table>
<thead>
<tr>
<th>Fix side</th>
<th>Free side</th>
<th>Bearing specifications</th>
<th>Lubrication system</th>
<th>Applicable product groups/ULTAGE</th>
<th>Considerations for selection procedure</th>
</tr>
</thead>
</table>
1. High-speed performance (general)  
High □ Low  
Contact angle 15˚, 20˚, 25˚, 30˚  
2. Rrigidity  
- Radial rigidity  
High □ Low  
Contact angle 15˚, 20˚, 25˚, 30˚  
- Axial rigidity  
Low □ High  
Contact angle 15˚, 20˚, 25˚, 30˚, 40˚, 60˚  
3. Recommended arrangement 4-row (DTBT) or 2-row (DB)  
4. Recommended lubrication specifications  
Standard main spindle : Grease  
High-speed main spindle : Air-oil  
Low-noise : Grease or eco-friendly air-oil  
5. Presence of cooling jacket around the bearing. In particular, grease lubrication is recommended. |
| Cylindrical roller bearing + Duplex angular contact ball bearing | Double-row cylindrical roller bearing or single-row cylindrical roller bearing | Bearing arrangement [Type I, II, IV, V, VII, X, or XI] | Grease lubrication | Double-row | NN30/NN30K NN30HS/NN30HSK NN49/NN49K NNU49/NNU49K | High (4-row)  
Medium (3-row)  
Low (2-row) |
| Tapered roller bearing + Cylindrical roller bearing | Bearing arrangement [Type I] | Angular contact ball bearing for axial load  
Contact angle less than 60˚  
4T-320X/320XU  
Inch series tapered roller bearing |
| Cylindrical roller bearing | Bearing arrangement [Type I] | Cylindrical roller bearing | Grease lubrication | Cylindrical roller bearing |  

- A set of bearing specifications applicable to the selected arrangement type is selected.
- A lubrication system suitable for the selected bearing specifications is chosen.
- A product group that satisfies the above-mentioned considerations is selected.
### Adjustable preload bearing unit

Higher speed has been increasingly needed for main spindles of machine tools, typically, machining centers, and, the maximum \( d \times n \) value (pitch circle diameter across rolling elements \( d \) [mm] multiplied by speed \( n \) [min\(^{-1}\)]) of main spindles that are air-oil lubricated reach 250 to 380 \( \times 10^4 \). At the same time, main spindles of machine tools are required of higher rigidity from a lower speed to a higher speed. Therefore, the bearings for main spindles must be capable of high-speed operation and high rigidity by optimal preloading.

As a bearing preloading system for satisfying both high speed and high rigidity, a fixed preload (spring preload) system is usually employed. To be able to increase the rigidity of main spindle, a spindle unit that can adjust a fixed position preload at an arbitrary speed appears to be advantageous.

The **NTN** Adjustable preload bearing unit is a high-speed high-rigidity unit that is capable to adjust from a particular fixed position preload to another fixed position preload.

![Adjustable preload bearing unit](image)

**Fig. 5.1** Adjustable preload bearing unit

A typical main spindle incorporating the **NTN** Adjustable preload bearing unit is illustrated in **Fig. 5.1**. By hydraulically shifting the position of the preload adjustable sleeve situated in the rear bearing section (rear position in this diagram) in steps to alter the preload in the bearing.

A spindle incorporating a 3-step adjustable preload bearing unit is illustrated in **Fig. 5.2**. The sleeve in the adjustable preload section comprises the hydraulic pressure chambers A and B, and the spiral groove for sliding motion. By exerting and removing oil pressure to and from the hydraulic pressure chambers A and B on the adjustable preload sleeve, the preload on the bearing can be adjusted to one of the three settings \( \text{high preload, medium preload and low preload} \). To achieve an instantaneous and reliable adjustable preload operation, high pressure oil (whose pressure is same as that for the hydraulic pressure chambers) is fed into the spiral groove that is formed on the outer circumference of the sleeve so as to move the sleeve smoothly.

![Operating mechanism of Adjustable preload](image)

**Fig. 5.3** Operating mechanism of Adjustable preload

#### Operating mechanism

Hydraulic pressure ON/OFF status for the hydraulic pressure chambers in the three preloading conditions as well as the associated motions of adjustable preload sleeve are illustrated in **Fig. 5.3**.

- **Low speed range (high preload)**: hydraulic pressure is fed into the hydraulic pressure chamber A.
  
  The component 1 moves to the right by the preset clearance \( L_1 \) to come into contact with the component 3, thereby the axial clearance on the bearing becomes 5.

- **Medium speed range (medium preload)**: hydraulic pressure is fed into the hydraulic pressure chamber B.
  
  The components 1 and 2 move to the right by the preset clearance \( L_2 \) to cause the component 2 to come into contact with the component 5, thereby the axial clearance on the bearing becomes 6.

- **High speed range (low preload)**: no hydraulic pressure is fed into the hydraulic pressure chambers A and B.
  
  The components 1 and 2 return to the left by the reaction force of bearing to cause the component 2 to come into contact with the component 5, thereby the axial clearance on the bearing returns to the initial setting of 6.

**NOTE:** The return motion of the components 1 and 2 is achieved by the reaction force of bearing or a separately provided spring.
Bearing jacket cooling system

With a built-in motor drive system, a main spindle is directly driven by a motor and is therefore suitable for rapid acceleration or deceleration. However, this system can be adversely affected by temperature rise and is oil-cooled with a spiral groove for cooling that is provided around the housing outside the motor and the outer surface of motor.

If heat generated on the motor affects the bearing, overheating of the bearing as well as degradation of grease can occur -- a problem which must be strictly avoided. When designing a cooling system with a spiral groove situated around the housing (called jacket cooling), the following considerations must be exercised.

Fig. 5.4 Inadequate cooling groove on jacket

Fig. 5.5 Adequate cooling groove on jacket

Considerations about cooling of jacket

With the bearing arrangement shown in Figs. 5.4 and 5.5, comprising a double-row cylindrical roller bearing and an angular contact ball bearing for bearing an axial load, the cooling groove on the jacket in Fig. 5.4 starts at around an area above the angular contact ball bearing for bearing an axial load, and appears not to cool the double-row cylindrical roller bearing effectively. (The fit of outside surface of outer ring of angular contact ball bearing for bearing an axial load into the bore of housing is clearance-fit -- the bearing is not directly in contact with the housing.) In the configuration in Fig. 5.5, the cooling groove extends to above the double-row cylindrical roller bearing, and appears to cool both not only the angular contact ball bearing for bearing an axial load but also the double-row cylindrical roller bearing effectively.