which require low noise and torque.

4.1.7 Running accuracy and bearing structure

Machine tool spindles etc. which require high running accuracy shall use precision bearings whose accuracy classes are Class 5, Class 4 and Class 2.Rolling bearing's running accuracy is specified according to different items. For different structures, the specified class are also different. Therefore, for those requiring high running accuracy, deep groove ball bearing, angular contact ball bearing and cylindrical roller bearing are often adopted.

4.1.8 Mounting, dismounting and bearing structure

The inner and outer rings of cylindrical roller bearing, needle roller bearing and tapered roller bearing, etc. are separable, and convenient for mounting and dismounting. The above-mentioned bearing structures are applicable where regular inspections are required, and dismounting and mounting are frequent. Tapered bore self-aligning ball bearing and spherical roller bearing (small type), etc. are easier to dismount and mount if adapter sleeves are used.

4.2 Arrangement

In general situation, a shaft has two bearings to be mounted. The following factors shall be considered when determining arrangement plans:

1) Shaft expansion and shrinkage caused by temperature fluctuation.

2) Practicality of the mounting and dismounting of bearings.

3) The misalignment of inner ring and outer ring caused by shaft deflection and mounting error.

4) Include the rigidity and mounting method of the whole running system of the bearings.

4.2.1 Fixed-end bearing and free-end bearing

The bearing that will be used as a fixed end bearing , and can take radial load or axial load at the fixed end. Other bearings except fixed end bearings are used as free end bearings which only take radial load, hereby to solve the shaft expansion and shrinkage caused by temperature fluctuation. Furthermore, this will also be good for the adjustment of the mounting position in axial direction.

If there is no sufficient countermeasures against the shaft deflection caused by temperature fluctuation, bearings will be affected by abnormal axial load, and early deterioration will be caused.

Free end bearings can be cylindrical roller bearing and needle roller bearing, whose inner and outer rings are separable and has ability of radial/axial movement. This type of bearings are easy to mount and dismount. When inseparable bearings are used As free end, generally outer ring and housing is used as clearance fit to eliminate the shaft expansion in operation. This can also be eliminated from the fitting surface of the inner ring.

Where the bearing intervals is short and shaft deflection is small, matched of angular contact ball bearings, tapered roller bearing, which can only take single direction axial load will be used in opposite direction. Axial clearance (after mounting movement allowance in the axial direction) can be adjusted by nuts and shims.

For the convenience of axial position and the other bearing is used as free-end bearing. mostly one bearing is used as fixed end bearing. The following Table 4.1 lists the selections of fixed end and free end bearing structures.

Table 4.1 Selection of fixed end and free end bearing structure

Bearing arrangement	Contents	Applied bearing type
Fixed-end bearing	• Used for bearing axial position and fixing • Adopt bearings which can take radial and axial load at the same time • To take two-direction axial load, from double directions strength shall be considered according to axial load when mounting	• Deep groove ball bearing matched angular contact ball bearing • Double row angular contact ball bearing Self-aligning ball bearing • Cylindrical roller bearing with rib (NUP type, NH type) • Double row tapered roller bearing spherical roller bearing
Free-end bearing	• Used to avoid shaft deflection caused by the temperature fluctuation during running and to adjust the axial position of the bearing. • Adopting bearings which can only take radial load and whose inner ring and outer ring are separable . • When applied to inseparable bearings, clearance fit is usually adopted between the outer ring and the housing, so that the bearing can act with the shaft in the axial direction when the shaft acting.	• Separate type • Cylindrical roller bearing • (NUP type, NH type) • Inseparable type • Deep groove ball bearing, matched angular contact ball bearing • Double row angular contact ball bearing • Self-aligning ball bearing • Double row tapered roller bearing • Spherical roller bearing
No fixed-end and free end	• When the bearing interval is small and the effect of shaft deflection is not large, two angular contact ball bearings or tapered roller bearings, etc. which take axial load can be used face to face or back to back arrangement. • Use nuts or shims to adjust the axial clearance after mounting.	• Deep groove ball bearing • Angular contact ball bearing • Self-aligning ball bearing • Cylindrical roller bearing (NJ, NF type) • Tapered roller bearing • Spherical roller bearing
Used for vertical shaft	• Use the bearing which can take radial load and axial load at the same time at the fixed end.When the axial load of the bearing is large, use thrust bearing together with radial bearing. • In the same way use the bearing which can only take radial load at the free end to avoid shaft displacement.	• Fixed end • Matched angular contact ball bearing (back-to-back) • Double row tapered • Thrust bearing and radial shaft

4.2.2 Example of typical arrangements

The arrangement example shown in Table 4.2 consider the shafting preload, rigidity , shaft displacement, mounting error, etc., and are typical bearing arrangements.

Table 4.2 Typical bearing arrangements and examples

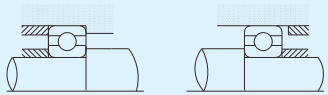
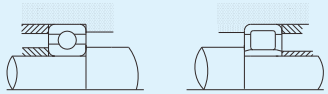
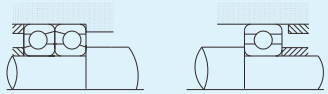
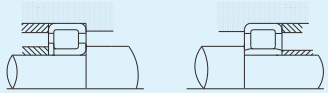
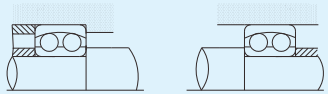
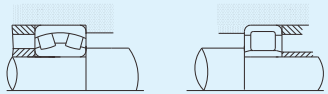
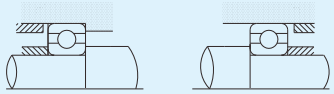
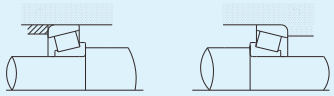
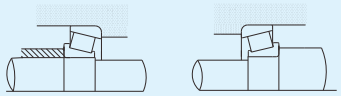
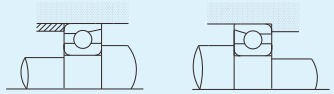
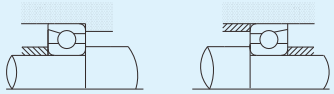
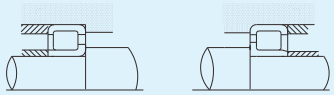
Bearing arrangement		Recommended application	Example (reference)
Fixed-end	Free-end		
		1.Minitype machinery and its general arrangement. 2.Besides radial load, can also take some axial load. 3.Sometimes using spring or shim to preload on one side of outer ring.	• Small motor • Small pump • Automobile transmissions
		1.Often used in high-speed operation. 2.Certain displacement of shaft is permitted. 3.Require small mounting error.	• Medium-sized motor • Blower, etc.
		1.Can take radial load and in two-direction axial load. 2.Can use a double row angular contact bearing to substitute for two matched bearings. 3.In case of large load can use double row tapered roller bearing and cylindrical roller bearing arrangement.	• Turbine speed reducer • Small machine tool spindle, etc.
		1.Can take heavy load, impact load, a certain degree of axial load. 2.Applied where inner ring and outer ring require interference. 3.Bearing separation structure facilitates mounting and dismounting.	• Automotive main motor • Automobile transmissions, etc.
		1.Applied where there is deflection and mounting error. 2.Not applicable where there is axial load, spherical roller bearing can take some axial load. 3.In case of heavy load and impact load, use spherical roller bearing instead. 4.Not applicable when there is shaft shoulder on the shaft, use adapter sleeve for mounting.	• General industrial machinery • Reducer, etc.
		1.Can take radial load and some axial load in two directions. 2.Mostly used to take heavy load and impact load.	• Reducers of general industrial machinery • Paper manufactory turning calender roller • Diesel locomotive axle journal, etc.

Table 4.2 Typical bearing arrangements and examples (continuation)

Bearing arrangement Condition without fixed-end and free-end	Recommended application	Example (reference)
	1.Sometimes use spring on one side of the outer ring.	• Small motor • Small pump • Small speed, etc.
 Face-to-face installation  Back to back installation	1.Widely used arrangement method, can take heavy load and impact load. 2.Face-to-face is applicable to the situation where inner ring requires interference. 3.Can also adopt back to back arrangement, applicable to the situation where the intervals between shafts is short and torque load is high. 4.Used in preload state, pay attention to the preload magnitude.	• Automobile differential gear • Pinion shaft • Automobile front, rear wheel • Turbine speed reducers, etc.
 Face-to-face installation  Back to back installation	1.Used where the radial load is not large and there is axial load. 2.The rigidity of the shaft can be improved by applying preload. 3.Back to back arrangement is preferable when taking torque load.	• Grinding spindle of grinder, etc.
 NJ + NJ arrangement	1.Can take heavy load. 2.Applied where inner ring and outer ring require interference. 3. The axial clearance shall not be too large.	• Construction machinery • Mining machine, etc.