4 Structure selection and arrangement of bearings

4.1 Structure selection

4.1.1 Bearing space and bearing structure

Rolling bearing and the bearing space are limited, so bearing structure and dimension must be selected within this limit space. The designer shall firstly fix shaft diameter, generally choosing bearing based on inner diameter. Rolling bearing have many standardized dimension series and structures, from which the optimal bearing structure can be chosen. The general radial dimension series and structures of radial bearings are shown in the following Fig. 4.1

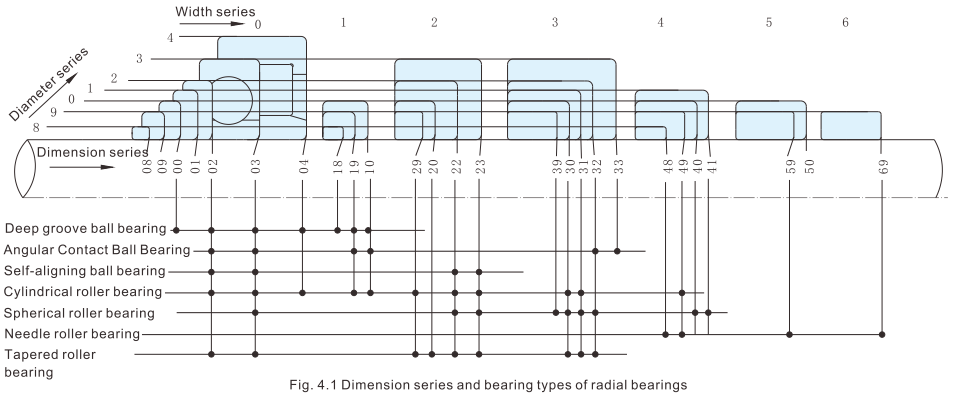

Fig. 4.1 Dimension series and bearing types of radial bearings

4.1.2 Load and bearing structure

Compare the basic load rating expressed bearing load capacity with axial load according to bearing structures, load and bearing structure can be devided as the following Fig. 4.2.The load capacity of roller bearings are larger than that of ball bearings of the same dimension series, and are applicable where there is impact load.

Note: Cylindrical roller bearings with rib has a certain degree of axial load capacity.

Bearing type	Radial load capacity				Axial load capacity			
	Weak → Strong				Weak → Strong			
	1	2	3	4	1	2	3	4
Single row deep groove ball bearing	—				—			
Single row angular contact ball bearing	—	—			—	—	—	
Cylindrical roller bearing	—	—	—					
Tapered roller bearing	—	—	—	—	—	—	—	
Spherical roller bearing	—	—	—	—	—	—		

Fig. 4.2 Compare load capacity according to bearing type

4.1.3 Limit speed and bearing type

Allowable limit speed of rolling bearings, does not only depend on bearing structure, but also the cage structure, material, bearing load, lubrication method, and state of cooling.In general oil bath lubrication condition, the limit speed of various bearing types are approximately shown in Figure 4.3.

Bearing type	Comparison proportion of limit speed					
	Weak → Strong					
	1	3	5	7	9	10
Deep groove ball bearing	→	→	→	→	→	→
Angular Contact Ball Bearing	→	→	→	→	→	→
Cylindrical roller bearing	→	→	→	→		
Needle roller bearing	→	→	→			
Tapered roller bearing	→	→	→			
Spherical roller bearing	→	→	→			
Thrust ball bearing	→					

Note: → For oil bath lubrication
→ Where high speed countermeasures are taken to bearings and bearing conditions.

Fig. 4.3 Compare limit speed according to bearing type

4.1.4 Misalignment and structure of inner and outer rings

Shaft deflection, axle or housing inaccuracy, mounting error and so on caused by load generate misalignment between the bearing inner ring and outer ring. Allowable misalignment angles of bearings depend on bearing structures and applicable conditions.But for non-self-aligning bearings the values are often below 0.0012 radian (4').

If large misalignment between inner ring and outer ring is anticipated in advance, self-aligning ball bearing, spherical roller bearing, spherical bearing with washer, etc. shall be chosen.

4.1.5 Rigidity and bearing structure

After bearing is loaded, the contacting surface of the rolling element and raceway of the bearing may generate elastic deformation. The rigidity of the bearing is determined by the load and the ratio of the elastic deformation Of inner ring, outer ring and rolling element.

Machine tool spindle etc. requires good rigidity, and the rigidity of bearing need to be improved. Therefore, roller bearing whose deformation after bearing loaded is smaller than that of ball bearing shall be used.

During bearing assembly, adopt preload to make the bearing's clearance negative, which can improve bearing's rigidity. This is applied to angular contact ball bearing and tapered roller bearing. Cylindrical roller bearing is not permitted to work in negative clearance condition.

4.1.6 Noise, torque and bearing structure

Rolling bearing are manufactured with precision work technology. The noise is low and the torque is small. Noise class are specified for deep groove ball bearings and roller bearings, etc. according to their usages. Low-noise precision deep groove ball bearings are suitable for electric motors and measure instruments

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.