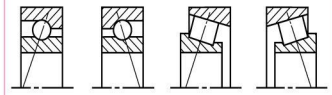
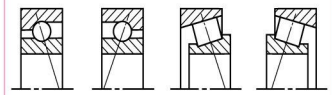
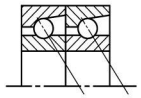
5. Application of rolling bearing

5.1 Rolling bearing arrangements and familiar type

5.1.1 Bearing arrangements

The arrangements of mechanical drive shaft, the shaft of machine tool, generally required two supports. Every support is composed of one or several bearings. The radial bearing, such as deep groove ball bearing, can be used in two supports if the bearings support the radial load only, sometimes taper roller bearing can be used for the convenience of mounting and dismounting. When supporting combined load, generally taper roller bearing, angular contact ball bearing can be used, these two types bearings can't be used singly or several bearings used in series in one direction, but two bearings used together. The arrangements type listed in table 5-1.

Table 5-1 the basic arrangement of bearing

The type of bearing	Diagram	characteristic
Back-to-back (wide edge of outer ring relatively)		The center of load acting outside the center line of bearing, the span between supports is long, the length of cantilever is short, and the stiffness is large. It doesn't easy to block when thermal expansion and clearance increase.
Face-to-face (narrow edge of outer ring relatively)		The center of load acting inside the center line of bearing, the span between supports is short, simple structure, easy to mounting and dismounting. It does easy to block when thermal expansion, generally, it applied in short support, and pay attention to adjust clearance.
Series		The center of load acting at same side of the center line of bearing, This arrangement usually applied in the situation that axial load is large, and need multi bearing to endure the load. It must be applied symmetrical, such as face-to-face or back-to-back.

5.1.2 The basic structure of bearing support

Generally, the locating in radial direction needs two supports, and there are three types of axial locating, that is two locating supports, one locating and one floating support, two floating supports.

(1) Two locating supports.The position between bearing and shaft and bore of shell is fixed (See plot 1 in table 5-3). Under the axial load, one bearing surface will approaches the bearing end plates, and there is a gap Δ between another bearing surface and another bearing end plates, and the gap can be used compensated the thermal expansion. If the gap is too large, the chatter of shaft and shock will too intensity, on the other hand, if the gap is too small, it can't play the role of entirely compensate. To steel shaft, the value of Δ can be calculated by using below equation.

$$\Delta = 12 \times 16^{-6} L \Delta t + 0.15, \ mm$$

Where, L： the length of shaft, mm

Δt：the change of shaft temperature, ℃

Generally, the value of Δ is 0.5~1mm, and it can be adjusted with cushion during mounting. This support is suitable where only radial load or small axial load is endured.

If the shaft accommodates the combined load, it's usually to use the two locating supports, which composed of the arrangement of face to face or back to back of angular contact ball bearing or taper roller bearing (See plot 4, 5, 6 in table 5-3). The clearance or preload can be modified by adjusting the

axial movement of bearing cushion through bearing end plates. The structure is very suitable for machines that need high running accuracy.

(2) One locating and one floating support. On this structure, the position between bearing and shaft or shell bore is fixed at one shaft end, so the shaft can be axial located, (See plot 8 in table5-3). At another shaft end, there is relative movement between bearing and shaft or shell bore, so that the thermal expansion and the error of manufacture and mounting can be compensated.

In this support, the precision of axial locating depends on the axial clearance of located bearing. Therefore, the precision of locating support composed of a pair of angular contact ball bearing or taper roller bearing or radial bearing is higher compared with using a pair of deep groove ball bearing.

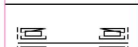
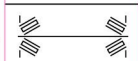
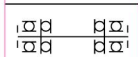
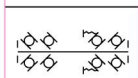
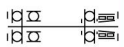
This structure can be applied in widely condition, so this structure is widely applied in the shaft of diverse machine tool, shaft that worked in high temperature and long shaft.

(3) Two floating supports. On this structure, the axial position of shaft needn't to be precisely located by two bearings, such as in the herringbone gear driving, this structure is generally used in the pinion shaft. The suitable mesh position of shaft in gearwheel can be located itself by floating around, and it helps to have enough gap at the two sides of bearing.

Almost of all bearings that needn't to be adjusted can be used as floating support, except deep groove ball bearing.

The familiar type and characteristics of support structure listed in table 5-2, and the typical structure of bearing support listed in table 5-3.

Table5-2 Familiar type and characteristics of support structure

Support type	Diagram	Bearing arrangement	Axial load	Accommodate shaft expansion	Others characteristics
Two locating supports		A pair of deep groove ball bearings	Can accommodate axial loads in single direction (one side which has no clearance)	The clearance between outer ring cover and end plates	High speed, simple structure and convenience to mounting and dismounting
		A pair of outer spherical deep groove ball bearings	Can accommodate axial loads in both directions	Bearing clearance	
		A pair of angular contact ball bearing with face-to-face arrangement			
		A pair of angular contact ball bearing with back-to-back arrangement			
		A pair of cylindrical roller bearing, which outer ring has single flange	Can accommodate small axial loads in both directions	The clearance between outer ring cover and end plates	Simple structure and convenience to mounting and dismounting
		A pair of taper roller bearing with face-to-face arrangement	Can accommodate axial loads in both directions		
		A pair of taper roller bearing with back-to-back arrangement			
		Two sets combined of deep groove ball bearing and thrust ball bearing			Employed vertical shaft with low speed
		Angular contact ball bearing series with back-to-back arrangement		Bearing clearance increase because of shaft thermal expansion, and the preload depends on the compressed spring.	Employed shaft with high speed
		The combined of deep groove ball bearing, thrust ball bearing and double row cylindrical roller bearing with taper bore		Bearing clearance	Enhance the stiffness of support by radial preload

Note: In diagram, " ¦ " is the symbol for limit housing ring move

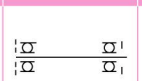
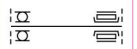
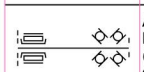
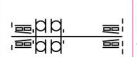
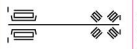
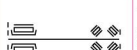
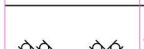
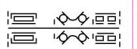
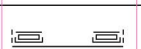
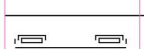
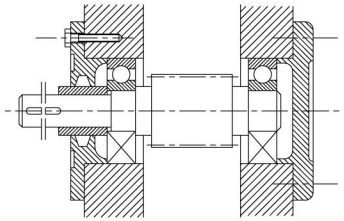
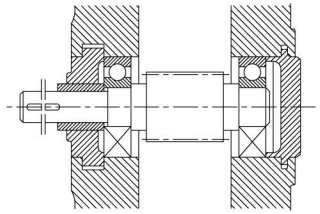
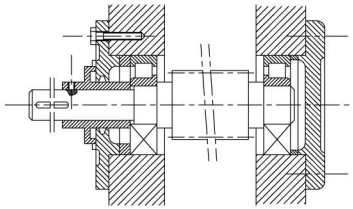
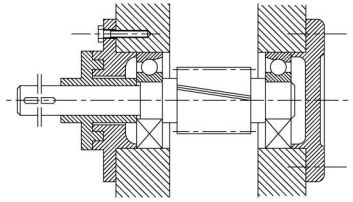
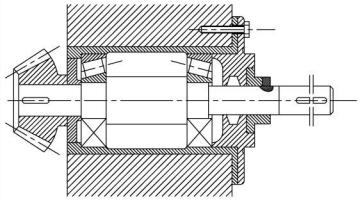
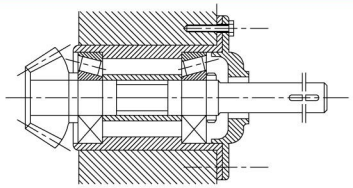
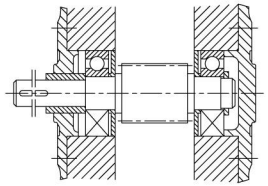
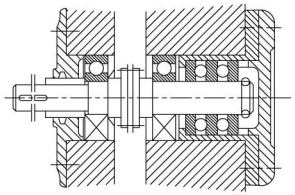
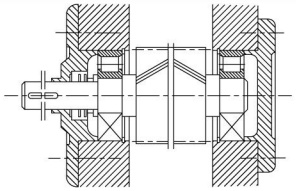
Support type	Diagram	Bearing arrangement		Axial load	Accommodate shaft expansion	Others characteristics
		Locating	Floating			
Locating and floating support		Deep groove ball bearing at left side	Deep groove ball bearing at left side	Can endure axial loads in both direction	Dynamic fit between outer ring of radial ball bearing at right side and housing bore	High speed, simple structure and convenience to mounting and dismounting
		Deep groove ball bearing at left side	Cylindrical roller bearing with outer ring has no flange		Roller axial move relatively to outer ring raceway	Simple structure and convenience to mounting and dismounting
		Angular contact ball bearing paired mounted (back-to-back) at right side	As above			Enhance the stiffness of support by axial preload
		Angular contact ball bearing paired mounted (face-to-face) at right side	As above			
		Three points contact ball bearing and cylindrical roller bearing which outer ring has no flange at right side	As above		Roller at left side axial move relatively to outer ring raceway	High speed, compact structure and can endure large radial loads
		Three points contact ball bearing and cylindrical roller bearing which outer ring has no flange at right side	Taper bore double rows cylindrical roller bearing			Can endure axial and radial loads, high stiffness of support
		Taper roller bearing paired mounted (back-to-back) at right side	Cylindrical roller bearing with outer ring has external flange			Can endure axial and radial loads, simple structure, and convenience to adjust
		Taper roller bearing paired mounted (face-to-face) at right side	As above			
		Angular contact ball bearing paired mounted (back-to-back) at right side	Angular contact ball bearing paired mounted (series)	Can endure axial loads in both direction	Dynamic fit between outer ring of bearing at left side and housing bore	High speed
		Thrust angular contact ball bearing in both directions and taper bore double rows cylindrical roller bearing at right side	Cylindrical roller bearing with inner ring have no flange		Roller of left bearing axial move relatively to inner ring raceway	High running precision, can endure axial and radial loads, high stiffness
		A pair of self-aligning roller bearing		Can accommodate small axial loads in both directions	Dynamic fit between outer ring of right side bearing and housing	Applied in shaft which under large radial load, and can self-aligning
Two floating supports		A pair of cylindrical roller bearing with no outer ring		Can not accommodate axial loads	Roller of two sides bearings move relatively to outer ring raceway	Applied in situation that have requirements of shaft moving in axial
		A pair of needle bearing with no inner ring			Needle at two sides supports move relatively to shaft	

Table5-3 the typical structure of bearing support

Number	Structure type	Characteristic and application
1		Deep groove ball bearing, bearing axial fixed by housing cover. There isn't large clearance (0.5~1mm) between outer ring of right side bearing and housing cover to move; This type need felt seal and lubrication oil, it is suitable to light load, the sliding speed of felt seal is v<=4-5 m/s, and cleanness environment.
2		The design is basically same as Number 1 design, the difference is embedded housing cover; Bearing necessary axial clearance is ensured by adjusting shim between outer ring of right side bearing and housing shim; grope seal.
3		Cylindrical roller bearing, its inner ring has no flange, and there is clearance between outer ring (right side in diagram) of bearing and adjustment shim; combined seal. It is suitable to biggish pure radial load, bad working environment, and the bearing span less than 600mm.
4		Angular contact ball bearing, labyrinth seal; it depends on adjustment shim between housing cover and box, a suitable axial clearance is needed when mounting; and can endures radial load and bidirectional axial load, It is suitable to light load, high speed, and the bearing span less than 300mm.
5		It is suitable to support with small taper gear, There are have below merits compared to Number 6 design 1, Bearing which endures small radial load endures axial load. 2, Axial clearance of bearing adjusted by adjusting the shim between housing cover and ring. 3, Simple structure, for example, there isn't need round nut for axial fix.

Number	Structure type	Characteristic and application
6		There are have below merits compared to Number5 design 1, The permission of shaft expansion is large. 2, The stiffness of structure is large, for example, if the bearing span equals, the distance between two bearings anti-force is 12>11.
7		The design is basically same as Number 6 design, the difference is the shaft bidirectional axial fixed by right side bearing; and can endure radial load and not large bidirectional axial load. Bearing inside adding flange to prevent grease to be diluted to loss. It applied in the support with large span.
8		Bidirectional thrust ball bearing and deep groove ball bearing mounted at right side, and removable deep groove ball bearing mounted at left side. It can endure very large bidirectional axial load, and also endure radial load at the same time; and large move is permitted. The suitable axial clearance can be achieved through the adjustment shim between housing cover and box shell.
9		The outer ring of cylindrical roller bearing has no flange. To chevron gear driven, a shaft (normal high speed shaft) is needed, Application of this design in order to adjust automatic and force equality on the two sides teeth. Rejection oil seal is applied.

5.2 The axial fix of rolling bearing

The axial fix of rolling bearing includes axial locating and axial retained.

5.2.1 Axial locating

Generally, the inner and outer rings are located by the abutment of shaft or shell bore. To guarantee the contact between the bearing end plates and abutment, and to prevent the friction between fillet and transition angle (see diagram 5-1), the maximal of fillet radius of shaft and shell bore should accord to the rules listed
in table 5-4.

The height of abutment is not only to guarantee the fully contact between abutment and bearing end plates, but also convenient for the usage of mounting and dismounting tools. General, the minimum of abutment height should accord to requirements listed in the table 5-5.

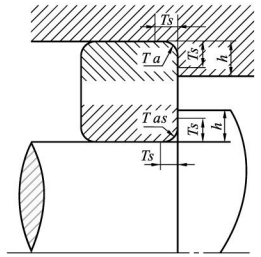


Diagram 5-1 The relationship between bearing fillet radius ra and height h of housing shoulder