14. Shaft and Housing Design

Depending upon the design of a shaft or housing, the shaft may be influenced by an unbalanced load or other factors which can then cause large fluctuations in bearing efficiency. For this reason, it is necessary to pay attention to the following when designing shaft and housing:

1) Bearing arrangement selection; most effective fixing method for bearing arrangement
2) Selection of shoulder height and fillet radius of housing and shaft.
3) Shape precision and dimensions of fitting; area runout tolerance of shoulder.
4) Machining precision and mounting error of housing and shaft suitable for allowable alignment angle and inclination of bearing.

14.1 Fixing of bearings

When fixing a bearing in position on a shaft or housing, there are many instances where the interference fit alone is not enough to hold the bearing in place. Bearings must be fixed in place by various methods so that they do not move axially when placed under load.

Moreover, **even bearings which are not subjected to axial loads (such as cylindrical roller bearings, etc.), must be fixed in place axially because of the potential for ring displacement due to shaft deflection by moment load which may cause damage.**

Table 14.1 shows general bearing fixing methods, and **Table 14.2** shows fixing methods for bearings with tapered bores.

Table 14.1 General bearing fixing methods

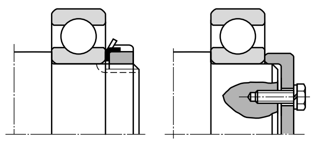
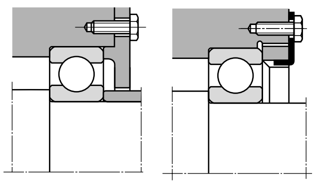
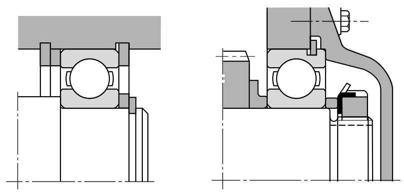
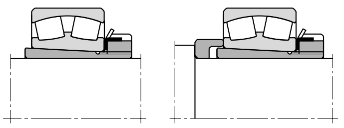
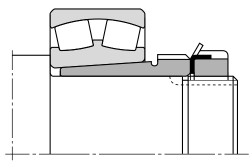
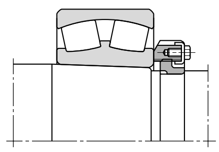
Inner ring clamp	Outer ring clamp	Snap ring
		
The most common method of fixing bearings in place is to use clamping nuts or bolts to hold the bearing or housing abutment against the ring end face.		Use of snap rings regulated under JIS B 2804, B 2805, and B 2806, makes construction very simple. However, interference with chamfers, bearing installation dimensions, and other related specifications must be considered carefully. Snap rings are not suitable for applications requiring high accuracy and where the snap ring receives large axial loads.

Table 14.2 Fixing methods for bearings with tapered bores

Adapter sleeve mounting	Withdrawal sleeve mounting	Split ring mounting
		
When installing bearings on cylindrical shafts, adapter sleeves or withdrawal sleeves can be used to fix bearings in place axially. The adapter sleeve is fastened in place by frictional force between the shaft and inner diameter of the sleeve.		For installation of tapered bore bearings directly on tapered shafts, the bearing is held in place by a split ring inserted into a groove on the shaft, and is fixed in place by a split ring nut or screw.

14.2 Bearing fitting dimensions

14.2.1 Abutment height and fillet radius

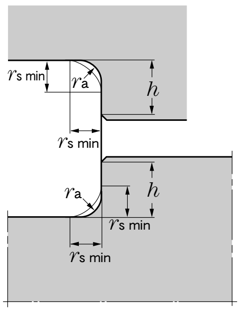
The shaft and housing abutment height (h) should be larger than the bearings' maximum allowable chamfer dimensions ($r_{s\ max}$), and the abutment should be designed so that it directly contacts the flat part of the bearing end face. The fillet radius (r_a) must be smaller than the bearing's minimum allowable chamfer dimension ($r_{s\ min}$) so that it does not interfere with bearing seating. **Table 14.3** lists abutment height (h) and fillet radius (r_a).

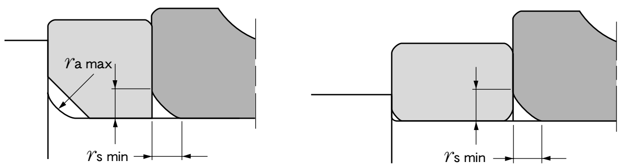
For bearings to be applied to very large axial loads as well, shaft abutments (h) should be higher than the values in the table.

14.2.2 For spacer and ground undercut

In cases where a fillet radius ($r_{a\ max}$) larger than the bearing chamfer dimension is required to strengthen the shaft or to relieve stress concentration (**Fig. 14.1a**), or where the shaft abutment height is too low to afford adequate contact surface with the bearing (**Fig. 14.1b**), spacers may be used effectively.

Relief dimensions for ground shaft and housing fitting surfaces are given in **Table 14.4**.





(a) (b)

Fig. 14.1 Bearing mounting with spacer

Table 14.3 Fillet radius and abutment height Unit mm

$r_{s\ min}$	$r_{as\ max}$	h (min) Normal use❶	h (min) Special use❷
0.05	0.05	0.3	
0.08	0.08	0.3	
0.1	0.1	0.4	
0.15	0.15	0.6	
0.2	0.2	0.8	
0.3	0.3	1.25	1
0.6	0.6	2.25	2
1	1	2.75	2.5
1.1	1	3.5	3.25
1.5	1.5	4.25	4
2	2	5	4.5
2.1	2	6	5.5
2.5	2	6	5.5
3	2.5	7	6.5
4	3	9	8
5	4	11	10
6	5	14	12
7.5	6	18	16
9.5	8	22	20
12	10	27	24
15	12	32	29
19	15	42	38

❶ If bearing supports large axial load, the height of the shoulder must exceed the value given here.
❷ Used when axial load is light. These values are not suitable for tapered roller bearings, angular ball bearings and spherical roller bearings.

Note: $r_{as\ max}$ maximum allowable fillet radius.

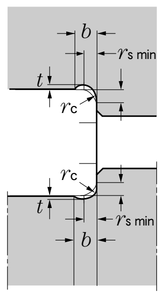


Table 14.4 Relief dimensions for ground shaft

Unit mm

$r_{s\ min}$	Relief dimensions b	t	r_c
1	2	0.2	1.3
1.1	2.4	0.3	1.5
1.5	3.2	0.4	2
2	4	0.5	2.5
2.1	4	0.5	2.5
2.5	4	0.5	2.5
3	4.7	0.5	3
4	5.9	0.5	4
5	7.4	0.6	5
6	8.6	0.6	6
7.5	10	0.6	7

14.2.3 Thrust bearings and fitting dimensions

For thrust bearings, it is necessary to make the raceway disc back face sufficiently broad in relation to load and rigidity, and fitting dimensions from the dimension tables should be adopted. (**Figs. 14.2** and **14.3**)

For this reason, shaft and abutment heights will be larger than for radial bearings. (Refer to dimension tables for all thrust bearing fitting dimensions.)

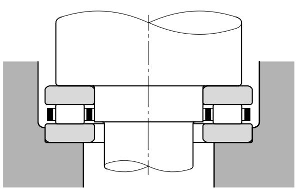


Fig. 14.2

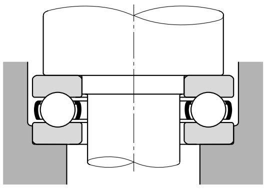


Fig. 14.3

14.3 Shaft and housing accuracy

Table 14.5 shows the accuracies for shaft and housing fitting surface dimensions and configurations, as well as fitting surface roughness and abutment squareness for normal operating conditions.

Table 14.5 Shaft and housing accuracy

Characteristics		Shaft	Housing
Dimensional accuracy		IT6 (IT5)	IT7 (IT5)
Roundness (max.) Cylindricity		IT3	IT4
Abutment squareness		IT3	IT3
Fitting surface roughness	Small size bearings	0.8a	1.6a
	Mid-large size bearings	1.6a	3.2a

Note: For precision bearings (P4, P5 accuracy), it is necessary to increase the circularity and cylindricity accuracies in this table by approximately 50%. For more specific information, please consult the **NTN** precision rolling bearing catalog.

14.4 Allowable bearing misalignment

A certain amount of misalignment of a bearing's inner and outer rings occurs as a result of shaft flexure, shaft or housing finishing irregularities, and minor installation error. In situations where the degree of misalignment is liable to be relatively large, self-aligning ball bearings, spherical roller bearings, bearing units and other bearings with aligning properties are advisable. Although allowable misalignment will vary according to bearing type, load conditions, internal clearances, etc., **Table 14.6** lists some general misalignment standards for normal applications. In order to avoid shorter bearing life and cage failure, it is necessary to maintain levels of misalignment below these standard levels.

Table 14.6 Bearing type and allowable misalignment/alignment allowance

Allowable misalignment	
Deep groove ball bearings	1/1,000～1/300
Angular contact ball bearings	
Single row	1/1,000
Multi row	1/10,000
back to back arrangement	1/10,000
Face to face arrangement	1/1,000
Cylindrical roller bearings	
Bearing series 2, 3, 4	1/1,000
Bearing series 22, 23, 49, 30	1/2,000
Tapered roller bearings	
Single row/back to back arrangement	1/2,000
Face-to-face arrangement	1/1,000
Needle roller bearings	1/2,000
Thrust bearings (excluding self-aligning roller thrust bearings)	1/10,000
Alignment allowance	
Self-aligning ball bearings	1/20～1/15
Spherical roller bearings	1/50～1/30
Self-aligning roller thrust bearings	1/30
Ball bearing units	
Without cover	1/30
With cover	1/50

www.bergab.ru Берг АБ bergab@ya.ru Тел. (495)-228-06-21, факс (495) 223-3071