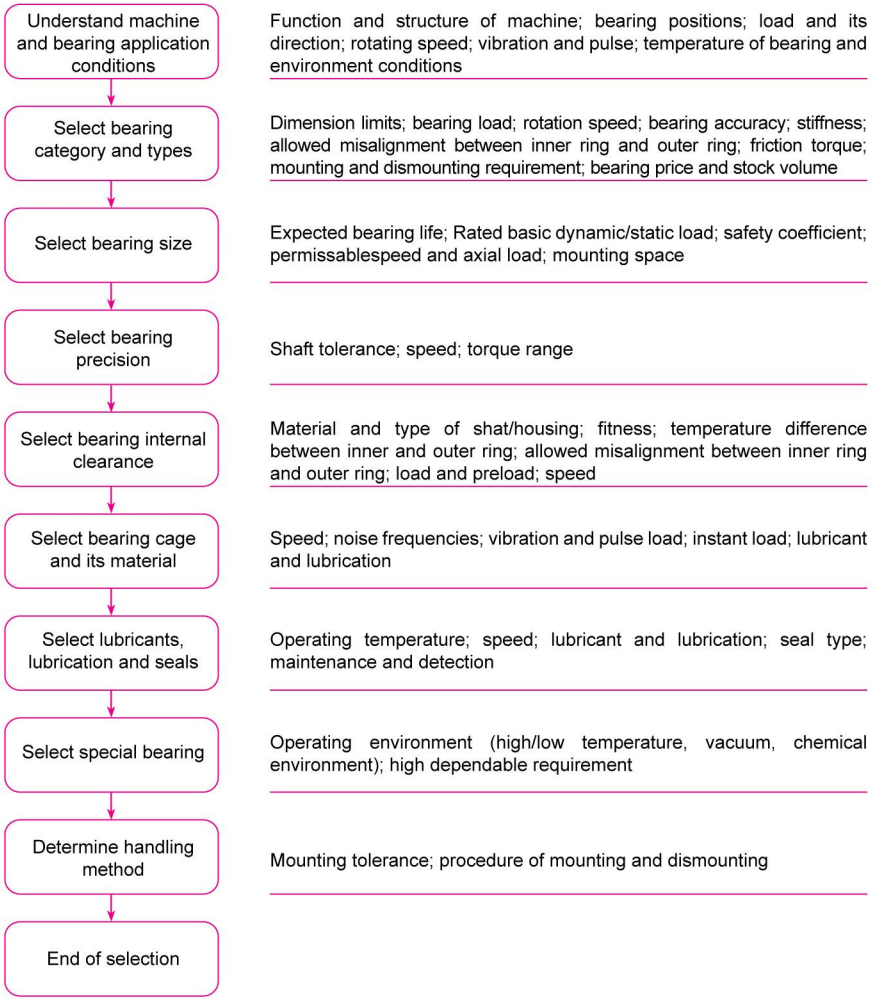
3. Rolling bearing selection

3.1 The diagram of rolling bearing selection

Rolling bearings have been one of the most important mechanical parts by its various applications and the increasing needs of industry development. There are so many types of roll bearings supplied to match different needs of various applications. How to select the right bearing has a significant impact to its running capacity and its service life, meanwhile it's also not easy to select the right bearing for one specific application from so many different bearings. Figure 3-1 illustrated the bearing selection process. Please contact UBC for support in the case of special applications.

Figure 3-1 Diagram of rolling bearing selection



3.2 Selection of bearing type, tolerance and clearance

3.2.1 Selection of bearing type

When selecting one bearing for specific applications, both the characteristic properties and application condition of the bearing must be taken into consideration, including load, speed, self-alignment, permeable mounting space, accuracy, stiffness, noise and vibration and axial displacement, meanwhile without neglect of its cost and purchase convenience. Following are the key factors of bearing selection.

3.2.1.1 Bearing load

The main factor of bearing selection is the load and its magnitude, direction and character usually determine the size of bearing.

(1) Magnitude and character of load. Most of ball bearings are usually applied for light or moderate and stable load, while roller bearings for heavy and high pulse load.

(2) Direction of load.

1) Radial load

all radial bearings can accommodate radial load. NU and N design cylindrical bearings and needle bearings can only support pure radial loads.

2) Axial load

Thrust ball bearing and four-point contact ball bearings are suitable for light or moderate loads that are purely axial. Thrust cylindrical roller bearing and thrust needle bearing are normally applied for purely heavy axial load. Single direction thrust bearings can only accommodate axial loads acting in one direction; for axial loads acting in both directions, double direction thrust ball bearings are needed. For heavy alternating axial loads, two paired thrust cylindrical roller bearings or self-aligning thrust roller bearings are needed.

3) Combined load

For combined loads, single and double row angular contact ball bearings and single row taper roller bearings are most commonly used. Self-aligning ball bearings and NJ and NUP design cylindrical roller bearings as well as NJ and NU design cylindrical can be used for combined loads where the axial load is relatively small. For axial loads of alternating direction these bearings must be combined with a second bearing.

Thrust angular ball bearing and four-point contact ball bearings as well as self-aligning thrust roller bearings can be used for combined loads where the radial load is relatively small.

4) Couple load

When a load acts eccentrically on a bearing, a titling couple will occur. Double row bearings, e.g. deep groove or angular contact ball bearings, can accommodate titling couple, but paired single row angular contact ball bearings or taper roller bearings arranged face-to-face, or back-to-back, are more suitable.

3.2.1.2 Speed

Bearing limiting speed is the maximum rotating speed under certain load and lubrication condition.
The limiting speed is depended on bearing's type, dimension, accuracy, internal clearance, cage material and structure, lubrication and lubricants, the magnitude and direction of the load, and heat dissipation, etc.

The limiting speed of different bearings could be found in its parameter table, and it's measured under lubricated by oil or grease, equivalent dynamic load P≤0.1C; normal lubrication and cooling; pure radial load for radial bearings and pure axial load for thrust bearings; rigid bearing housing and shaft tolerance of Grade 0. When the actual operation condition changed, the limiting speed can also be calculated, e.g., when bearing accommodating heavy loads (P > 0.1C) or combined loads, its actual limiting speed (rpm) would be calculated as,

$$n_{max} \leqslant f_1 f_2 n_{lim}$$

f_1: load coefficient refer to Figure 3-2, when bearing running at equivalent dynamic load P > 0.1C, bearing contact stress increases and will generate more heat and worsen lubrication effect, thus reduce the limiting speed of the bearing.

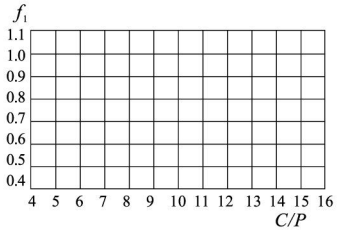


Figure 3-2 Load coefficient

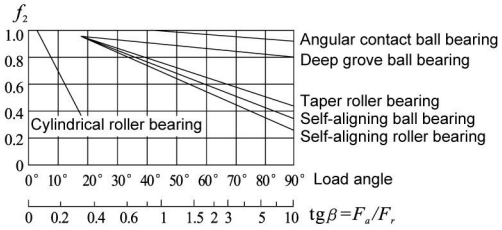


Figure 3-3 Load distribution coefficient

f_2: load distribution coefficient to Figure 3-3, when bearing running at combined loads, the number of roller taking load increases and will cause more friction with raceway and worsen lubrication effect, thus reduce the limiting speed of the bearing.

N_{lim}: measured limiting speed from one batch of bearing sample.

To run the bearing at higher speeds than limiting speed given in bearing tables, some of the speed-limiting factors need to be improved, such as the running accuracy, cage material and design, lubrication and heat dissipation, and bigger bearing internal clearance.

Following are some guidelines for bearing selection based on rotating speed,

(1) Ball bearings have higher limiting speed than roller bearings and ball bearings are the most suitable selection for high speed applications.

(2) The smaller of the bearing contact angle, the bigger of the centrifugal force undertaken by the bearing. So the limiting speed of thrust bearings are less than radial bearings and the limiting speed of single row radial bearings is higher than double row self-aligning bearings. For light and moderate axial load, angular contact ball bearings are the most suitable selection.

(3) For high speed applications, it's recommended to select the smaller outer diameter bearings if the bore diameters are same. Two bearing in tandem arrangement or wide width bearings could be applied if the carrying load is bigger than single bearing could take.

(4) The limiting speed of bearings with machined cage is higher than bearings with pressed sheet steel.

3.2.1.3 Self-alignment

For the misalignment of the centerline of housing and shaft caused by manufacture and/or mounting error, or deformation of shaft and housing, bearings with good self-alignment property would be the preferred selection, such as self-aligning ball bearings and self—aligning roller bearings. U designation bearings are the most suitable for the misalignment from early bearing mounting process. Needle bearings and roller bearings are not recommended for the applications with a sloped shaft line.

3.2.1.4 Stiffness

Generally the stiffness of rolling bearing is characterized by the magnitude of the elastic deformation under load, which is very small and can be neglected. In some cases, however, e.g. spindle bearing arrangements for machine tools or pinion bearing arrangements, stiffness is very important.

Because of the contact conditions between the rolling elements and raceways, roller bearings, e.g cylindrical or taper roller bearings have a higher degree of stiffness than ball bearings. Bearing stiffness can be further enhanced by applying a preload.

3.2.1.5 Axial displacement

UN design or N design cylindrical roller bearings and needle bearings are the suitable for the applications which need the bearing moving forward or backward in axial direction and one of the rings must have an interference fit. If non-separable bearings are used such as deep groove ball bearings or self-aligning roller bearings, one of the rings must have a loose as to have enough freedom of axial displacement. Many rolling bearings can accommodate very minor axial displacement by its internal clearance.

3.2.1.6 Available space

When radial space is limited, bearings with a small cross section should be selected, such as needle roller bearings, deep groove ball bearings, angular contact ball bearings, cylindrical roller bearings and other low cross-sectional height bearings.

When axial space is limited, small width series bearings can be used, such as ball bearings or roller bearings with width serial 0 or 1.

3.2.1.7 Mounting and dismounting

Separable bearings are preferable if frequent mounting and dismounting are required or in difficult mounting or dismounting applications, e.g. cylindrical roller bearings and taper roller bearings. Tapered bore bearings with an adapter sleeve can be easily mounted for long shaft.

3.2.1.8 Others

Whether the bearings are chosen with snap ring, seal, shield or quiet running is depended on actual application conditions and their prices and market supply condition.

3.2.2 Selection of bearing tolerance

Bearing tolerance selected must be matched with the accuracy of the machine. Machine's accuracy, vibration and noise can not be fully improved by increasing bearing tolerance only, they also related with the precision and quality of manufacturing and mounting of the fitted components.

Each types of bearings are supplied with tolerance grade 0 and widely applied. For most of machine applications, bearing with tolerance grade 0 can meet the application requirement. For higher rotating precision, bearings with higher grade tolerance or special tolerance can be selected, e.g. bearings for machine spindles, high precision machines and instruments. For high speed machines, bearings with high grade tolerance are also preferable.

3.2.3 Selection of bearing clearance

Bearing internal clearance has a significant impact to its load capacity, service life and temperature increase and noise level. Radial clearance can be defined as initial clearance, mounting clearance and operational clearance. Bearing initial clearance is greater than its operational clearance. The basic rated dynamic load in the bearing table is based on zero operational clearance.

Correct selection of bearing clearance must consider the fitness and temperature difference of bearing rings and its carrying load as to achieve its best operation condition. Generally, bearings with normal clearance are preferable for normal operating temperature and fitness. Where operating and mounting conditions differ from the normal, e.g. interference fit are used for both rings, unusual temperature differences, external heat resource, etc, bearings with greater or smaller internal clearance are required. For high rotating accuracy or limited axial displacement, smaller internal clearance is preferable.

For low speed or oscillating movement applications, bearings without internal clearance or preloaded are often selected.

The operational clearance of angular contact ball bearings, taper roller bearings and tapered bore bearings can be adjusted during mounting or handling process.

Under normal application conditions, bearings with Grade 0 clearance can be used if the fitness grade of bearing rings with the range as Table 3-1.

Table 3-1 Fitness for Normal internal clearance

Bearing Type	Shaft	Housing
Ball bearing	jk…k5	J6
Roller bearing Needle roller bearing	k5…m5	K6