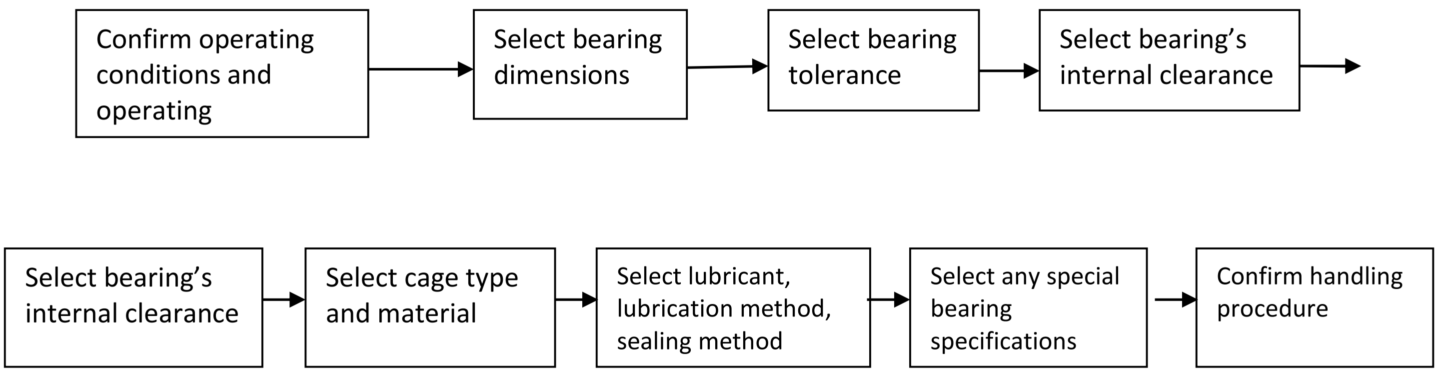
BEARING SELECTION

Rolling element bearings are available in a variety of types, configurations, and sizes. When selecting the correct bearing for your application, it is important to consider several factors and analyses in various means.

As a general guideline, the basic procedure for selecting the most appropriate bearing is shown in the following flow chart.

Bearing selection flow chart

Basic Procedure



Selection of bearing type and Configuration

Dimensional limitations

The allowable space for bearings is generally limited. In most cases, shaft diameter (or the bearing bore diameter) has been determined according to the machine's other design specifications. Therefore, bearing's type and dimensions are determined according to bearing bore diameters. For this reasons all dimension tables are organized according to standard bore diameters. There is a wide range of standardized bearing types and dimensions; the right one for a particular application can usually be found in these tables.

Bearing load

The characteristics, magnitude, and direction of loads acting upon a bearing are extremely variables. In general, the basic load ratings shown in bearing dimension tables indicate their load capacity. However, in determining the appropriate bearing type, consideration must also be given to whether the acting load is a radial load only or combined radial and axial load etc. When ball and roller bearings within the same dimension series are considered, the roller bearings have a larger load capacity and are also capable of withstanding greater vibration and shock loads.

Rotational speed

The allowable speed of a bearing will differ depending upon bearing type, size, tolerances, cage type, load, lubricating conditions, and cooling conditions.

The allowable speeds listed in the bearing tables for grease and oil lubrication are for normal tolerance NTN bearings. In general, deep groove ball bearings, angular contact ball bearings, and cylindrical roller bearings are most suitable for high speed applications.

Bearing tolerances

The dimensional accuracy and operating tolerances of bearings are regulated by ISO standard. For equipment requiring high tolerance shaft runout or high speed operation, bearings with higher class are recommended. Deep groove ball bearings, angular contact ball bearings, and cylindrical roller bearings are recommended for high rotational tolerances.

(1) **Rigidity**
Elastic deformation occurs along the contact surfaces of a bearing's rolling elements and raceway surfaces under loading. With certain types of equipment it is necessary to reduce this deformation as much as possible. Roller bearings exhibit less elastic deformation than ball bearings. Furthermore, in some cases, bearings are given a load in advance (preloaded) to increase their rigidity. This procedure is commonly applied to deep groove ball bearings, angular contact ball bearings, and tapered roller bearings.

(2) **Misalignment of inner and outer rings**
Shaft flexure, variations in shaft or housing accuracy, and fitting errors, result in a certain degree of dis-alignment between the bearing's inner and outer rings. In cases where the degree of misalignment is relatively large, self-aligning ball bearings, spherical roller bearings, or bearing units with self-aligning properties are the most appropriate choices. (Refer to fig. 2.1) .

(3) **Noise and torque levels**
Rolling bearings are manufactured and processed according to high precision standards, and therefore generally produce only slight amounts of noise and torque. For applications requiring particularly low-noise or low-torque operation, deep groove ball bearings and cylindrical roller bearings are most appropriate.

(4) **Installation and disassembly**
Some applications require frequent disassembly and reassembly to enable periodic inspections and repairs. For such applications, bearings with separable inner/outer rings. Such as cylindrical roller bearings, needle roller [bearings, and tapered roller bearings are most appropriate. Incorporation of adapter sleeves simplifies the installation and dissembly of self-aligning ball bearings and spherical roller bearings with tapered bores.

Load Rating and Life

Bearing Life

Even in bearings operating under normal conditions, the surfaces of the raceway and rolling elements are constantly being subjected to repeated compressive stresses which causes flaking of these surfaces to occur. This flaking is due to material fatigue and will eventually cause the bearings to fall. The effective life of a bearing is usually defined in terms of the total number of revolutions a bearing can undergo before flaking of either the raceway surface or the rolling element occurs.

Other causes of bearing fatigue are often attributed to problems such as seizing, abrasions, cracking, chipping, scuffing, rust, etc. However, these so called "causes" of bearing failure are usually themselves caused by improper installation. Insufficient or improper lubrication, faulty sealing or inaccurate bearing selection. Since the above mentioned "causes" of bearing failure can be avoided by taking the proper precautions, and are not simply caused by material fatigue, they are considered separately from the flaking aspect.

Basic rating life and basic dynamic load rating

A group of seemingly identical bearings when subjected to identical load and operating conditions will exhibit a wide diversity in their durability.

The "life" disparity can be accounted for by the difference in the fatigue of the bearing material itself. This disparity is considered statistically when calculating bearing life, and the basic rating life is defined as follows:

The basic rating life is based on a 90% statistical model which is expressed as the total number of revolutions 90% of the bearings in an identical group of bearings subjected to identical operating conditions will attain or surpass before flaking due to material fatigue occurs. For bearings operating at fixed constant speeds, the basic rating life (90% reliability) is expressed in the total number of hours of operation.

Basic dynamic load rating expresses a rolling bearing's capacity to support a dynamic load. The basic dynamic load rating is the load under which the basic rating life of the bearing is 1 million revolutions. This is expressed as pure radial load for radial bearings and pure axial load for thrust bearings. There are referred to as "basic dynamic load rating (C)" and "basic dynamic axial load rating (Ca)". The relationship between the basic rating life, the basic dynamic load rating and bearing load given in formula

For ball bearings: $L_{10} = \left(\frac{C}{P}\right)^3$

For roller bearings: $L_{10} = \left(\frac{C}{P}\right)^{10/3}$

where

L_{10} : Basic rating life 10^6 revolution

C : Basic dynamic load rating, N (kgf) (Cr; radial bearings, Ca; thrust bearings)

P: Equivalent dynamic load, N (kgf)

(P_r; radial bearings, P^2, thrust bearings) n: Rotational speed, mm^{-1}

The relationship between Rotational speed and speed factor f_n as well as the relation between the basic rating life L_{10h} and the life factor f_c is shown in the Table and Figure below.

Correlation of bearing basic rating life, life factor, and speed factor

Classification	Ball bearing	Roller bearing
Basic rating life L_{10h} h	$\frac{10^6}{60n}\left(\frac{C}{P}\right)^3 = 500\ fn^3$	$\frac{10^6}{60n}\left(\frac{C}{P}\right)^{10/3} = 500\ fn^{10/3}$
Life factor f_h	$fn\ \frac{C}{P}$	$fn\ \frac{C}{P}$
Speed factor f_n	$\left(\frac{33.3}{n}\right)^{1/3}$	$\left(\frac{33.3}{n}\right)^{5/10}$

When several bearings are incorporated in machines or equipment as complete units, all the bearings in the unit are considered as a whole when computing bearing life.

$$L = \frac{1}{\left(\frac{1}{L_1} + \frac{1}{L_2} + ...\frac{1}{L_n^v}\right)^{1/e}}$$

where

L: Total basic rating life of entire unit, h

L_1, L_2… L_n: Basic rating life of individual bearings, 1, 2, ….n, h

e= 10/9……..For ball bearings

e=9/8 ……….For roller bearings

When the load conditions vary at regular intervals, the life can be given by formula (3.4)

$$L_{in} = \left(\frac{\phi_1}{L_1} + \frac{\phi_2}{L_2} + ...\frac{\phi_1}{L_1}\right)^{-1}$$

where

L_m = Total life of bearing

ϕ : Frequency of individual load conditions

$(\Sigma\phi_1 = 1)$

L: Life under individual conditions

It equivalent load P and rotational speed *n* are operating conditions of the bearing, basic rated dynamic load C that satisfies required life of the bearing is determined using table above and formula below . Bearings that satisfy the required C can be selected from the bearing dimensions table provided in the catalog.

$$C = P\frac{f_h}{f_n}$$

Adjusted rating life

The basic bearing rating life (90% reliability factor) can be calculated through the formulas mentioned earlier. However, in some applications a bearing life factor of over 90% reliability may be required. To meet these requirements, bearing life can be lengthened by the use of specially improved bearing materials or manufacturing process. Bearing life is also sometimes affected by operating conditions such as lubrication, temperature and rotational speed.

Basic rating life adjusted to compensate for this is called “adjusted rating life”, and is determined using formula

$L_{na} = a_1 . A_2 . a_3 L_{10}$

where

L_{10} : Adjusted rating life in millions of revolutions (10^6)

a_1: Reliability factor

a_2: Bearing characteristics factor

a_3: Operating conditions factors

Basic Static load rating

When stationary rolling bearings are subjected to static loads, they suffer from partial permanent deformation of the contact surfaces at the contact point between the rolling elements and the raceway. The amount of deformity increases as the load increases, and if this increase in load exceeds certain limits, the subsequent smooth operation of the bearings is impaired.

It has been found through experience that a permanent deformity of 0.0001 times the diameter of the rolling element, occurring at the most heavily stressed contact point between the raceway and the rolling elements, can be tolerated without any impairment in running efficiency.

Bearing Load Calculation

Dynamic equivalent load

When both dynamic radial loads and dynamic axial loads act on a bearing at the same time, the hypothetical load acting on the center of the bearing which gives the bearings the same life as if they had only a radial load or only an axial load is called the dynamic equivalent load.

For radial bearings, this load is expressed as pure radial load and is called the dynamic equivalent radial load. For thrust bearings, it is expressed as pure axial load, and is called the dynamic equivalent axial load.

(1) **Dynamic equivalent radial load**

The dynamic equivalent radial load is expressed by formula

$P_1 = XF + YF$

where

P_1: Dynamic equivalent radial load, N (kgf)

F_1: Actual radial load, N(kgf)

F_2: Actual axial load, N ((kgf)

X: Radial load factor

Y: Axial load factor

Dynamic equivalent axial load

As a rule, standard thrust bearings with a contact angle of 90^o cannot carry radial loads. However, self-aligning thrust roller bearings can accept some radial load. The dynamic equivalent axial load for these bearings is given in formula

$P_a = F_a + 1.2F_1$

where

P_a: Dynamic equivalent axial load, N (kgf)

F_a: Actual axial load, N (kgf)

F_r : Actual radial load, N (kgf)

Provided that $F_r / F_a \leq 0.55$ only

Static Equivalent load

The static equivalent load is a hypothetical load which would cause the same total permanent deformation at the most heavily stressed contact point between the rolling elements and the raceway as under actual load conditions; that is when both static radial loads and static axial loads are simultaneously applied to the bearing.

For radial bearings this hypothetical load refers to pure radial loads, and for thrust bearings it refers to pure centric axial loads. These loads are designated static equivalent radial loads and static equivalent axial loads respectively.

(1) **Static equivalent radial load**

For radial bearings the static equivalent radial load can be found by using formula for p_{or} . The greater of the two resultant values is always taken for P_{or} .

$$P_{or} = X_0 \ F_1 + Y_0 \ F_a$$
$$P_{or} = F_r$$

where,

P_{or} : Static equivalent radial load, N (kgf)

F_r : Actual radial load, N (kgf)

F_a : Actual axial load, N (kgf)

X_o : Static radial load factor

Y_o : Static axial load factor

(2) **Static equivalent axial load**

For spherical thrust roller bearings the static equivalent axial load is expressed by formula

$$P_a = F_a + 2.7F_r$$

where

P_a: Static equivalent axial load, N (kgf)

F_a: Actual axial load, N (kgf)

F_r : Actual radial load, N (kgf)

Provided that $F_r/F_a \leq 0.55$ only.

Load Calculation for angular contact ball bearings and tapered roller bearings

For angular contact ball bearings and tapered roller bearings the pressure cone apex (load center) is located as shown in Figure below and their values are listed in the bearing tables.

When radial loads act on these types of bearings the component force is induced in the axial direction. For this reason, these bearings are used in pairs. For load calculation this component force must be taken into consideration and is expressed by formula

$$F_a = \frac{0.5F_r}{Y}$$

where,

F_a: Axial component force, N (kgf)

F_r: Radial load, N (kgf)

Y: Axial load factor

Example :

What is the rating life in hours of operation (L_{10h}) for deep groove ball bearing 6208 operating at rotational speed *n=650* min^{-1}, with a radial load F_r of 3.2 kN (326 kgf)?

From $P_{or} = F_r = 3.2\,kN$

Basic dynamic load rating C_r for bearing 6208 is 29.1 kN, ball bearing speed factor in relative to rotational speed n = 650 min^{-1} from bearing life rating scale is f_n = 0.37. Thus life factor f_h from formula is:

$$f_h = fn\ \frac{C}{P} = 0.37 \times \frac{29.1}{3.2} = 3.36$$

Therefore, with f_h = 3.36 from bearing life scale, threated life, L_{10h} = approximately 19,000 hours.