3. Load Rating and Life

3.1 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 fail. 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 surfaces occurs.

Other causes of bearing failure 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.

3.2 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.

This "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. These are referred to as "basic dynamic load rating (C_r)" and "basic dynamic axial load rating (C_a)." The basic dynamic load ratings given in the bearing tables of this catalog are for bearings constructed of **NTN** standard bearing materials, using standard manufacturing techniques.

The relationship between the basic rating life, the basic dynamic load rating and the bearing load is given in formula.

For ball bearings: $$L_{10} = \left(\frac{C}{P}\right)^3 \quad \cdots\cdots\cdots\cdots\cdots (3.1)$$

For roller bearings: $$L_{10} = \left(\frac{C}{P}\right)^{10/3} \quad \cdots\cdots\cdots\cdots (3.2)$$

where,

L_{10} : Basic rating life 10^6 revolutions
C : Basic dynamic load rating, N {kgf}
(C_r: radial bearings, C_a: thrust bearings)
P : Equivalent dynamic load, N {kgf}
(P_r: radial bearings, P_a: thrust bearings)
n : Rotational speed, min^{-1}

The relationship between Rotational speed n and speed factor f_n as well as the relation between the basic rating life L_{10h} and the life factor f_n is shown in **Table 3.1** and **Fig. 3.1.**

Table 3.1 Correlation of bearing basic rating life, life factor, and speed factor

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

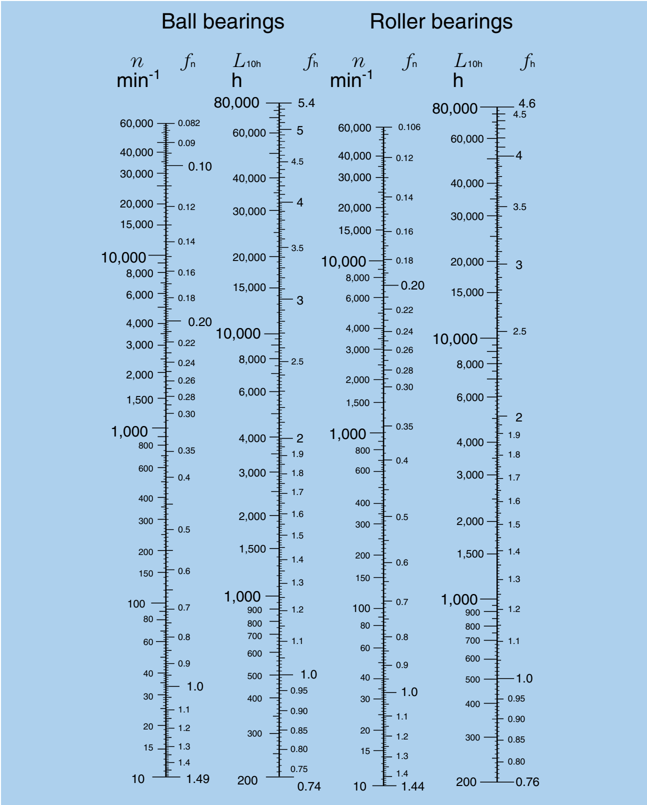

Fig. 3.1 Bearing life rating scale

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 (see formula 3.3).

$$L=\frac{1}{\left(\frac{1}{L_1^e}+\frac{1}{L_2^e}+\cdots\frac{1}{L_n^e}\right)^{1/e}}\cdots\cdots\cdots\cdots(3.3)$$

where,

L : Total basic rating life of entire unit, h

L_1 , L_2 $\cdots L_n$: Basic rating life of individual bearings, 1, 2, $\cdots$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).

$$L_m=\left(\frac{\Phi_1}{L_1}+\frac{\Phi_2}{L_2}+\cdots\frac{\Phi_j}{L_j}\right)^{-1}\cdots\cdots\cdots\cdots(3.4)$$

where,

L_m : Total life of bearing

Φ_j : Frequency of individual load conditions ($\Sigma\Phi_j = 1$)

L_j : Life under individual conditions

If 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 3.1** and formula (3.5). Bearings that satisfy the required C can be selected from the bearing dimensions table provided in the catalog.

$$C=P\frac{f_h}{f_n}\cdots\cdots\cdots\cdots(3.5)$$

3.3 Adjusted rating life

The basic bearing rating life (90% reliability factor) can be calculated through the formulas mentioned earlier in Section 3.2. 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 (3.6).

$$L_{na}=a_1\cdot a_2\cdot a_3 L_{10}\cdots\quad(3.6)$$

where,

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

a_1 : Reliability factor

a_2 : Bearing characteristics factor

a_3 : Operating conditions factor

3.3.1 Reliability factor a_1

The value of reliability factor a_1 is provided in **Table 3.2** for reliability of 90% or greater.

3.3.2 Bearing characteristics factor a_2

Bearing characteristics concerning life vary according to bearing material, quality of material and if using special manufacturing process. In this case, life is adjusted using bearing characteristics factor a_2.

The basic dynamic load ratings listed in the catalog are based on **NTN**'s standard material and process, therefore, the adjustment factor $a_2 = 1$. $a_2 > 1$ may be used for specially enhanced materials and manufacturing methods.If this applies, consult with **NTN** Engineering.

Dimensions change significantly if bearings made of high carbon chrome bearing steel with conventional heat treatment are used at temperatures in excess of 120˚C for an extended period of time. **NTN** Engineering therefore offers a bearing for high-temperature applications specially treated to stabilize dimensions at the maximum operating temperature (TS treatment). The treatment however makes the bearing softer and affects life of the bearing. Life is adjusted by multiplying by the values given in **Table 3.3**.

Table 3.2 Reliability factor a_1

Reliability %	L_n	Reliability factor a_1
90	L_{10}	1.00
95	L_5	0.62
96	L_4	0.53
97	L_3	0.44
98	L_2	0.33
99	L_1	0.21

Table 3.3 Treatment for stabilizing dimensions

Symbol	Max. operating temperature (C˚)	Bearing characteristics factor a_2
TS2	160	1.00
TS3	200	0.73
TS4	250	0.48

3.3.3 Operating conditions factor a_3

Operating conditions factor a_3 is used to compensate for when lubrication condition worsens due to rise in temperature or rotational speed, lubricant deteriorates, or becomes contaminated with foreign matter.

Generally speaking, when lubricating conditions are satisfactory, the a_3 factor has a value of one; and when lubricating conditions are exceptionally favorable, and all other operating conditions are normal, a_3 can have a value greater than one. a_3 is however less than 1 in the following cases:

- Dynamic viscosity of lubricating oil is too low for bearing operating temperature
  ($13\ mm^2/s$ or less for ball bearings, $20\ mm^2/s$ for roller bearings)
- Rotational speed is particularly low
  (If sum of rotational speed n min^{-1} and rolling element pitch diameter D_{pw} mm is $D_{pw} \cdot n < 10{,}000$)
- Bearing operating temperature is too high
  If bearing operating temperature is too high, the raceway becomes softened, thereby shortening life. Life is adjusted by multiplying by the values given in **Fig. 3.2** as the operating condition factor according to operating temperature. This however does not apply to bearings that have been treated to stabilize dimensions.
- Lubricant contaminated with foreign matter or moisture
  If using special operating condition, consult with **NTN** Engineering. Even if $a_2 > 1$ is used for specially bearings made of enhanced materials or produced by special manufacturing methods, $a_2 \times a_3 < 1$ is used if lubricating conditions are not favorable.

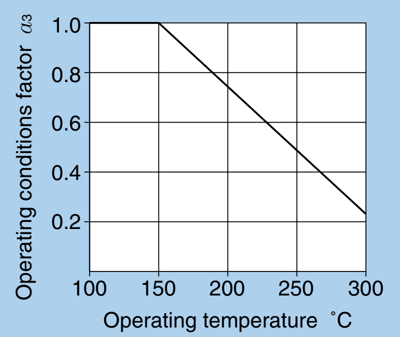

Fig. 3.2 Operating conditions factor according to operating temperature

When a super heavy load is applied, harmful plastic distortion could be produced on the contact surfaces of the rolling elements and raceway. The formulae for determining basic rating life (3.1, 3.2, and 3.6) do not apply if P_r exceeds either C_{or} (Basic static load rating) or 0.5 C_r for radial bearings, or if P_a exceeds 0.5 C_a for thrust bearings.

3.4 Machine applications and requisite life

When selecting a bearing, it is essential that the requisite life of the bearing be established in relation to the operating conditions. The requisite life of the bearing is usually determined by the type of machine in which the bearing will be used, and duration of service and operational reliability requirements. A general guide to these requisite life criteria is shown in **Table 3.4**. When determining bearing size, the fatigue life of the bearing is an important factor; however, besides bearing life, the strength and rigidity of the shaft and housing must also be taken into consideration.

3.5 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.

Table 3.4 Machine application and requisite life (reference)

Service classification	Machine application and requisite life (reference) L_{10h} $\times 10^3$ h				
	～4	4～12	12～30	30～60	60～
Machines used for short periods or used only occasionally	• Household appliances • Electric hand tools	• Farm machinery • Office equipment			
Short period or intermittent use, but with high reliability requirements	• Medical appliances • Measuring instruments	• Home air-conditioning motor • Construction equipment • Elevators • Cranes	• Crane (sheaves)		
Machines not in constant use, but used for long periods	• Automobiles • Two-wheeled vehicles	• Small motors • Buses/trucks • General gear drives • Woodworking machines	• Machine spindles • Industrial motors • Crushers • Vibrating screens	• Main gear drives • Rubber/plastic • Calender rolls • Printing machines	
Machines in constant use over 8 hours a day		• Rolling mills • Escalators • Conveyors • Centrifuges	• Railway vehicle axles • Air conditioners • Large motors • Compressor pumps	• Locomotive axles • Traction motors • Mine hoists • Pressed flywheels	• Papermaking machines • Propulsion equipment for marine vessels
24 hour continuous operation, non-interruptable					• Water supply equipment • Mine drain pumps/ventilators • Power generating equipment

The basic static load rating refers to a fixed static load limit at which a specified amount of permanent deformation occurs. It applies to pure radial loads for radial bearings and to pure axial loads for thrust bearings. The maximum applied load values for contact stress occurring at the rolling element and raceway contact points are given below.

For ball bearings	4,200 MPa {428kgf/mm^2}
For self-aligning ball bearings	4,600 MPa {469kgf/mm^2}
For roller bearings	4,000 MPa {408kgf/mm^2}

Referred to as "basic static radial load rating" for radial bearings and "basic static axial load rating" for thrust bearings, basic static load rating is expressed as C_{or} or C_{oa} respectively and is provided in the bearing dimensions table.

3.6 Allowable static equivalent load

Generally the static equivalent load which can be permitted (See page A-25) is limited by the basic static rating load as stated in **Section 3.5**. However, depending on requirements regarding friction and smooth operation, these limits may be greater or lesser than the basic static rating load.

This is generally determined by taking the safety factor So given in **Table 3.5** and formula (3.7) into account.

$$S_o = C_o / P_o \cdots \quad (3.7)$$

where,

S_o : Safety factor

C_o : Basic static load rating, N {kgf}
(radial bearings: C_{or}, thrust bearings: C_{oa})

P_o : Static equivalent load, N {kgf}
(radial: P_{or}, thrust: C_{oa})

Table 3.5 Minimum safety factor values S_0

Operating conditions	Ball bearings	Roller bearings
High rotational accuracy demand	2	3
Normal rotating accuracy demand (Universal application)	1	1.5
Slight rotational accuracy deterioration permitted (Low speed, heavy loading, etc.)	0.5	1

Note 1: For spherical thrust roller bearings, min. S_0 value=4.
2: For shell needle roller bearings, min. S_0 value=3.
3: When vibration and/or shock loads are present, a load factor based on the shock load needs to be included in the P_0 max value.
4: If a large axial load is applied to deep groove ball bearings or angular ball bearings, the contact oval may exceed the raceway surface. For more information, please contact **NTN** Engineering.