4. Basic Load Rating and Life

4.1 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 cause 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, gnawing, 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.

4.2 Basic rated 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 rated life is defined as follows.

The basic rated life is based on a 90% statistical model which is expressed as the total number of revolutions 90% of the bearings, in an identical groups 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 rated life (90% reliability) is expressed in the total number of hours of operation.

The basic dynamic load rating is an expression of the load capacity of a bearing based on a constant load which the bearing can sustain for one million revolutions (the basic life rating). For radial bearings this rating applies to pure radial loads, and for thrust bearings it refers to pure axial loads, and for thrust bearings it refers to pure axial loads. 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. Please consult NTN for basic load ratings of bearings constructed of special materials or using special manufacturing techniques.

The relationship between the basic rated life, the basic dynamic load rating and the bearing load is given in the formula (4.1).

$$L_{10} = \left(\frac{C_r}{P_r}\right)^3 \cdots\cdots (4.1)$$

where,

- L : Basic rated life of 106 revolutions
- C_r : Basic dynamic rated load, N, lbf
- P_r : Equivalent dynamic load, N, lbf

The basic rated life can also be expressed in terms of hours of operation (revolution), and is calculated as shown in formula (4.2).

$$L_{10} = 500 f_h^3 \cdots\cdots (4.2)$$

$$f_h = f_n \frac{C_r}{P_r} \cdots\cdots (4.3)$$

$$f_n = \left(\frac{33.3}{n}\right)^{1/3} \cdots\cdots (4.4)$$

where

- $L10$: Basic rated life, h
- fh : Life factor
- fn : Speed factor
- n : Rotational speed, r/min

Formula (4.2) can also be expressed as shown in formula (4.5).

$$L_{10h} = \frac{10^6}{60n}\left(\frac{C_r}{P_r}\right)^3 \cdots\cdots (4.5)$$

The relation between rotational speed n and speed factor f_n as well as the relation between the basic rated life L_{10h} and the life factor f_h is shown in Fig. 4.1.

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 4.6). The total bearing life of the unit is a life rating based on the viable lifetime of the unit before even one of the bearings fails due to rolling contact fatigue.

$$L = \frac{1}{\left(\frac{1}{L_1^{1.1}} + \frac{1}{L_2^{1.1}} + \cdots\cdots + \frac{1}{L_n^{1.1}}\right)^{1/1.1}} \cdots\cdots\cdots\cdots\cdots (4.6)$$

where,

L : Total life of the whole bearing assembly h

$l_1, L_2, \ldots, L_n$: Rated life of bearing 1, 2, …, n, h

In the case where load and the number of revolutions change at regulated intervals, after finding the rated life $l_1, L_2, \ldots, L_n$ under conditions of n_1, P_1; n_2, P_2;…; n_n, P_n; the built-in life L_m can be given by the formula (4.7).

$$L_1 = \frac{10^6}{60n_1}\left(\frac{C_r}{P_1}\right)^3$$

$$L_2 = \frac{10^6}{60n_2}\left(\frac{C_r}{P_2}\right)^3$$

$$\vdots$$

$$L_n = \frac{10^6}{60n_n}\left(\frac{C_r}{P_n}\right)^3$$

$$L_m = \left(\frac{\phi_1}{L_1} + \frac{\phi_2}{L_2} + \cdots\cdots + \frac{\phi_n}{L_n}\right)^1 \cdots\cdots\cdots\cdots\cdots\cdots (4.7)$$

where,

$l_1, L_2, \ldots, L_n$: Rated life under condition 1, 2,…, n, h

$n_1, n_2, \ldots, n_n$: Number of revolutions under condition 1, 2, …, n, r/min

$P_1, P_2, \ldots, P_n$: Equivalent load under condition 1, 2, …, n, N, lbf

$\phi_1, \phi_2, \ldots, \phi_n$: Ratio of condition 1, 2, …, n accounting for the total operating time

L_m : Built-in life, h

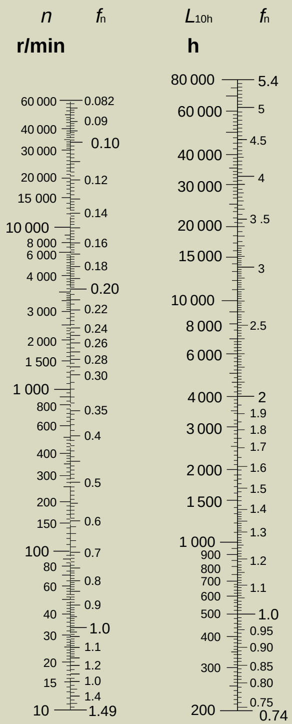

Fig. 4.1 Bearing life rating scale

Service classification	Machine application	Life time L_n
Machines used occasionally	Door mechanisms, Garage shutter	500
Equipment for short perior or intermittent service-interruption permissible	Household appliances, Electric hand tools, Agriculture machines, Lifting tackles in shops	4000~ 8000
Intermittent service machines-high reliability	Power-Station auxiliary equipment, Elevators Conveyors, Deck cranes	8000~ 14000
Machines used for 8 hours a day, but no always in full operation	Ore wagon axles, Important gear units	14000~ 20000
Machines fully used for 8 hours	Blowers, General machinery in shops, Continuous operation cranes	20000~ 30000
Machines continuously used for 24 hours a day	Compressors, Pumps	50000~ 60000
Machines continuously used for 24 hours a day with maximum reliability	Power-station equipment, Water-supply equipment for urban areas, Mine ventilators	100000~ 200000

4.3 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 the bearing is to be used in, and duration of service and operational reliability requirements. A general guide to these requisite life criteria is shown in Table 4.1. 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.

4.4 Adjusted life rating factor

The basic bearing life rating (90% reliability factor) can be calculated through the formulas mentioned earlier in Section 4.2. 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 spatially improved bearing materials or special construction techniques. Moreover, according to elastohydrodynamic lubrication theory, it is clear that the bearing operating conditions (lubrication, temperature, speed, etc.) all exert an effect on bearing life. All these adjustment factors are taken into consideration when calculating bearing life, and using the life adjustment factor as prescribed in ISO 281, the adjusted bearing life can be arrived at:

$$L_{na} = a_1\, a_2\, a_3 \left(\frac{C}{P}\right)^3 \cdots\cdots\cdots\cdots (4.8)$$

where,

L_{na} : Adjusted life in millions of revolutions (10^6) (adjusted for reliability, material and operating conditions)
a_1 : Reliability adjustment factor
a_2 : Material/construction adjustment factor
a_3 : Operating condition adjustment factor

4.4.1 Life adjustment factor for reliability a_1

The values for the reliability adjustment factor a_1 (for a reliability factor higher than 90%) can be found in Table 4.2.

Table 4.2 Reliability adjustment factor values 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

4.4.2. Life adjustment factor for material/ construction a_2

The values for the basic dynamic load ratings given in the bearing dimension table are for bearing constructed from NTN's continued efforts at improving the quality and life of its bearings.

Accordingly, a_2=1 is used for life adjustment factor in formula (4.8). For bearing constructed of specially improved materials or with special manufacturing methods, the life adjustment factor a_2 in formula (4.8) can have a value greater than one. Please consult NTN for special bearing materials or special construction requirements.

When high carbon chromium steel bearings, which have undergone only normal heat treatment, are operated for long periods of time at temperatures in excess of 120°C, 248°F, considerable dimension deformation may take place. For this reason, there are special high temperature bearings which have been treated for dimensional stability. This special treatment allows the bearing to operate at its maximum operational temperature without the occurrence of dimensional changes. However, these dimensionally stabilization-treated bearing, designated "HT", have a reduced hardness with a consequent decrease in bearing life. The adjusted life factor values used in formula (4.8) for such heat-stabilized bearings can be found in Table 4.3.

Table 4.3 Dimension stabilized bearings

Code	Max. operating temperature °C	°F	Adjustment factor a_2
—	100	212	1.00
HT1	140	284	0.87
HT2	200	392	0.68

4.4.3 Life adjustment factor a_3 for operating conditions

The operating conditions life adjustment factor a_3 is used to adjust for such conditions as lubrication, operating temperature, and other operating factors which have an effect on bearing life.

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.

However, when lubricating conditions are particularly unfavorable and the oil film formation on the contact surfaces of the raceway and rolling elements is insufficient, the value of a_3 becomes less than one. This insufficient oil film formation can be caused, for example, by lubricating oil viscosity being too low for the operating temperature (below 13 mm^2/s for ball bearings); or by exceptionally low rotational speed (n r/min $\times$ d_p mm less than 10000). For bearings used under special operating conditions, please consult NTN.

As the operating temperature of the bearing increases, the hardness of the bearing material decreases, Thus, the bearing life correspondingly decreases. The operating temperature adjustment values are shown in Fig. 4.2.

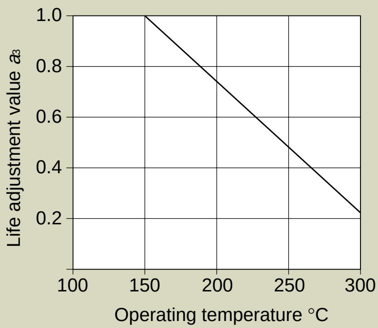

Fig. 4.2 Life adjustment value for operating temperature

4.5 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 bearing 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.

The basic rated static load 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. The maximum applied load values for contact stress occurring at the rolling element and raceway contact points are given below.

For ball bearings (for bearing unit): 4200 Mp_a.

4.6 Allowable static equivalent load

Generally the static equivalent load which can be permitted (see section 5.3) is limited by the basic static rated load as stated in Section 4.5. However, depending on requirements regarding friction and smooth operation, these limits may be greater or lesser than the basic static rated load.

In the following formula (4.9) and Table 4.4 the safety factor S_o can be determined considering the maximum static equivalent load.

$$S_o = \frac{C_o}{P_{o\,max}} \quad \cdots\cdots (4.9)$$

where,

S_o : Safety factor
C_o : Basic static rated load, N, lbf
$P_{o\,max}$: Maximum static equivalent load, N, lbf

Table 4.4 Minimum safety factor values S_o

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

Note: 1) When vibration and/or shock loads are present, a load factor based on the shock load needs to be included in the $P_{o\,max}$ value.