5. Load Rating and Life

5.1 Bearing life

Even in bearings operating under normal conditions, the surfaces of the raceway and rollling 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, 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.

5.2 Basic rated life and basic dynamic load rating

A group of seemingly identical bearings when subjected to indentical 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 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 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. 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 formula (5.1).

where, $$L_{10} = \left(\frac{C}{P}\right)^{p} \quad \cdots\cdots (5.1)$$

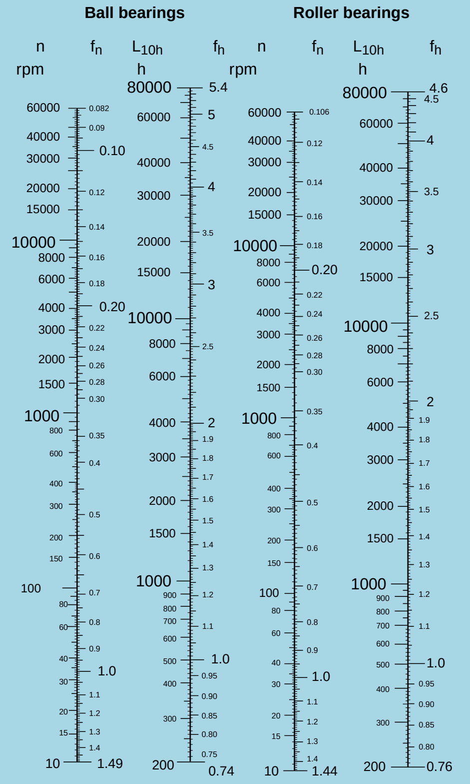

Fig. 5.1 Bearing life rating scale

p = 3 ························ For ball bearings

p = 10/3 ························ For roller bearings

L_{10} : Basic rated life 10 revolutions

C : Basic dynamic rated load N
(Cr : radial bearings, Ca : thrust bearings)

P : Equivalent dynamic load N
(Pr : radial bearings, Pa : thrust bearings)

The basic rated life can also be expressed in terms of hours of operation (revolution), and is calculated as shown in formula (5.2).

where,

$$L_{10h} = 500 f_h^{\ p} \cdots\cdots (5.2)$$

$$f_h = f_n \frac{C}{P} \cdots\cdots (5.3)$$

$$f_n = \left(\frac{33.3}{n}\right)^{1/p} \cdots\cdots (5.4)$$

L : Basic rated life h

fn : Life factor

fn : Speed

n : Rotational speed, r/min

Formula (5.2) can also be expressed as shown in formula (5.5).

$$L_{10h} = \frac{10^6}{60n}\left(\frac{C}{P}\right)^p \cdots\cdots (5.5)$$

The relation between Rotational speed n and speed factor fn as well as the relation between the basic rated life L10h and the life factor fh is shown in Fig. 5.1.

When several bearings are incorporated in machines or equipment as complete units, all the bearings in the unit are

Table 5.1 Machine application and requisite life

Service classification	Life factor f_h and machine application				
	~2.0	2.0~3.0	3.0~4.0	4.0~5.0	5.0~
Machines used for short periods or used only occasionally	Electric hand tools Household appliances	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 Drivers 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

considered as a whole when computing bearing life (see formula 5.6). 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.

$$L = \frac{1}{\left(\frac{1}{L_1^{\,e}} + \frac{1}{L_2^{\,e}} + \cdots\cdots + \frac{1}{L_n^{\,e}}\right)^{1/e}} \cdots\cdots\cdots\cdots (5.6)$$

where,

$e = 10/9 \cdots\cdots\cdots\cdots\cdots\cdots$ For ball bearings

$e = 9/8 \cdots\cdots\cdots\cdots\cdots\cdots$ For roller bearings

L : Total basic rated life of entire unit h

$L_1, L_2 \cdots L_n$: Basic rated life of individual bearing 1, 2 $\cdots$ n h

When the load conditions vary at regular intervals, the life can be given by formula (5.7).

$$L_m = \left(\sum \phi_j \big/ L_j\right)^{-1} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5.7)$$

where,

Φ_j : Frequency of individual load conditions

L_j : Life under individual conditions

5.3 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 5.1. 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.

5.4 Adjusted life rating factor

The basic life rating (90% reliability factor) can be calculated through the formulas mentioned earlier in Section 5.2. 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 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.

$$L_{na} = a_1 \quad a_2 \quad a_3 \left(\frac{C}{P}\right)^p \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5.8)$$

where,

L_{na} = Adjusted life rating in millions of revolutions (10^6) (adjusted for reliability, material and operating conditions)

a_1 = Reliability adjustment factor

a_2 = Material adjustment factor

a_3 = Operating condition adjustment factor

5.4.1. 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 5.2.

Table 5.2 Reliability adjustment factor values a_1

Reliability %	L_n	Reliabiltiy factor a1
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

5.4.2. Life adjustment factor for material a_2

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

Accordingly, a_2=1 is used for the life adjustment factor in formula (5.8). For bearings constructed of specially improved materials or with special manufacturing methods, the life adjustment factor a_2 in formula (5.8) 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, considerable dimensional 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 stabilized bearings, designated with a "TS", prefix have a reduced hardness with a consequent decrease in bearing life. The adjusted life factor values used in formula (5.8) for such heat-stabilized bearings can be found in Table 5.3.

Table 5.3 Dimension stabilized bearings

Code	Max. operating temperature °C	Adjustment factor *a*
TS2	160	0.87
TS3	200	0.68
TS4	250	0.30

5.4.3. 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 operation factors which have an effect on bearing life.

Generally speaking, when lubricating conditions are satisfactory, the a_3 factor has a value on 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 the lubricating oil viscosity being too low for the operating temperature (below 13 mm^2/s for ball bearings; below 20 mm^2/s for roller bearings); or by exceptionally low rotational speed (n r/min x d_p mm less than 10,000). For bearings used under special operating conditions, please consult NTN.

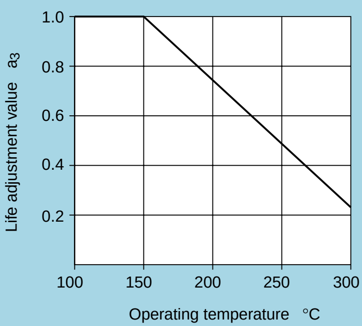

Fig. 5.2 Life adjustment value for operating temperature

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. 5.2.

5.5 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, occuring 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 and to pure axial loads for contact stress occurring at the rollling element and raceway contact points are given below.

For ball bearings (except self-aligning ball bearings	4200 MP_a
For self-aligning ball bearings	4600MP_a
For roller bearings	4000MP_a

5.6 Allowable static equivalent load

Generally the static equivalent load which can be permitted (See Section 6.4.2. page A-50) is limited by the basic static rated load as stated in Section 5.5. 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 (5.9) and Table 5.4 the safety factor S_o can be determined considering the maximum static equivalent load.

$$S_o = \frac{C_o}{P_{o\,max}} \quad \cdots\cdots (5.9)$$

where,

S_o : Safety factor

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

$P_{o\,max}$: Maximum static equivalent load N (radial: $P_{or\,max}$, thrust $P_{oa\,max}$)

Table 5.4 Minimum safety factor values S_o

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_o value = 4.

2. For shell needle roller bearings, min. S_o 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 $P_{o\,max}$ value.