6. Load rating and life

6.1 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, 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.

6.2 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 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 NIKO standard bearing materials, using standard manufacturing techniques. Please consult NIKO Engineering 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 (6.1).

$$L_{10} = \left(\frac{C}{P}\right)^{P} \text{ .... Formula (6.1)}$$

where,

$P = 10/3$ .... For needle roller bearings

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

C : Basic dynamic rating load, N

(C_r: radial bearings, C_a: thrust bearings)

P : Equivalent dynamic load, N

(P_r: radial bearings, P_a: thrust bearings)

The basic rating life can also be expressed in terms of hours of operation (revolution), and is calculated as shown in formula (6.2).

$L_{10h} = 500\ f_h^{\,p}$ .... Formula (6.2)

$f_h\ =\ f_n \frac{C}{P}$ .... Formula (6.3)

$f_n = (\frac{33.3}{n})^{1/p}$ .... Formula (6.4)

where,

L_{10} : Basic rating life, h

f_h : Life factor

f_n : Speed factor

n : Rotational speed, r/min

Formula (6.2) can also be expressed as shown in formula (6.5).

$L_{10h} = \frac{10^6}{60n}\ (\frac{C}{P})^P$ .... Formula (6.5)

Roller bearings

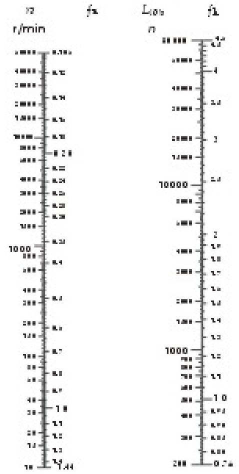

Fig. 7.1 Bearing life rating scale

The relationship between Rotational speed n and speed factor fn as well as the relation between the basic rating life $L10_h$ and the life factor fn is shown in Fig. 6.1. When several bearings are incorporated in machines or equipment as complete units, all the bearings in the unit are considered as a whole whencomputing bearing life (see formula 6.6). 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.

$L = \frac{1}{(\frac{1}{L_1^e} + \frac{1}{L_2^e} + ... \frac{1}{L_n^e})^{1/e}}$ .... Formula (6.6)

where,

e = 9/8.......................For roller bearings

L = Total basic rating life or entire unit, h

$L_1, L_2 ... L_n$: Basic rating life or individual bearings, 1, 2,...n, h

6.3 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 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 6.1. 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.

6.4 Adjusted life rating factor

The basic bearing life rating (90% reliability factor) can be calculated through the formula mentioned earlier in Section 6.2. 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.

$L_{na} = a_1 \cdot a_2 \cdot a_3\ (C/P)^P$.......... Formula (6.7)

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

6.4.1 Life adjustment factor for reliability a_1

The values for the reliability adjustment factor as (for a reliability factor higher than 90%) can be found in Table 6.1.

Table 6.1 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

6.4.2 Life adjustment factor for material a_2

The life of a bearing is affected by the material type and quality as well as the manufacturing process. In this regard, the life is adjusted by the use of an a_2 factor.

The basic dynamic load ratings listed in the catalog are based on NIKO's standard material and process, therefore, the adjustment factor $a_2=1$. When special materials or processes are used the adjustment factor can be larger than 1.

NIKO bearings can generally be used up to 120°C. If bearings are operated at a higher temperature, the bearing must be specially heat treated (stabilized) so that inadmissible dimensional change does not occur due to changes in the micro-structure. This special heat treatment might cause the reduction of bearing life because of a hardness change.

6.4.3 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 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 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 (nr/min x d_p mm less than 10,000). For bearings used under special operating conditions, please consult NIKO Engineering.

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. 6.2.

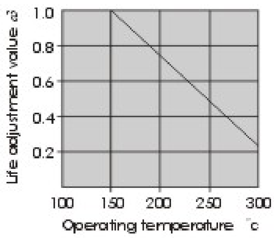

Fig. 6.2 Life adjustment value for operating temperature

6.5 Life of bearing with oscillating motion

The life of a radial bearing with oscillating motion can be calculated according to formula (6.8).

$L_{osc} = \Omega\, LRot$ .... Formula (6.8)

where,

L_{osc} : life for oscillating bearing

LR_{ot} : rating life at assumed number of rotations same as oscillation cycles

Ω : oscillation factor (Fig.6.3 indicates the relationship between half oscillation angle β and Ω).

Fig. 6.3 is valid only when the amplitude exceeds a certain degree (critical angle $2\beta c$). The critical angle is determined by the internal design of the bearing, in particular by the number of rolling elements in one row. Critical angle values are given in Table 6.3. When the magnitude of the oscillation is less than the critical angle, the life may be shorter than that calculated to be the value in Fig.6.3 It is safer to calculate life with the factor Ω corresponding to the critical angle. For the critical angle of an individual bearing, please consult NIKO Engineering. Where the amplitude of the oscillation 2β is small, it is difficult for a complete lubricant film to form on the contact surfaces of the rings and rolling elements, and fretting corrosion may occur. Therefore it is necessary to exercise extreme care in the selection of bearing type, lubrication and lubricant.

Table 6.3 Critical angle

Number of rolling elements	Half critical angle βc
10	10°
25	4°
40	2.6°

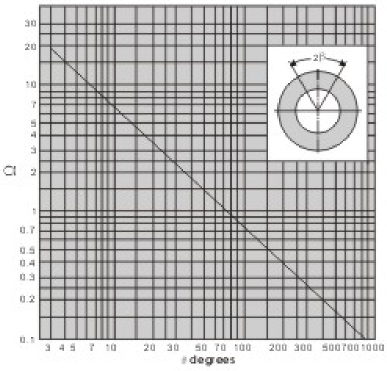

Fig. 6.3 Relationship between half angle β and factor Ω

6.6 Life of bearing with linear motion

With a linear motion bearing such as a linear ball bearing or linear flat roller bearing, the relation among the axial travel distance, bearing load, and load rating is expressed by formulas (6.9).

When the rolling elements are rollers:

$$L = 100 \times \left(\frac{C_r}{P_r}\right)^{\frac{10}{3}} \text{..................} (6.9)$$

where,

L :	Load rating	km
C_r :	Basic dynamic load rating	[kgf]
P_r :	Bearing load	[kgf]

Fig. 6.4 summarizes the relation between C_r/P_r and L.

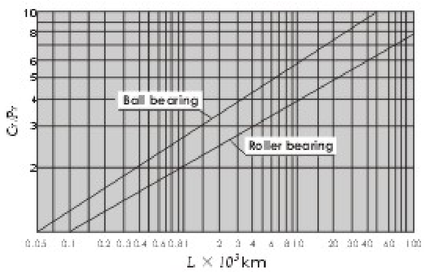

Fig. 6.4 Life of bearing with axial motion

If the cycle and travel distance within a particular travel motion remain constant, the rating life of the bearing can be determined by formulas (6.10) .

$$L_h = \frac{50X10^8}{10 \cdot S}\left(\frac{C_r}{P_r}\right)^{\frac{10}{3}} \text{ .... Formula (6.10)}$$

Where,

L_h : Travel life, h

S : Travel distance per minute, m/min.

$S = 2 \cdot L \cdot N$

L : Stroke length, m

n : Stroke cycle, N{kgf}

6.7 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.

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

For roller bearings 4,000 Mpa

6.8 Allowable static equivalent load

Generally the static equivalent load which can be permitted is limited by the basic static rated load as stated in Section 6.7. 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 (6.11) and Table 6.4 the safety factor S_o can be determined considering the maximum static equivalent load.

$S_o = C_o / P_o$ ...... Formula (6.11)

where,

S_o : Safety factor

C_o : Basic static rated load, N

(radial bearings: C_{or}, thrust bearings: C_{oa})

P_{omax} : Maximum static equivalent load, N

(radial: $P_{or\ max}$, thrust: $C_{oa\ max}$)

Table 6.4 Minimum safety factor values S_o

Operating conditions	Roller bearings
High rotational accuracy demand	3.0
Normal rotating accuracy demand (Universal application)	1.5
Slight rotational accuracy deterioration permitted (Low speed, heavy loading, etc.)	1.0

Note 1 : For drawn-cup needle roller bearings, min. S_o value=3.
2 : 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.

7. Bearing handling

Bearings are precision parts and, in order to preserve their accuracy and reliability, care must be exercised in their handling. In particular, bearing cleanliness must be maintained, sharp impacts avoided, and rust prevented.

7.1 Bearing storage

Most rolling bearings are coated with a rust preventative before being packed and shipped, and they should be stored at room temperature with a relative humidity of less than 60%.

7.2 Installation

When bearings are being installed on shafts or in housings, the bearing rings should never be struck directly with a hammer or a drift, as shown in Fig. 8.1, because damage to the bearing may result. Any force applied to the bearing should always be evenly distributed over the entire bearing ring face.

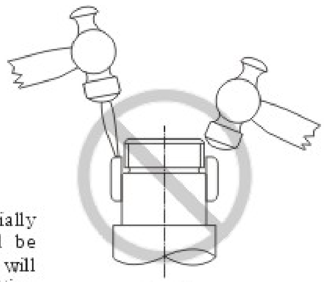

Fig. 8.1

7.2.1 Installation preparations

Bearings should be fitted in a clean, dry work area. Especially for small and miniature bearings, a "clean room" should be provided as any contamination particles in the bearing will greatly affect bearing efficiency. Before installation, all fitting tools, shafts, housings, and related parts should be cleaned and any burrs or cutting chips removed if necessary. Shaft and housing fitting surfaces should also be checked for roughness, dimensional and design accuracy, and to ensure that they are within allowable tolerance limits.

Bearings should not be unwrapped until just prior to installation. Normally, bearings to be usedwith grease lubricant can be installed as is, without removing the rust preventative. However, for bearings which will use oil lubricant, or in cases where mixing the grease and rust preventative would result in loss of lubrication efficiency, the rust preventative should be removed by washing with benzene or petroleum solvent and dried before installation. Bearings should also be washed and dried before installation if the package has been damaged or there are other chances that the bearings have been contaminated. Double shielded bearings and sealed bearings, one way clutches should never be washed.