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 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.

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 **TPI** standard bearing materials, using standard manufacturing techniques. Please consult **TPI** for basic load ratings of bearings constructed of special materials or using special manufacturing techniques.

The relationship between the basic rating life, the basic dynamic load rating and the bearing load is given in formula (6.1).

$$L_{10} = \left(\frac{C_r}{P}\right)^p \quad \text{……(6-1)}$$

where,

p=3……………for ball bearings

p=10/3………..for roller bearings

L_{10}: Basic rated life 10^6 revelutions

C_r: Basic dynamic rated load, N or kgf

P: Equivalent dynamic load, N or kgf

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

$$L_{10h} = 500 f_h^{\ P} \quad \text{……(6-2)}$$

$$f_h = f_n \frac{C_r}{P} \quad \text{……(6-3)}$$

$$f_n = \left(\frac{33.3}{n}\right)^{1/p} \quad \text{……(6-4)}$$

where,

L_{10h}: Basic rated life, hour

f_h : Life factor

f_n : Speed factor

n: Rotational speed, rpm

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

$$L_{10h} = \frac{10^6}{60n}\left(\frac{C_r}{P}\right)^p \quad \text{……(6-5)}$$

The relation ship 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_h is shown in **Fig. 6.1.**

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 Equivalent load

(1) 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,

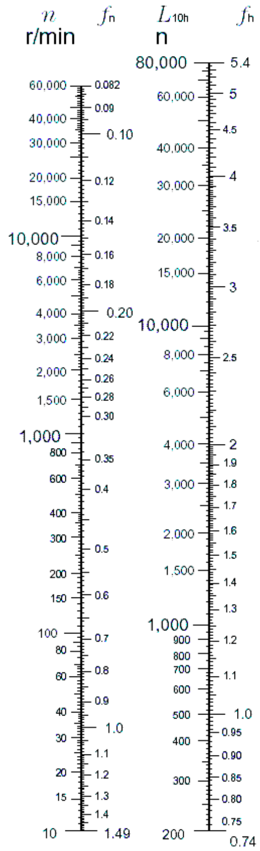

圖 6-1 Bearing life rating scale

Table 6-1 Machine application and requisite life L_{10h}

Service classfication	Life factor and machine application L_{10h} hour				×10³
	～ 4	4～12	12～30	30～60	60～
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 contant 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

this load is expressed as pure radial load and is called the dynamic equivalent radial load.

The dynamic equivalent radial load is expressed by formula (6.6).

$P_r = XF_r + YF_a$ ....I............(6-6)

where,

P_r : Dynamic equivalent radial load, N or kgf

F_r : Actual radial load, N or kgf

F_a : Actual axial load, N or kgf

X : Radial load factor

Y : Axial load factor

The values for X and Y are listed in the bearing tables. Generally speaking, it is considered that bearings are under the light load condition if the magnitude of equivalent radial load ≦ 0.06 Cr. Normal and heavy load conitons are defined as follows:

Normal loads: 0.06 Cr <equivalent radial load ≦ 0.12 Cr

Heavy loads: 0.12 Cr <equivalent radial load

(2) 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.

For radial bearings the static equivalent radial load can be found by using formula (6.7) or (6.8). The greater of the two resultant values is always taken for Por.

$P_{or} = X_oF_r + Y_oF_a$ ....(6-7)

$P_{or} = F_r$ ....(6-8)

where,

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

F_r : Actual radial load, N or kgf

F_a : Actual axial load , N or kgf

X_o : Static radial load factor

Y_o : Static axial load factor

The values for Xo and Yo are given in the respective bearing tables.

6.5 Bearing load distribution

For shafting, the static tension is considered to be supported by the bearings, and any loads acting on the shafts are distributed to the bearings.

For example, in the gear shaft assembly depicted in **Fig. 6.2**, the applied bearing loads can be found by using formulas (6.9) and (6.10).

$$F_{rA} = \frac{a+b}{b}F_I + \frac{d}{c+d}F_{II} \quad \text{(6-9)}$$

$$F_{rB} = -\frac{a}{b}F_I + \frac{c}{c+d}F_{II} \quad \text{(6-10)}$$

where,

F_{rA} : Radial load on bearing A, N or kgf

F_{rB} : Radial load on bearing B, N or kgf

F_I , F_{II} : Radial load on shaft, N or kgf

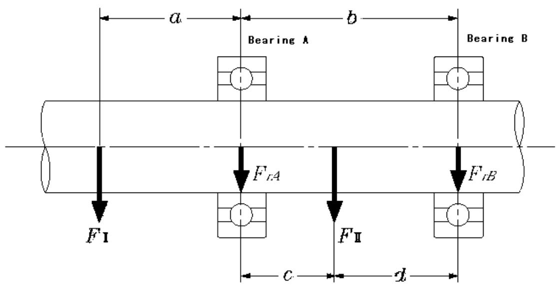

Fig 6.2 Gear shaft

【Example 1】 What is the rating life in hours of operation (L10h) for deep groove ball bearing **6207** operating at 650 r/min, with a radial load Fr of 2.8 kN{286kgf} ?

【Solution 1】 From formula (6.6) the dynamic equivalent radial load:

$P_r = F_r = 2.8$ kN or 286kgf

The basic dynamic rated load for bearing 6207 (from bearing table) is 25.7kN or 2620kgf, and the speed factor (fn) for ball bearings at 650 r/min (n) from **Fig. 6.1** is 0.37. The life factor, fh, from formula (6.3) is:

$$f_h = f_n \frac{C_r}{P_r} = 0.37 \times \frac{25.7}{2.8} = 3.40$$

Therefore, with f_h = 3.40 from **Fig. 6.1** the rated life, L_{10h}, is approximately 20,000 hours.

【**Example 2**】What is the life rating L_{10h} for the same bearing and conditions as in **Example 1**, but with an additional axial load F_a of 1.6 kN or 1560 kgf?

【**Solution 2**】To find the dynamic equivalent radial load value for P_r, the radial load factor X and axial load factor Y are used. The basic static load rating, C_{or}, for bearing 6207 is 15.3kN or 1560kgf.

F_a / C_{or}=1.6 / 15.3 = 0.10

e = 0.29

For the operating radial load and axial load:

F_a / F_r=1.6 / 2.8 = 0.57 ＞ e = 0.29

From the bearing tables X = 0.56 and Y = 1.48, and from formula (6.6) the equivalent radial load, P_r, is:

$$P_r = XF_r + YF_a = 0.56 \times 2.8 + 1.48 \times 1.6$$

$$= 3.94 \text{ kN 或 } 420\text{kgf}$$

From Fig. 4.1 and formula (4.3) the life factor, f_h, is:

$$f_h = f_n \frac{C_r}{P_r} = 0.37 \times \frac{29.1}{4.46} = 2.41$$

Therefore, with life factor f_h = 2.41, from **Fig. 4.1** the rated life, L_{10h}, is approximately 7,000 hours.