NRB INDUSTRIAL

White Paper

Concept of Bearing Life and Bearing Load Carrying Capacity

- **Concept of fatigue theory**

The concept of the fatigue theory depends on the calculation s in the ISO 281 with the accordance of the Lundeberg and Palmgren's theory for the calculation of the bearing rating life.

The actual bearing operational life is however more than the calculated life. Thus the life adjustment factor comes in to the role for the calculation of the bearing life.

The life adjustment factor is influenced by the following factors,

  - The bearing load
  - The fatigue limit of the material
  - The extent to which the surfaces are separated by the lubricated
  - The cleanliness in the lubrication gap
  - Additives in the lubricants
  - The internal load distribution
  - Frictional condition in the bearing

- **Dynamic load carrying capacity of bearing and its dependency on bearing life**

The basic dynamic load rating of rolling bearings is defined as the constant load applied on bearings with stationary outer rings that the inner rings can endure for a rating life (90% life) of one million revolutions. Radial load on the center of the bearing defines the basic load rating of radial bearings and an axial load of constant direction and magnitude defines the basic load rating of the thrust bearings.

The dynamic load carrying capacity is described in terms of the basic dynamic load rating and the basic rating of bearing life.

The fatigue life of the bearing depends on the following factors,

- Load acting on bearing
- Operating speed of bearing
- Statistical probability of the first appearance of the bearing failure

The basic dynamic load rating is defined by C. Constant radial load for radial bearing is Cr and for axial load is Co.

- **Bearing life calculation**

Bearing application decides the various function included in the rolling bearings. These functions should work defect free for the maximum number of period. Bearings will eventually fail to perform satisfactorily due to an increase in noise and vibration, loss of running accuracy, deterioration of lubricant, or fatigue flaking of the rolling surfaces even if bearings are properly mounted and correctly operated.

Bearing life is defined as, satisfactory performance of bearing function even after the continuously operated. Bearing life depends on the factor of evaluation of noise life, grease life abrasion life or rolling fatigue life.

Factors which cause bearing failure other than the above mentioned factors are seizure due to heat, fracture, scoring of the rings, damage of seals or cage, or any other damage occurs.

As a result of errors in bearing selection, improper design or manufacture of the bearing surroundings, incorrect mounting, or insufficient maintenance; if such condition occurred then failure should not be interpreted as normal bearing failure.

1. Basic bearing life

The following relation exists between bearing load and basic rating life:

For ball bearing $L=\left(\frac{C}{P}\right)^{3}$

For roller bearing $L=\left(\frac{C}{P}\right)^{\frac{10}{3}}$

Where,

L: Basic rating life

P: Bearing load (equivalent load) (N) /{kgf}

C: Basic load rating (N) /{kgf}

For radial bearings, C is written Cr

For thrust bearings, C is written Ca

When the operating speed of the bearing is constant the life of the bearings is determined from the operating hours.

2. Equivalent dynamic load

In some cases, the loads applied on bearings are purely radial or axial loads; however, in most cases, the loads are a combination of both. In addition, such loads usually fluctuate in both magnitude and direction. In such cases, the loads actually applied on bearings cannot be used for bearing life calculations; therefore, a hypothetical load that has a constant magnitude and passes through the center of the bearing, and will give the same bearing life that the bearing would attain under actual conditions of load and rotation should be estimated. Such a hypothetical load is called the equivalent load.

The equivalent load on radial bearings may be calculated using the following equation:

$P = XFr + YFa$

Where,

P: Equivalent Load (N) / {kgf}

Fr: Radial load (N) / {kgf}

Fa: Axial load (N) / {kgf}

X: Radial load factor

Y: Axial load factor

The equivalent radial load for radial roller bearings with

$\alpha = 0°$ is

$P = Fr$

In general, thrust ball bearings cannot take radial loads, but spherical thrust roller bearings can take some radial loads. In this case, the equivalent load may be calculated using the following equation:

$P = Fa + 1.2Fr$

Where,
Fr Fa ≤0.55

3. Load factor

When a radial or axial load has been mathematically calculated, the actual load on the bearing may be greater than the calculated load because of vibration and shock present during operation of the machine. The actual load may be calculated using the following equation:

$F r = f w .F r c$

$Fa = fw.Fac$

Where,

Fr, Fa : Loads applied on bearing (N or kgf)

Frc, Fac: Theoretically calculated load (N or kgf)

fw: Load factor

The values given in Table are usually used for the load factor fw.

Operating conditions	Typical Application	fw
Smooth operation free from shocks	Electric motors, Machine tools, Air conditioners	1 to 1.2
Normal Operation	Air blowers, compressors, Elevators, Cranes, Paper making machine	1.2 to 1.5
Operation accompanied by shock and vibration	Construction equipment, crshers, vibrating screen, rolling mills	1.5 to 3

Table 1.1 Values of Load Factor *fw*

- **Bearing life calculation at various operating conditions**

1. **Variable load and speed**

If the load and speed vary over the period of time T, the speed n and equivalent bearing load P are calculated as follows

$$n=\frac{1}{T}\int_0^T n(t)\ .dt$$

$$P=\sqrt[P]{\frac{\int_a^T \frac{1}{a(T)}.n(t)F^P\ (t).dt}{\int_0^T n(t).dt}}$$

2. **Variation in steps**

If the load and speed vary in steps over the period of time T, n and P are calculated as follows

$$n=\frac{q1.n1+q2.n2+\cdots..+qz.nz}{qi.ni+\cdots+qz.nz}$$

$$P=\sqrt[P]{\frac{\frac{1}{ai}.qi.ni.FiP+\cdots+\frac{1}{az}.qz.nz.F\ z\ p}{qi.ni+\cdots+qz.nz}}$$

3. **Variable load at constant speed**

If the function F describes he variation in the load over the time period T and the speed is constant, P is calculated as follows

$$P=\sqrt[P]{\frac{1}{T}\int_0^T \frac{1}{a(t0}.F^p(\ t).dt}$$

4. **Load varying in steps and constant speed**

If the load varies in steps over a time period T and the speed is constant, P is calculated as follows

$$P=\sqrt[P]{\frac{\frac{1}{ai}.qi.Fpi+\cdots+\frac{1}{az}.qz.Fzp}{100}}$$

5. **Constant load at variable speed**

If the speed varies but the load remains constant, the following applies

$$n=\frac{1}{T}\int_0^T \frac{1}{a(t)}.n(t).dt$$

5. **Constant load with speed varying in steps**

If the speed varies in steps, the following applies

$$n = \frac{\frac{1}{ai}.qi.ni + \cdots + \frac{1}{az}.qz.nz}{100}$$

6. **Under oscillating motion**

$$n = n_{osc} \frac{\varphi}{180°}$$

n	Mean speed (min^{-1})
T	Time period under consideration (min)
P	Equivalent bearing load (N)
p	Life exponent for roller bearings; p=10/3
	For ball bearings; p=3
a_i, a(t)	Life adjustment factor a_{iso}
n_i , n(t)	Bearing speed for current operating conditions (min^{-1})
q_i	Duration of operating condition as a proportion of the total operating period (%)
Fi, F(t)	Bearing load during the current operating condition (N)
n_{osc}	Frequency of oscillation (min^{-1})
φ	Angle of oscillation

- **Concept of operating life**

The operating life of the bearing is defined as the actual life achieved by the bearing during operation. The actual life of the bearing may differ from the calculated life of the bearing theoretically.

The difference may be caused due to following factors;

- deviations in operating conditions
- misalignment between the shaft and the housing
- insufficient or excessive operating clearance
- contamination
- insufficient lubrication
- excessive operating condition
- high vibration
- false brinelling
- very high shock loads
- prior damage during installation

- **Static load carrying capacity of Bearing**

When subjected to an excessive load or a strong shock load, rolling bearings may incur a local permanent deformation of the rolling elements and permanent deformation of the rolling elements and raceway surface if the elastic limit is exceeded. The non-elastic deformation increases in area and depth as the load increases, and when the load exceeds a certain limit, the smooth running of the bearing is impeded. The basic static load rating is defined as that static load which produces the following calculated contact stress at the center of the contact area between the rolling element subjected to the maximum stress and the raceway surface.
In this most heavily stressed contact area, the sum of the permanent deformation of the rolling element and that of the raceway is nearly 0.0001 times the rolling element's diameter.

(a) Static equivalent load on radial bearings

The greater of the two values calculated from the following equations should be adopted as the static equivalent load on radial bearings.

Po = XoFr+ YoFa

Po = Fr

Where,
Po: Static equivalent load (N or kgf)

Fr: Radial load (N or kgf)

Fa: Axial load (N or kgf)

Xo: Static radial load factor

Yo: Static axial load factor

(b) Static equivalent load on thrust bearings

Po = XoFr + Fa $\qquad$ $\alpha \neq 90°$

Where
Po: Static equivalent load (N or kgf),
α: Contact angle

- **Static load safety factor**

The permissible static equivalent load on bearings varies depending on the basic static load rating and also their application and operating conditions. The permissible static load factor f_s is a safety factor that is applied to the basic static load rating, and it is defined by the ratio in Equation

$$L = \frac{Co}{Po}$$

Where

C_o: Basic static load rating (N), {kgf}

P_o: Static equivalent load (N), {kgf}