10. Friction and temperature rise

10.1 Friction

One of the main functions required of a bearing is that it must have low friction. Under normal operating conditions rolling bearings have a much **smaller friction coefficient** than sliding bearings, especially when comparing **starting friction**.

The friction coefficient for rolling bearings is expressed by formula (10.1).

$$\mu = \frac{2M}{Pd} \quad \cdots\cdots\cdots\cdots (10.1)$$

Where:

μ : Friction coefficient

M : Friction moment, N · mm

P : Load, N

d : Bearing bore, mm

The dynamic friction coefficient for rolling bearings varies with the type of bearing, load, lubrication, speed, and other factors. For normal operating conditions, the approximate friction coefficients for various bearing types are listed in **Table 10.1**.

Table 10.1 Friction coefficient for bearings (reference)

Bearing type	Friction coefficient $\mu \times 10^{-3}$
Deep groove ball bearings	1.0～1.5
Angular contact ball bearings	1.2～1.8
Self-aligning ball bearings	0.8～1.2
Cylindrical roller bearings	1.0～1.5
Needle roller bearings	2.0～3.0
Tapered roller bearings	1.7～2.5
Self-aligning roller bearings	2.0～2.5
Thrust ball bearings	1.0～1.5
Thrust roller bearings	2.0～3.0

10.2 Temperature rise

Almost all friction loss in a bearing is transformed into heat within the bearing itself and causes the temperature of the bearing to rise. The amount of thermal generation caused by the friction moment can be calculated using formula (10.2).

$$Q = 0.105 \times 10^{-6} M \times n \quad \cdots\cdots\cdots\cdots (10.2)$$

Where:

Q : Thermal value, kW

M : Friction moment, N · mm

n : Rotational speed, min^{-1}

Bearing operating temperature is determined by the equilibrium or balance between the amount of heat generated by the bearing and the amount of heat conducted away from the bearing. In most cases the temperature rises sharply during initial operation, then increases slowly until it reaches a stable condition and then remains constant. The time it takes to reach this steady state depends on the amount of heat produced, heat capacity/diffusion of the shaft and housing, amount of lubricant and method of lubrication. If the temperature continues to rise and does not become constant, it must be assumed that there is some improper function.

When any **abnormal temperature rise** is observed, examine the equipment. Remove the bearing for inspection if necessary. Some possible causes of abnormal temperature rises would be as follows.

- **Bearing misalignment** (due to moment load or incorrect installation)
- **Insufficient internal clearance**
- **Excessive preload**
- **Amount of lubricant too small** or **large**
- **Unsuitable lubricant**
- **Heat generated from sealing mechanism**
- **Excessive load**
- **Rapid acceleration and deceleration**
- **Heat conducted from external sources**

Friction and Temperature Rise

10.3 Starting torque calculation

The starting torque refers to the torque generated at the time of initial bearing rotation, and the torque generation factor differs between ball bearings and roller bearings. For ball bearings, this calculation is shown below with an angular contact ball bearing. For roller bearings, a tapered roller bearing is used as an example.

Even if the actual starting torque value is the same number, the torque calculation value is a reference value because there is measurement variation for each bearing.

1) Preload and staring torque of angular contact ball bearings

Bearings having a contact angle such as angular contact ball bearings and tapered roller bearings cannot be used by themselves. Two bearings must face each other or be used in combination. In this case, the bearings are often used by applying a preload, and the larger the preload is, the larger the friction torque of the bearing becomes. The starting torque of the angular contact ball bearing when a preload is applied generates the majority of the spin slip and the rolling friction torque.

The relationship between the preload and the starting torque of angular contact ball bearings is not a simple proportional relationship, and the calculation is complicated; therefore, please contact **NTN** Engineering.

2) Preload and starting torque of tapered roller bearings

The starting torque of tapered roller bearings are influenced by the following factors.

(1) Sliding friction between roller large end surface and inner ring large rib surface
(2) Rolling friction of rolling surface
(3) Sliding friction of roller and cage
(4) Stirring resistance of lubricant

However, (2) to (4) are extremely small compared with (1); therefore, the starting torque of tapered roller bearings is calculated by (1).

Starting torque M of tapered roller bearings is represented by formula (10.3).

$$M = \mu \cdot e \cdot \cos(\beta/2) \cdot F_a \quad \text{N·mm} \cdots (10.3)$$

M : Starting torque, N · mm
μ : Friction coefficient
e : Contact position between roller and inner ring rib, mm (**see Figure 10.1**)
β : Roller angle, ° (**see Figure 10.1**)
F_a : Preload, N

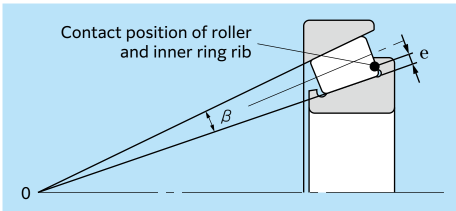

Figure 10.1 β and e

Figure 10.2 shows calculation examples. For details, please contact **NTN** Engineering.

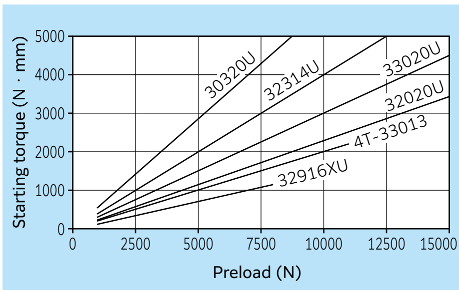

Figure 10.2 Preload and starting torque of tapered roller bearings