3. Friction in bearings

Friction in rolling bearings is considerably lower than in sliding bearings. Power lost through friction in bearing is generally negligible, in various bearing joints and mechanisms. If a certain frictional moment is required in some applications, the coefficient of friction for the bearing should be known.

It depends on many factors such as: bearing design, speed, direction and magnitude of load, finishing quality of active surfaces, operating temperature, lubricant, bearing material etc.

The frictional moment can be calculated accurately enough using the following equation:

$M = 0.5\mu P d$ - for radial bearings
$M = 0.5\mu P D_m$ - for thrust bearings

where:
M - frictional moment, N mm,
μ - coefficient of friction, table 3.1
P - bearing load, N,
d - bearing bore diameter, mm,
D_m - thrust bearing mean diameter $0.5(d + D)$, mm

The values of the friction coefficient μ for various bearing types are given in table 3.1.

The frictional moment can be more accurately determined with the equation:

$$M = M_0 + M_1,$$

where:
M_0 - frictional moment which is independent of the bearing load and depends on the hydrodynamic friction
M_1 - resistance moment depending on the bearing load and the size of the elastic contact surfaces

M_0 can be calculated from:

$$M_0 = f_0(\nu_1 n)^{2/3} D_m^3 10^{-7}, \text{ for } n > 2\,000,$$
$$M_0 = 16 f_0 D_m^3 10^{-6}, \quad \text{for } n \le 2\,000,$$

where:
M_0 - frictional moment which is independent of the bearing load, N mm
f_0 - factor which depends on the bearing type and lubricant, table 3.1,
n - rotational speed, r/min,
ν_1 - kinematic viscosity of lubricant at operating temperature, mm^2/s. In case of grease lubrication, calculation should be done considering the basic oil viscosity,
D_m - bearing mean diameter, mm.

M_1 can be calculated using the equation:

$$M_1 = f_1 P_1 D_m$$

where:
M_1 - load - dependent resistance moment, N mm,
f_1 - factor which depends on the bearing type and load, table 3.1,
P_1 - bearing combined load, determined using the equation in the table 3.1, N,
D_m - bearing mean diameter $= 0.5 (d + D)$, mm.

Frictional moment for cylindrical roller bearings which also have to support axial loads

In case of these bearings, the total frictional moment is obtained by adding the frictional moment which depends on the magnitude of the axial load F_a:

$$M = M_0 + M_1 + M_2$$

The frictional moment M_2 can be calculated from:

$$M_2 = f_2 F_a D_m, \text{ N mm}$$

where:
M_2 - axial frictional moment, N mm,
f_2 - factor depending on bearing design and lubrication, table 3.2,
F_a - axial load, N,
D_m - bearing mean diameter $= 0.5 (d + D)$, mm.

The values of the friction coefficient μ for various bearing types and factors f_0 and f_1

Table 3.1

Bearing type		Friction coefficient μ	Factor f_0 Lubrication: grease[1)]	oil spot	oil bath	oil bath with vertic. shaft, oil jet	Factors for calculating M_1: f_1	P_1 [5)] N
Deep groove ball bearings	single row	0,0010 - 0,0020	0,75-2[2)]	1	2	4	$(8\text{-}9)\times10^{-4}\,(P_{0r}/C_{0r})^{0,55}$ [2)]	$3F_a - 0{,}1F_r$
	double row		3	2	4	6		
Self-aligning ball bearings		0,0010 - 0,0020	1,5-2[2)]	0,7-1[2)]	1,5-2[2)]	3-4[2)]	$3\times10^{-4}\,(P_{0r}/C_{0r})^{0,4}$	$1{,}4\,Y_2F_a - 0{,}1F_r$
Angular contact ball bearings	single row	0,0012 - 0,0025	2	1,7	3,3	6,6	$10^{-3}\,(P_{0r}/C_{0r})^{0,33}$	$F_a - 0{,}1F_r$
	double row		4	3,4	6,5	13	$10^{-3}\,(P_{0r}/C_{0r})^{0,33}$	$1{,}4F_a - 0{,}1F_r$
Four-point contact bearings		0,0025 - 0,0045	6	2	6	9	$10^{-3}\,(P_{0r}/C_{0r})^{0,33}$	$1{,}5F_a + 3{,}6F_r$
Cylindrical roller bearings	with cage	0,0010 - 0,0025	0,6-1	1,5-2,8	2,2-4	2,2-4[2)3)]	$(2\text{-}4)\times10^{-4}$	F_r [6)]
	without cage	0,0020 - 0,0040	5-10[4)]	-	5-10	-	$5{,}5\times10^{-4}$	F_r [6)]
Needle roller bearings	with cage	0,0020 - 0,0035	12	6	12	24	10^{-3}	F_r
	without cage	0,0035 - 0,0055	24	12	24	-	10^{-3}	F_r
Spherical roller bearings		0,0020 - 0,0025	3,5-7	1,75-3,5	3,5-7	7 - 14	$(1{,}5\text{-}8)\times10^{-4}$	$1{,}35\,Y_2F_a$, $F_r/F_a < Y_2$; $F_r[1+0{,}3\,(Y_2F_a/F_r)^3]$, $F_r/F_a \geq Y_2$
Tapered roller bearings	single row	0,0017 - 0,0020	6	3	6	8-10[2)3)]	4×10^{-4}	$2\,Y F_a$
	paired	0,0030 - 0,0040	12	6	12	16-20[2)3)]	4×10^{-4}	$1{,}2\,Y_2F_a$
Thrust bearings	ball	0,0010 - 0,0025	5,5	0,8	1,5	3	$8\times10^{-4}\,(F_a/C_{0r})^{0,33}$	F_a
	roller	0,0050 - 0,0070	9	-	3,5	7	$1{,}5\times10^{-3}$	F_a
Needle roller thrust bearings		0,0050 - 0,0075	14	-	5	11	$1{,}5\times10^{-3}$	F_a
Spherical roller thrust bearings		0,0020 - 0,0030	-	-	2,5-5	5-10	$(2{,}3\text{-}5)\times10^{-4}$	F_a, $F_{rmax} < 0{,}55F_a$

1) The values apply to normal operating conditions. In case of bearing relubrication, they apply after 2...4 operating hours.

2) The low values apply to small series bearings, the high values to large series bearings.

3) The values are valid for oil jet lubrication. For oil bath lubrication and a vertical shaft, the value should be doubled.

4) The values for low speeds up to 20% of the speed values given in the catalogue. At higher speeds they should be doubled.

5) If $P_1 < F_r$, then $P_1 = F_r$

6) For bearings which are also axially loaded, specifications for f_2, on page 30, should be considered.

Symbols

P_0 = Equivalent static load,

C_0 = Basic static load

F_r = Radial component of dynamic bearing load,

F_a = Axial component of dynamic bearing load

Y, Y_2 = axial load factors

Values for factor f_2

Table 3.2

Bearing type	Lubrication: oil	grease
Bearings with cage		
- E design	0,002	0,003
- other bearings	0,006	0,009
Bearings without cage		
- single row	0,003	0,006
- double row	0,009	0,015

The values of factor f_2 in the table 3.2 are valid only if the value of ratio F_a/F_r doesn't exceed:

- 0,5 = for single row cylindrical roller, E design
- 0,4 = for bearings with cage and without cage, normal design
- 0,25 = for double row cylindrical roller bearings, without cage

Frictional moment for sealed bearings

In case of sealed bearings, the seal washers produce additional frictions which usually exceed those arising from the bearing.

The frictional moment M_3 for a bearing which is sealed on both sides can be calculated using the following equation:

$$M_3 = \frac{d + D}{f_3} + f_4$$

where:

M_3	- Frictional moment caused by seals, N mm,
d	- Bearing bore diameter, mm
D	- Bearing outside diameter, mm
f_3, f_4	- Factors, table 3.3

Values for factors f_3 and f_4

Table 3.3

Type	Factors	
	f3	f4
Deep groove ball bearings 2RSR, 2RS	20	10
Self-aligning ball bearings 2RS	20	15
Single row deep groove ball bearings with extended inner ring (UC, UE, US etc.)	20	20
Bearings for water pumps	20	25
Sealed cylindrical roller bearings without cage	10	50

Starting torque

The starting torque of a rolling bearing is defined as the bearing resistance moment which must be overcome so that the bearing should start rotating from the stationary condition.

Generally, the value of the starting torque is approximately twice the load dependent moment M_1.

For tapered roller bearings with a large contact angle (series 313, 322B and 323B), the starting torque can be four times higher and for spherical roller thrust bearings up to eight times higher.