8. Bearing type and allowable axial load

8.1 Change of contact angle of radial ball bearings and allowable axial load

8.1.1 Change of contact angle due to axial load

When an axial load acts on a radial ball bearing, the rolling element and raceway develop elastic deformation, resulting in an increase in the contact angle and width. When heat generation or seizure has occurred, the bearing should be disassembled and checked for running trace to discover whether there has been a change in the contact angle during operation. In this way, it is possible to see whether an abnormal axial load has been sustained.

The relation shown below can be established among the axial load F_a on a bearing, the load of rolling element Q, and the contact angle α when the load is applied. (See Equations (3), (4), and (5) in Section 6.4)

$$F_a = Z\,Q\,\sin\alpha$$
$$= K\,Z\,D_w^2\left\{\sqrt{(\sin\alpha_0+h)^2+\cos^2\alpha_0}-1\right\}^{3/2}\cdot\sin\alpha \quad\cdots\cdots (1)$$

$$\alpha = \sin^{-1}\frac{\sin\alpha_0+h}{\sqrt{(\sin\alpha_0+h)^2+\cos^2\alpha_0}} \quad\cdots\cdots (2)$$

$$h = \frac{\delta_a}{m_0} = \frac{\delta_a}{r_e+r_i-D_w}$$

Namely, δ_a is the change in Equation (2) to determine α corresponding to the contact angle known from observation of the raceway. Thus, δ_a and α are introduced into Equation (1) to estimate the axial load F_a acting on the bearing. As specifications of a bearing are necessary in this case for calculation, the contact angle α was approximated from the axial load. The basic static load rating C_{0r} is expressed by Equation (3) for the case of a single row radial ball bearing.

$$C_{0r} = f_0\,Z\,D_w^2\cos\alpha_0 \quad\cdots\cdots (3)$$

where, f_0: Factor determined from the shape of bearing components and applicable stress level

Equation (4) is determined from Equations (1) and (3):

$$\frac{f_0}{C_{0r}}F_a = A\,F_a$$
$$= K\left\{\sqrt{(\sin\alpha_0+h)^2+\cos^2\alpha_0}-1\right\}^{3/2}\cdot\frac{\sin\alpha}{\cos\alpha_0} \quad\cdots\cdots (4)$$

where, K: Constant determined from material and design of bearing

In other words, "h" is assumed and α is determined from Equation (2). Then "h" and α are introduced into Equation (4) to determine $A\,F_a$. This relation is used to show the value A for each bore number of an angular contact ball bearing in Table 1. The relationship between $A\,F_a$ and α is shown in Fig. 1.

Example 1

Change in the contact angle is calculated when the pure axial load F_a = 35.0 kN (50% of basic static load rating) is applied to an angular contact ball bearing 7215C.

A=0.212 is calculated from Table 1 and $A\,F_a$=0.212×35.0=7.42 and α≒26° are obtained from Fig. 1. An initial contact angle of 15° has changed to 26° under the axial load.

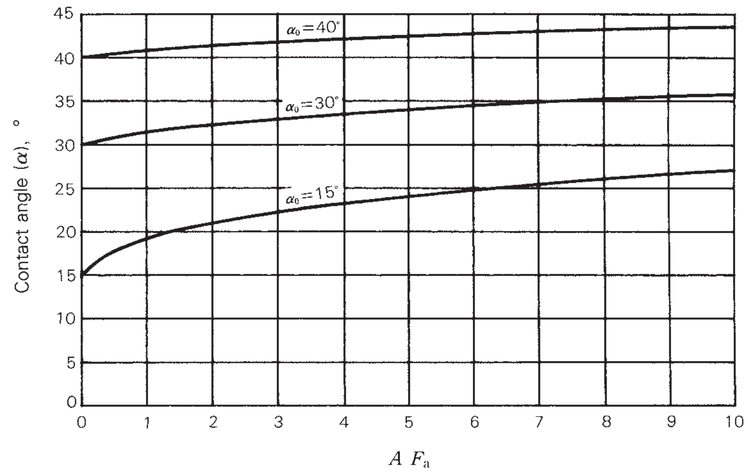


Fig. 1 Change of the contact angle of angular contact ball bearing under axial load

Table 1 Constant A value of angular contact ball bearing

Units: kN^{-1}

Bearing bore No.	Bearing series 70			Bearing series 72			Bearing series 73		
	15°	30°	40°	15°	30°	40°	15°	30°	40°
05	1.97	2.05	2.31	1.26	1.41	1.59	0.838	0.850	0.961
06	1.45	1.51	1.83	0.878	0.979	1.11	0.642	0.651	0.736
07	1.10	1.15	1.38	0.699	0.719	0.813	0.517	0.528	0.597
08	0.966	1.02	1.22	0.562	0.582	0.658	0.414	0.423	0.478
09	0.799	0.842	1.01	0.494	0.511	0.578	0.309	0.316	0.357
10	0.715	0.757	0.901	0.458	0.477	0.540	0.259	0.265	0.300
11	0.540	0.571	0.681	0.362	0.377	0.426	0.221	0.226	0.255
12	0.512	0.542	0.645	0.293	0.305	0.345	0.191	0.195	0.220
13	0.463	0.493	0.584	0.248	0.260	0.294	0.166	0.170	0.192
14	0.365	0.388	0.460	0.226	0.237	0.268	0.146	0.149	0.169
15	0.348	0.370	—	0.212	0.237	0.268	0.129	0.132	0.149
16	0.284	0.302	0.358	0.190	0.199	0.225	0.115	0.118	0.133
17	0.271	0.288	0.341	0.162	0.169	0.192	0.103	0.106	0.120
18	0.228	0.242	0.287	0.140	0.146	0.165	0.0934	0.0955	0.108
19	0.217	0.242	0.273	0.130	0.136	0.153	0.0847	0.0866	0.0979
20	0.207	0.231	0.261	0.115	0.119	0.134	0.0647	0.0722	0.0816

Values for a deep groove ball bearing are similarly shown in Table 2 and Fig. 2.

Example 2

Change in the contact angle is calculated when the pure axial load F_a=24.75 kN (50% of the basic static load rating) is applied to the deep groove ball bearing 6215. Note here that the radial internal clearance is calculated as the median (0.020 mm) of the normal clearance.

The initial contact angle 10° is obtained from Section 4.6 (Fig. 3, Page 99). A=0.303 is determined from Table 2 and $A\ F_a$=0.303× 24.75≒7.5 and α≒24° from Fig. 2.

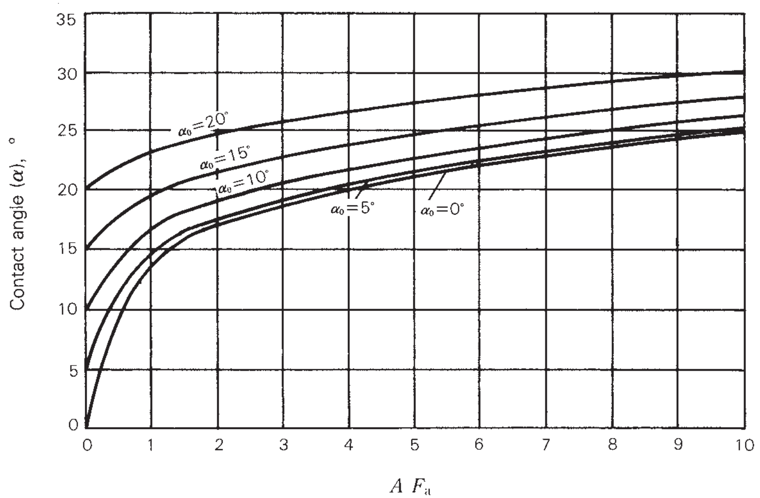


Fig. 2 Change in the contact angle of the deep groove ball bearing under axial load

Table 2 Contact A value of deep groove ball bearing

Units: kN^{-1}

Bearing bore No.	Bearing series 62				
	0°	5°	10°	15°	20°
05	1.76	1.77	1.79	1.83	1.88
06	1.22	1.23	1.24	1.27	1.30
07	0.900	0.903	0.914	0.932	0.958
08	0.784	0.787	0.796	0.811	0.834
09	0.705	0.708	0.716	0.730	0.751
10	0.620	0.622	0.630	0.642	0.660
11	0.490	0.492	0.497	0.507	0.521
12	0.397	0.398	0.403	0.411	0.422
13	0.360	0.361	0.365	0.373	0.383
14	0.328	0.329	0.333	0.340	0.349
15	0.298	0.299	0.303	0.309	0.317
16	0.276	0.277	0.280	0.285	0.293
17	0.235	0.236	0.238	0.243	0.250
18	0.202	0.203	0.206	0.210	0.215
19	0.176	0.177	0.179	0.183	0.188
20	0.155	0.156	0.157	0.160	0.165

8.1.2 Allowable axial load for a deep groove ball bearing

The allowable axial load here means the limit load at which a contact ellipse is generated between the ball and raceway due to a change in the contact angle when a radial bearing, which is under an axial load, rides over the shoulder of the raceway groove. This is different from the limit value of a static equivalent load P_0 which is determined from the basic static load rating C_{0r} using the static axial load factor Y_0. Note also that the contact ellipse may ride over the shoulder even when the axial load on the bearing is below the limit value of P_0.

The allowable axial load $F_{a\ max}$ of a radial ball bearing is determined as follows. The contact angle α for F_a is determined from the right term of Equation (1) and Equation (2) in Section 8.1.1 while Q is calculated as follows:

$$Q=\frac{F_a}{Z\ \sin\alpha}$$

θ of Fig. 1 is also determined from Equation (2) of Section 5.4 as follows:

$$2a=A_2\ \mu\left(\frac{Q}{\Sigma\rho}\right)^{1/3}$$

$$\therefore\ \theta \fallingdotseq \frac{a}{r}$$

Accordingly, the allowable axial load may be determined as the maximum axial load at which the following relation is established.

$$\gamma \geqq \alpha+\theta$$

As the allowable axial load cannot be determined unless internal specifications of a bearing are known, Fig. 2 shows the result of a calculation to determine the allowable axial load for a deep groove radial ball bearing.

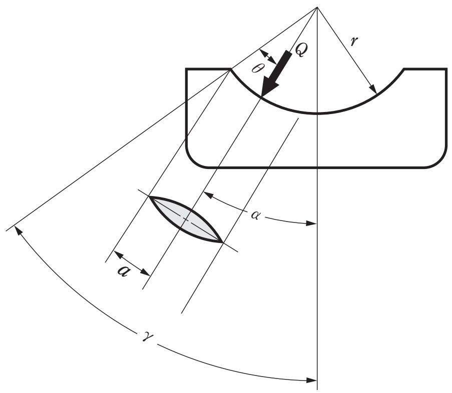


Fig. 1

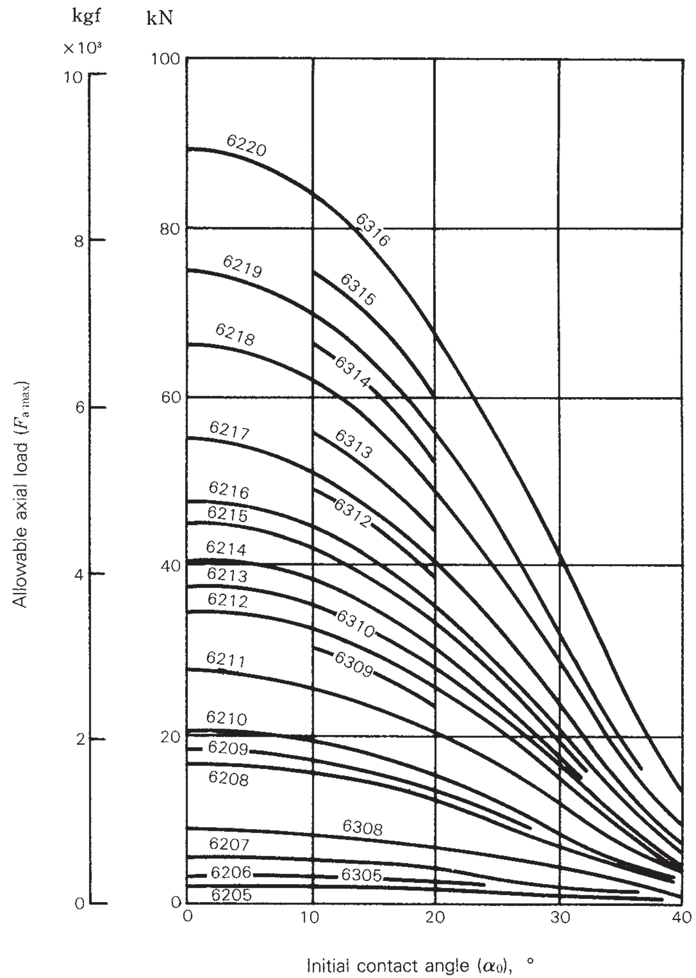


Fig. 2 Allowable axial load for a deep groove ball bearing

8.2 Allowable axial load (break down strength of the ribs) for a cylindrical roller bearings

Both the inner and outer rings may be exposed to an axial load to a certain extent during rotation in a cylindrical roller bearing with ribs. The axial load capacity is limited by heat generation, seizure, etc. at the slip surface between the roller end surface and rib, or the rib strength.

The allowable axial load (the load considered the heat generation between the end face of rollers and the rib face) for the cylindrical roller bearing of the diameter series 3, which is applied continuously under grease or oil lubrication, is shown in Fig. 1.

Grease lubrication (Empirical equation)

$$C_A = 9.8f\left\{\frac{900\,(k\cdot d)^2}{n+1\,500} - 0.023\times(k\cdot d)^{2.5}\right\}\ \text{(N)}$$

$$= f\left\{\frac{900\,(k\cdot d)^2}{n+1\,500} - 0.023\times(k\cdot d)^{2.5}\right\}\ \{\text{kgf}\} \quad \cdots\cdots (1)$$

Oil lubrication (Empirical equation)

$$C_A = 9.8f\left\{\frac{490\,(k\cdot d)^2}{n+1\,000} - 0.000135\times(k\cdot d)^{3.4}\right\}\ \text{(N)}$$

$$= f\left\{\frac{490\,(k\cdot d)^2}{n+1\,000} - 0.000135\times(k\cdot d)^{3.4}\right\}\ \{\text{kgf}\} \quad \cdots\cdots (2)$$

where, C_A: Allowable axial load (N), {kgf}
d: Bearing bore diameter (mm)
n: Bearing speed (min^{-1})

In the equations (1) and (2), the examination for the rib strength is excluded. Concerning the rib strength, please consult with NSK.

To enable the cylindrical roller bearing to sustain the axial load capacity stably, it is necessary to take into account the following points concerning the bearing and its surroundings.

- ○ Radial load must be applied and the magnitude of radial load should be larger than that of axial load by 2.5 times or more.
- ○ There should be sufficient lubricant between the roller end face and rib.
- ○ Use a lubricant with an additive for extreme pressures.
- ○ Running-in-time should be sufficient.
- ○ Bearing mounting accuracy should be good.
- ○ Don't use a bearing with an unnecessarily large internal clearance.

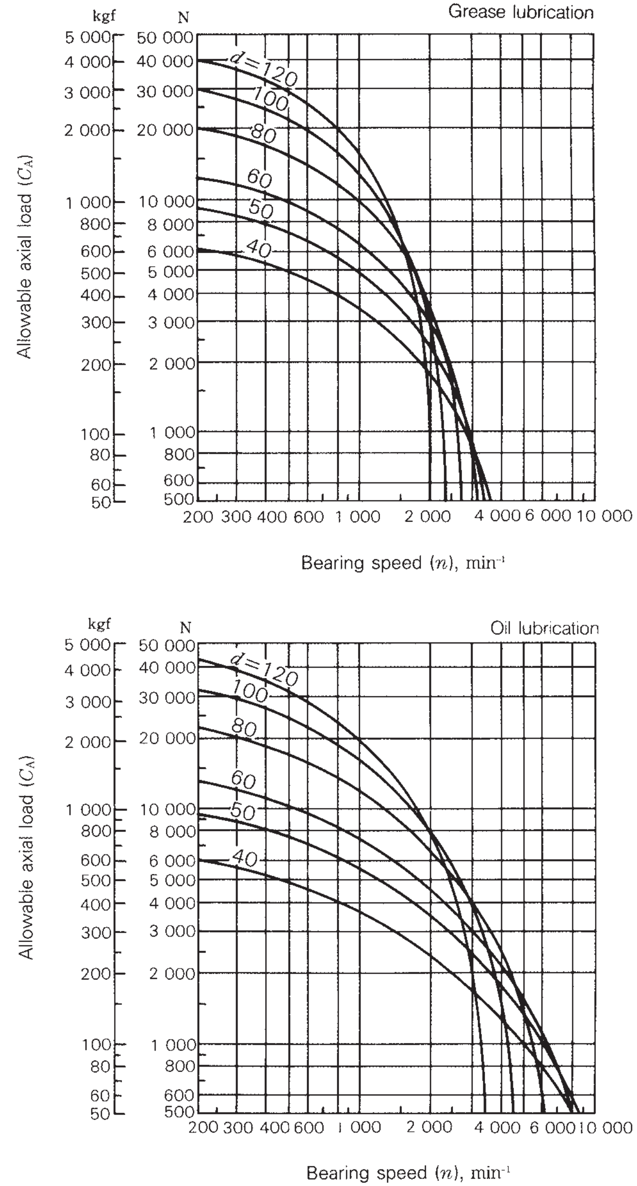
Moreover, if the bearing speed is very slow or exceeds 50% of the allowable speed in the bearing catalog, or if the bearing bore diameter exceeds 200 mm, it is required for each bearing to be precisely checked for lubrication, cooling method, etc. Please contact NSK in such cases.

f: Load factor

	f value
Continuous loading	1
Intermittent loading	2
Short time loading	3

k: Dimensional factor

	k value
Bearing diameter series 2	0.75
Bearing diameter series 3	1
Bearing diameter series 4	1.2



Conditions are continuous loading ($f = 1$) and bearing diameter series 3 ($k = 1.0$)

Fig. 1 Allowable axial load for a cylindrical roller bearing