10. Examples of bearing calculation

Example no. 1

Operating conditions

- Oscillating movement with angular amplitude $\gamma = 15°$,
- Steady radial load: 5 kN.

Problem to be solved

A deep groove ball bearing, single row, with the smallest width is to be selected so that a rating life of 10 000 cycles should be economically satisfied.

Answer

On page 23, the following equation can be found:

$$L_{10osc} = \frac{180°}{2\gamma} L_{10}$$

Using this equation, bearing rating life for complete rotary movement can be determined:

$$L_{10} = \frac{2\gamma}{180} L_{10osc}$$

$$C_r = P_r \sqrt[3]{L_{10}} = P_r \sqrt[3]{\frac{2\gamma}{180} L_{osc}} = 5 \sqrt[3]{\frac{2 \cdot 15}{180} 10 \cdot 10^3} = 59,3 \text{ kN}$$

Bearing 6310 can be found on page 133 with: $C_r = 61,8$ kN şi d = 50 mm, D = 110 mm, B = 27 mm.

Example no. 2

Operating conditions

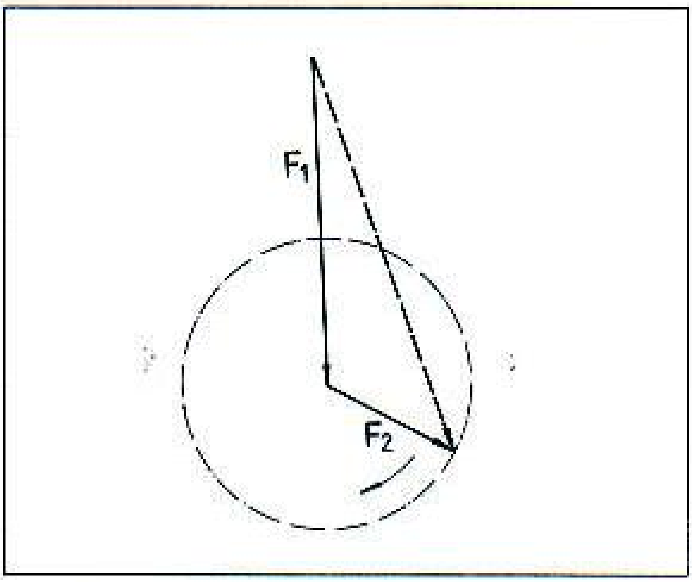
- Rotary movement under a radial load with a component steady in magnitude and direction $F_1 = 25$ kN and a component with variable direction and steady magnitude $F_2 = 10$ kN. Components F_1 and F_2 are acting in the same plane (see the figure below).
- Component F_2 rotates n = 3 000 r/min.
- Oil lubrication.

Problem to be solved

A single row cylindrical roller bearing NU type, with outside diameter less than 220 mm, and a rating life L_{10h} = 20 000 operating hours should be selected.

Answer

We calculate



$$k = \frac{F_1}{F_1 + F_2} = \frac{25}{25+10} = 0,7$$

From fig. 5, page 25, for k = 0,7 corresponds $f_m = 0,79$

Then, mean load is to be calculated:

$$F_m = f_m(F_1 + F_2) = 0,79 \cdot 35 = 27,65 \text{ kN}$$

We further use the equation:

$$L_{10h} = \frac{16\,666}{n} (C/P)^p,\ p = 10/3 \text{ for roller bearings.}$$

$$C = P \sqrt[10/3]{\frac{n L_{10h}}{16\,666}} = 27,65 \sqrt[10/3]{\frac{3\,000 \cdot 20\,000}{16\,666}} = 322,54 \text{ kN}$$

From the bearing table, page 246, we find out that the bearings NU420 or NU2224MA are proper.

Example no. 3

Operating conditions

A deep groove ball bearing, single row, 6312, mounted in the gearbox of a vehicle is to operate under the following conditions:

Operating conditions	1	2	3
The fraction of operating time in conditions i and q_i	0,2	0,3	0,5
Speed, n (min^{-1})	400	800	1000
Radial load, F_{ri} (kN)	14,32	7,613	3,57
Axial load, F_{ai} (kN)	4,76	2,36	1,18

Problem to be solved

Which will be the rating life of this bearing (L_{10h}, operating hours)?

Answer

In the bearing table on page 134, for the bearing 6312, C_r = 81,9 kN and C_{0r} = 51,9 kN can be found.

0,5(d + D) = 0,5(60 + 130) = 95 mm

From fig.3, page 120, f_0 = 13,14 can be determined.

For the operating conditions 1:

$$\frac{f_0 F_{a1}}{C_{0r}} = \frac{13{,}14 \cdot 4{,}726}{51{,}9} = 1{,}20 \text{ and corresponds to } e = 0{,}28,$$

$$\frac{F_{a1}}{F_{r1}} = \frac{4{,}726}{14{,}320} = 0{,}33 > e.$$

By insert, for e = 0,28 and normal radial clearance, from table 4, page 120, we select:

X_1 = 0,56, Y_1 = 1,56,
X_2 = 0,56, Y_2 = 1,81,
X_3 = 0,56, Y_3 = 2,10,

The equivalent radial force in case i can be calculated using the equation:

$$P_i = X_i F_{ri} + Y_i F_{ai},$$

P_1 = 0,56·14,320 + 1,56·4,726 = 15,39 kN,
P_2 = 0,56·7,613 + 1,81·2,360 = 8,53 kN,
P_3 = 0,56·3,57 + 2,1·1,18 = 4,48 kN.

Number of bearing revolutions under steady load F_i will be:

$$N_i = n_i q_i L_{10hi};\ n_m = \sum_{i=1}^{n} n_i q_i$$

The bearing total number of revolutions can be calculated from:

$$N = \sum_{i=1}^{n} N_i = L_{10h} \sum_{i=1}^{n} n_i q_i$$

To calculate the equivalent mean dynamic load, the following equation on page 25 can be used

$$P_m = \sqrt[3]{\frac{P_1^3 n_1 + P_2^3 n_2 + P_3^3 n_3}{n_1 + n_2 + n_3}} =$$

$$= \sqrt[3]{\frac{P_1^3 n_1 q_1 L_{10h} + P_2^3 n_2 q_2 L_{10h} + P_3^3 n_3 q_3 L_{10h}}{n_1 q_1 L_{10h} + n_2 q_2 L_{10h} + n_3 q_3 L_{10h}}} =$$

$$= \sqrt[3]{\frac{P_1^3 n_1 q_1 + P_2^3 n_2 q_2 + P_3^3 n_3 q_3}{n_1 q_1 + n_2 q_2 + n_3 q_3}} =$$

$$= \sqrt[3]{\frac{15{,}39^3 \cdot 400 \cdot 0{,}2 + 8{,}53 \cdot 800 \cdot 0{,}3 + 4{,}48^3 \cdot 1000 \cdot 0{,}5}{400 \cdot 0{,}2 + 800 \cdot 0{,}3 + 1000 \cdot 0{,}5}} = 8{,}39 \text{ kN}$$

The rating life L_{10h} is to be calculated using the equation on page 19

$$L_{10h} = \frac{1\,000\,000}{60\,n}\left(\frac{C}{P}\right)^3$$

L_{10h} = 20 437 operating hours

Example no. 4

Operating conditions

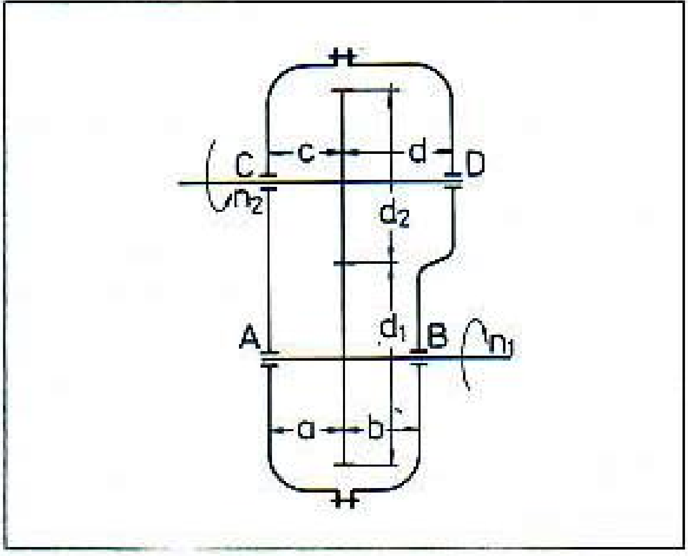
For the reverser shown in the adjoining figure, the following data are known:

Input power:	N = 97 kW,
Input shaft speed:	n_1 = 1 000 r/min,
An axial load is intermittently acting on the input shaft for a period of 5% of the operating period:	F_a = 4 kN,
Operating period:	L_{10h} = 10 000 operating hours,
Constructive details:	a = b = c = 38 mm, d = 62 mm, d_1 = 172 mm, d_2 = 148 mm.

Lubrication in oil bath.

Problem to be solved

The type and dimensions of the bearing suitable for the bearing joints (A, B, C, D) of the reverser should be determined.



Answer

Output shaft speed:

$$n_2 = \frac{n_1 d_1}{d_2} = \frac{1\,000 \cdot 172}{148} = 1\,162 \text{ r/min}$$

Input moment can be calculated from:

$$M = \frac{9{,}74\,N}{n_1} = \frac{9{,}74 \cdot 97}{1\,000} = 0{,}94 \text{ kN m}$$

Tangential force on the wheels 1 and 2:

$$T = \frac{M}{0{,}5\,d_1} = \frac{0{,}94}{0{,}5\cdot 172\cdot 10^{-3}} = 10{,}93\ \text{kN}$$

Rejecting force between wheels 1 and 2:

$$R = T\,\text{tg}\alpha = 10{,}93\cdot \text{tg}\,20^\circ = 3{,}97\ \text{kN}$$

Loading force of the shafts 1, 2:

$$F = \sqrt{T^2 + R^2} = \sqrt{10{,}93^2 + 3{,}97^2} = 11{,}63\ \text{kN}.$$

Loading forces in bearing joints:

$$F_{rA} = F_{rB} = \frac{F}{2} = \frac{11{,}63}{2} = 5{,}82\ \text{kN},$$

$$F_{rC} = \frac{F\,d}{c+d} = \frac{11{,}63\cdot 52}{38+52} = 6{,}72\ \text{kN},$$

$$F_{rD} = \frac{F\,c}{c+d} = \frac{11{,}63\cdot 38}{38+52} = 4{,}91\ \text{kN}.$$

Cylindrical roller bearings in all bearing joints:

$$P = F_r$$

Minimum radial dynamic loads which are necessary for the bearings in the joints A, B, C, D can be calculated using the equation on page 19:

$$C_{rA} = C_{rB} = 5{,}82\ \sqrt[10/3]{\frac{60\cdot 10\,000\cdot 1\,000}{10^6}} = 39{,}66\ \text{kN},$$

$$C_{rC} = 6{,}72\ \sqrt[10/3]{\frac{60\cdot 10\,000\cdot 1\,162}{10^6}} = 47{,}91\ \text{kN},$$

$$C_{rD} = 4{,}91\ \sqrt[10/3]{\frac{60\cdot 10\,000\cdot 1\,162}{10^6}} = 35\ \text{kN}.$$

For the joints A, B and C a bearing NJ207E with $C_r = 48{,}9$ kN, $C_{0r} = 49{,}7$ kN can be used.

For joint D, a bearing NJ206E with $C_r = 39{,}7$ kN, $C_{0r} = 37{,}9$ kN can be used.

Maximum axial loads admitted by the bearings NJ207E and NJ206E respectively, can be calculated from:

$$F_{ap} = \frac{K_1\,C_{0r}\,10^4}{n(d+D)} + K_2\,F_r$$

We select from table 5, pag. 228, $K_1 = 1{,}5$ şi $K_2 = 0{,}15$.

$$F_{apC} = \frac{1{,}5\cdot 49{,}7\cdot 10^4}{1\,162(35+72)} - 0{,}15\cdot 6{,}72 = 4{,}98\ \text{kN},$$

$$F_{apD} = \frac{1{,}5\cdot 37{,}9\cdot 10^4}{1\,162(35+72)} - 0{,}15\cdot 4{,}91 = 3{,}83\ \text{kN}.$$

One can notice that $F_{apD} < F_a$. The problem can be correctly solved by using the same bearing NJ207E also in joint D.

Example no. 5

Operating conditions

Loads in bearings: $F_{rA} = 2\,100$ N, $F_{rB} = 3\,200$ N, $F_a = 400$ N.

Angular deformation: $\varphi_A = \varphi_B = 2^\circ$

Shaft diameters: $d_A = d_B = 70$ mm

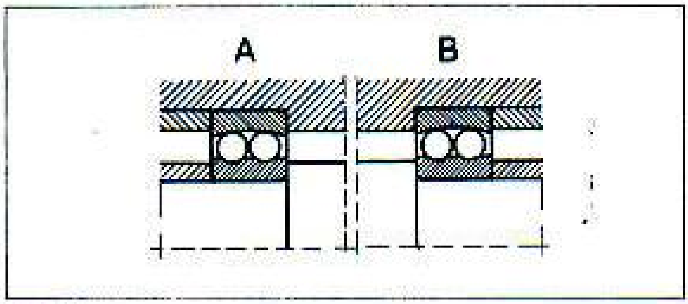
Housing maximum diameters: $D_{Amax} = D_{Bmax} = 140$ mm

Shaft speed: $n = 1\,400$ r/min

Requisite rating life: $L_{10h} = 20\,000$ h

Problem to be solved

Selecting and checking the bearings, in the figure below:



Answer

Due to the great angular deformations in bearing units, self-aligning ball bearings, small width series 1214, are to be selected, characteristics in the catalogue on page 165:

d = 70 mm,	$C_r = 34\,600$ N,
D = 125 mm < 140,	e = 0,18,
B = 24 mm,	$Y_1 = 3{,}5$,
	$Y_2 = 5{,}4$.

Equivalent load for each bearing is to be calculated:

For bearing unit A: $F_{aA} = F_a$

$$\frac{F_{aA}}{F_{rA}} = \frac{400}{2\,100} = 0{,}19 > e.$$

$$P_A = 0{,}65\,F_{rA} + Y_2\,F_{aA} = 0{,}65\cdot 2\,100 + 5{,}4\cdot 400 = 3\,525\ \text{N}.$$

For bearing unit B: $F_{aB} = 0$,

$$P_B = F_{rB} = 3\,200\ \text{N}.$$

Since $P_A > P_B$, the bearing in the bearing unit A should be checked. Rating life, operating hours, can be calculated using the equation:

$$L_{10h} = \frac{1\,000\,000}{60\,n}\left(\frac{C_r}{P_A}\right)^3 = \frac{1\,000\,000}{60\cdot 1\,400}\left(\frac{34\,600}{3\,525}\right)^3 = 11\,258\ \text{hours} < L_{10h}$$

Other bearings should be selected, wide series 2214, with the characteristics in the catalogue, page 165.

d = 70 mm,	$C_r = 44\,200$ N,
D = 125 mm < 140 mm,	e = 0,27,
B = 31 mm,	$Y_1 = 2{,}3$,
	$Y_2 = 3{,}6$.

Equivalent load is to be calculated:

for bearing unit A: $\frac{F_{aA}}{F_{rA}} = 0{,}19 < e$,

$$P_A = F_{rA} + Y_1\,F_{aA} = 2\,100 + 2{,}3\cdot 400 = 3\,020\ \text{N}.$$

for bearing unit B: $F_{aB} = 0$,
$P_B = F_{rB} = 3\,200$ N.

In this case, $P_B > P_A$, then the bearing in bearing unit B should be checked:

$$L_{10h} = \frac{1\,000\,000}{60\cdot 1\,400}\left(\frac{44\,200}{3\,200}\right)^3 = 31\,371\ \text{operating hours} > \text{requisite}\ L_{10h}$$

Example no. 6

Operating conditions

Loads in bearing units: $F_r = 1\,000$ N, $F_a = 1\,800$ N.

Shaft diameter: d = 30 mm

Shaft speed: n = 2 500 r/min

Requisite rating life: $L_h = 15\,000$ operating hours.

Problem to be solved

Checking the angular ball bearing, double row, 3306.

Answer

The bearing 3306 is to be checked, characteristics in the catalogue, page 218:

d = 30 mm, C_r = 38 000 N,
D = 72 mm, C_{0r} = 24 500 N,
B = 30,2 mm,
α = 32°.

$$\frac{F_a}{F_r} = \frac{1\,800}{1\,000} = 1{,}8 > 0{,}86,$$

$$P_r = 0{,}62\,F_r + 1{,}17\,F_a = 0{,}62 \cdot 1\,000 + 1{,}17 \cdot 1\,800 = 2\,726 \text{ N},$$

$$L_{10h} = \frac{1 \cdot 10^6}{60\,n}\left(\frac{C_r}{P_r}\right)^3 = \frac{1 \cdot 10^6}{60 \cdot 2\,500}\left(\frac{38\,000}{2\,726}\right)^3 = 18\,058 \text{ hours} > 15\,000 \text{ hours}.$$

Example no. 7

Operating conditions

Loads in bearing units: F_r = 7 900 N,
F_a = 7 100 N.

Shaft diameter: d = 60 mm

Shaft speed: n = 4 500 r/min

Requisite rating life: L_{10h} = 6 000 operating hours

Problem to be solved

Checking the arrangement: four-point contact bearing and cylindrical roller bearing

Answer

The bearing QJ212, characteristics in the catalogue, page 212, is to be checked under a pure axial load:

d = 60 mm, C_r = 92 300 N,
D = 110 mm, C_{0r} = 71 000 N,
B = 22 mm.

$F_r = 0,$

$P_a = 1{,}07\,F_a = 1{,}07 \cdot 7\,100 = 7\,597$ N,

$$L_{10h} = \frac{1 \cdot 10^6}{60 \cdot 4\,500}\left(\frac{92\,300}{7\,597}\right)^3 = 6\,642 \text{ hours} > 6\,000 \text{ hours}.$$

The bearing NU212E, characteristics in the catalogue, page 238, is to be checked under a pure radial load:

d = 60 mm, C_r = 93 400 N,
D = 110 mm, C_{0r} = 101 000 N,
B = 22 mm.

$P_r = F_r = 7\,900$ N,

$$L_{10h} = \frac{1 \cdot 10^6}{60 \cdot 4\,500}\left(\frac{93\,400}{7\,900}\right)^3 = 6\,120 \text{ hours} > 6\,000 \text{ hours}.$$

Example no. 8

Determining the size of a needle cage and the thickness of the case-hardened layer for the adjoint parts for the operating conditions specified below:

Fraction of operating time	Speed r/min	Radial load F_r (N)
m_1 = 0,2	n_1 = 300	F_{r1} = 16 500
m_2 = 0,025	n_2 = 540	F_{r2} = 12 000
m_3 = 0,015	n_3 = 720	F_{r3} = 9 000
m_4 = 0,76	n_4 = 1 200	F_{r4} = 6 000

Shaft diameter: $d_{a\,min}$ = 57 mm
Material: case-hardening steel 13CrNi35X
Hardness: 60-62 HRC

Problem to be solved

The needle cage is to be selected so that the bearing rating life should be L_{10h} = 6 000 hours.

Answer

We calculate the equivalent radial load (see page 24):

$$F_{re} = \sqrt[10/3]{\frac{m_1 n_1 F_{r1}^{10/3} + m_2 n_2 F_{r2}^{10/3} + m_3 n_3 F_{r3}^{10/3} + m_4 n_4 F_{r4}^{10/3}}{m_1 n_1 + m_2 n_2 + m_3 n_3 + m_4 n_4}} =$$

$$= \sqrt[10/3]{\frac{0{,}2 \cdot 300 \cdot 16\,500^{10/3} + 0{,}025 \cdot 540 \cdot 12\,000^{10/3} + 0{,}015 \cdot 720 \cdot 9\,000^{10/3} + 0{,}76 \cdot 1\,200 \cdot 6\,000^{10/3}}{0{,}2 \cdot 300 + 0{,}025 \cdot 540 + 0{,}015 \cdot 720 + 0{,}76 \cdot 1\,200}} = 8\,214 \text{ N}$$

Equivalent medium speed:

$n_e = m_1 n_1 + m_2 n_2 + m_3 n_3 + m_4 n_4 = 0{,}2 \cdot 300 + 0{,}025 \cdot 540 + 0{,}015 \cdot 720 + 0{,}76 \cdot 1\,200 = 996$ r/min,

$$L_{10} = \frac{60 \cdot L_h \cdot n_e}{10^6} = \frac{60 \cdot 6\,000\,996}{10^6} = 478 \text{ mil. revolutions}$$

Requisite dynamic load carrying capacity:

$$C_r = F_{re}\sqrt[10/3]{L_{10}} = 8\,214\sqrt[10/3]{478} = 52\,286 \text{ N}$$

From the bearings tables, page 310, a double row needle cage KK 576343 is to be selected:
F_w = 57 mm,
E_w = 63 mm,
C_r = 55,55 kN.

Rolling element diameter is: $D_W = \frac{E_W - F_W}{2} = 3$ mm

In accordance with the specifications on page 288, the minimum thickness of the case-hardened layer (t_{min}) can be determined from the equation:

$t_{min} = (0{,}07...0{,}12)D_W = 0{,}3 ... 0{,}36$ mm.

Example no. 9

Operating conditions

A drawn cup needle roller bearing, RHNA 253226, rotates at a speed n = 4 000 r/min on a shaft with surface hardness 50 HRC. Bearing rating life must be L_{10h} = 5 000 operating hours.

Problem to be solved

What radial dynamic load can this bearing carry?

Answer

Basic radial dynamic load C_r = 24,5 kN found in the table, page 301, should be multiplied by 0,6, so that the shaft hardness of 50 HRC, table 1, page 288, could be considered.

$C_r = 24{,}5 \cdot 0{,}6 = 14{,}7$ kN

On page 21, for 4 000 r/min and 5 000 hours it corresponds C/P = 8,39.

Admissible dynamic load will be:

$$P_r = \frac{C_r}{8{,}39} = \frac{14{,}7}{8{,}39} = 1{,}75 \text{ kN.}$$

Example no. 10

Operating conditions

Loads on bearings: $F_{rA} = F_{rB} = F_r = 300$ N, Ka = 200 N.

Shaft diameter: d = 20 mm

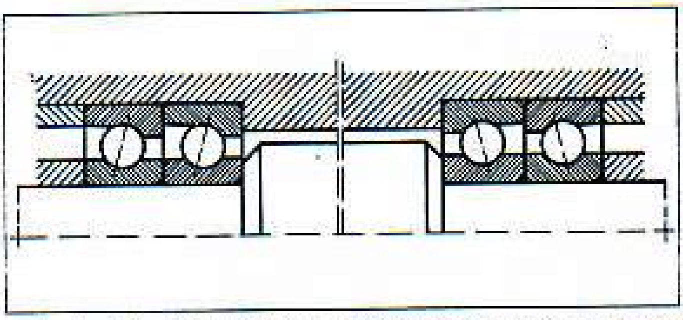
Shaft speed: n = 30 000 r/min

Lubrication: oil spot

Temperature: t = 180°C

Problem to be solved

From constructive considerations, the bearing 7204CTAP4 is to be selected. A set of 2 bearings in tandem arrangement, 7204CTAP4DT, should be mounted as in the figure below.



The basic load rating is to be calculated and the speed limit is to be checked, considering that the axial load K_a, may be oriented toward any of the two bearings.

Answer

The characteristics of the bearing pair 7204 CTAP4DT are:

d = 20 mm, C_{0r} = 18 000 N,
D = 47 mm, C_r = 25 300 N,
B = 14 mm, n = 43 000 r/min (oil).

The axial loads in bearings are (page 178, item 1a):

$F_{aA} = F_{aB} = 1{,}14\,F_r + K_a = 1{,}14 \cdot 300 + 200 = 542$ N.

The factors for the axial load are to be selected from table 6, page 179, depending on the equation:

$$\frac{f_0\, i\, F_a}{C_{0r}} = \frac{13{,}3 \cdot 2 \cdot 542}{18\,000} = 0{,}80$$ (f_0, according to page 178, fig. 2)

We find: e = 0,44, Y = 1,28

The equivalent load is to be calculatedz:

$$\frac{F_a}{F_r} = \frac{542}{300} = 1{,}81 > e,$$

$P_r = 0{,}44 \cdot 300 + 1{,}28 \cdot 542 = 826$ N.

Requisite rating life is:

$$L_{10h} = \frac{1 \cdot 10^6}{60 \cdot 30\,000}\left(\frac{25\,300}{826}\right)^3 = 15\,964 \text{ hours}$$

Adjusted rating life:

$L_{nah} = f_t\, L_{10h} = 0{,}89 \cdot 15\,964 = 14\,208$ hours (f_t, from table 2.9, page 27).

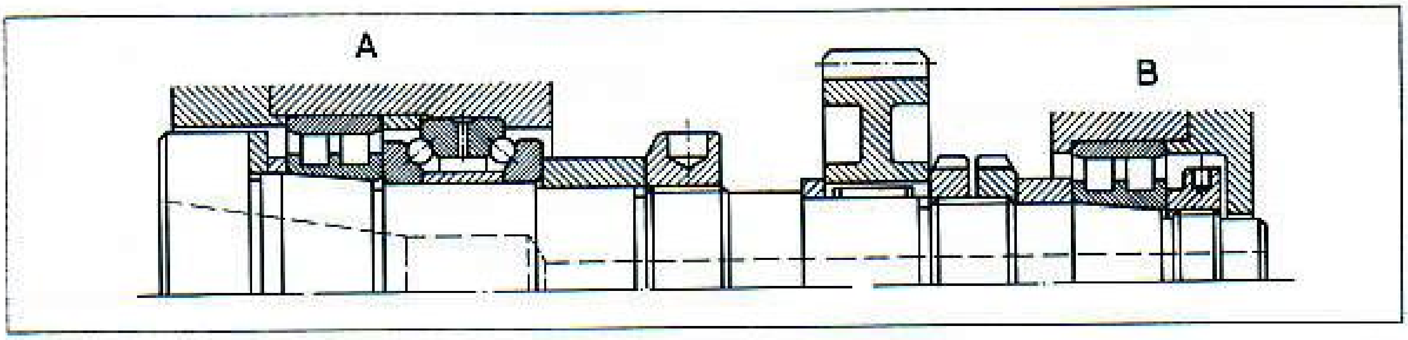
Permissible speed limit:

$n_{adm} = f_1\, n = 0{,}94 \cdot 43\,000 = 40\,400$ r/min > 30 000
(f_1, according to the figure 13, page 36)

Example no. 11

Operating conditions

The bearing of an universal milling machine (see figure below) consist of a cylindrical roller bearing, double row, NN3020KMP41 type. For axial location, the thrust ball bearing, double row, 234420SP is used.



The loads in the bearing $F_a = 4\,000$ N,
$F_r = 12\,000$ N.

Medium speed: $n_{med} = 3\,000$ r/min.

Problem to be solved

Determining the rating life for the bearings in the locating ring.

Answer

Radial load F_r and P_r, respectively, are taken over by the cylindrical roller bearing. In accordance with the table on page 261,

$C_r = 152\,000$ N

The rating life of this bearing is:

$$L = \left(\frac{C_r}{P_r}\right)^{10/3} = \left(\frac{152\,000}{12\,000}\right)^{10/3} = 4\,737{,}5 \text{ mil. revolutions,}$$

and the requisite rating life:

$$L_{10h} = \frac{10^6 L_{10}}{60\, n_{med}} = \frac{10^6 \cdot 4\,737{,}5}{60 \cdot 3\,000} = 26\,320 \text{ hours,}$$

this value correspond to table 2.4, page 21.

The axial load F_a and P_a, respectively, are taken over by the thrust ball bearing. In accordance to table on page 446:

$C_a = 62\,000$ N

The bearing rating life is:

$$L = \left(\frac{C_a}{P_a}\right)^3 = \left(\frac{62\,000}{4\,000}\right)^3 = 3\,724 \text{ mil. revolutions,}$$

and the requisite rating life, in operating hours, is:

$$L_{10h} = \frac{10^6 L_{10}}{60\, n} = \frac{10^6 \cdot 3\,724}{60 \cdot 3\,000} = 20\,690 \text{ hours,}$$

this value correspond to table 2.4, page 23.

The same results can be obtained using the table 2.2, page 20 and table 2.3, page 21, respectively:

for the bearing NN3020KMP41:
$C_r/P_r = 12{,}66$, $n = 3\,000$ r/min,
$L_{10h} = 26\,244$ hours.

for the bearing 234420SP:
$C_a/P_a = 15{,}5$, $n = 3\,000$ r/min.
$L_{10h} = 20\,833$ hours.

Example no. 12

Operating conditions

Loads in bearing units: $F_{rA} = 6\,500$ N,
$F_{rB} = 7\,200$ N,
$K_a = 2\,500$ N,

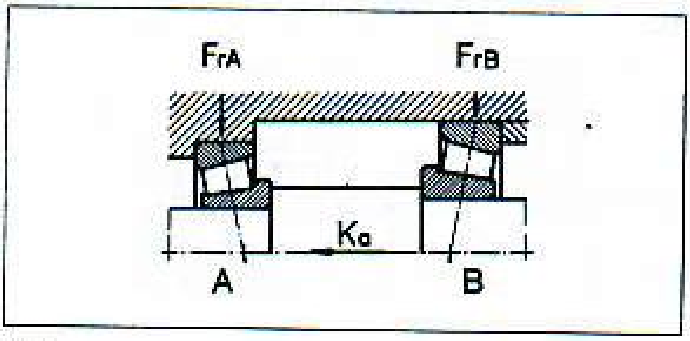
Shaft diameters $d_A = 25$ mm,
$d_B = 30$ mm.

Shaft speed: $n = 550$ r/min

Requisite rating life: $L_{10h} = 2\,000$ hours

Problem to be solved

Selecting the tapered roller bearings for the arrangement in the adjoining figure:



Answer

For constructive reasons, the following bearings are to be selected:
- 30305A for the bearing unit A, with: $C_{rA} = 43\,000$ N, page 382,
$e_A = 0{,}3$,
$Y_A = 2$.

- 32006XA for the bearing unit A, with: $C_{rB} = 34\,000$ N, page 382,
$e_B = 0{,}43$,
$Y_B = 1{,}4$.

We calculate:

$$\frac{F_{rA}}{Y_A} = \frac{6\,500}{2} = 3\,250,$$

$$\frac{F_{rB}}{Y_B} = \frac{7\,200}{1{,}4} = 5\,143,$$

Since

$\frac{F_{rA}}{Y_A} < \frac{F_{rB}}{Y_B}$ şi $K_a \geq 0$, it is the case 2a in table 4, page 381.

The total axial loads in the two bearing units can be calculated with the equation:

$$F_{aA} = F_{aB} + K_a = 2\,250 + 2\,500 = 4\,750 \text{ N,}$$

$$F_{aB} = \frac{0{,}5\, F_{rB}}{Y_B} = \frac{0{,}5 \cdot 7\,200}{1{,}4} = 2\,571 \text{ N.}$$

Equivalent dynamic load on bearing unit should be calculated:

$$\frac{F_{aA}}{F_{rA}} = \frac{4\,750}{6\,500} = 0{,}73 > e_A, \text{ bearing unit A:}$$

$$P_{rA} = 0{,}4\, F_{rA} + Y_A\, F_{aA} = 0{,}4 \cdot 6\,500 + 2 \cdot 4\,750 = 12\,100 \text{ N}$$

$$\frac{F_{aB}}{F_{rB}} = \frac{2\,250}{7\,200} = 0{,}31 < e_B, \text{ bearing unit B:}$$

$$P_{rB} = F_{rB} = 7\,200 \text{ N.}$$

The rating life of the two bearings can be determined considering the requisite rating life:

$$L_{10} = \frac{60\, n\, L_{10h}}{10^6} = \frac{60 \cdot 550 \cdot 2\,000}{10^6} = 66 \text{ mil. revolutions}$$

The requisite dynamic load should be determined:

$$C_{rA\,nec} = P_A \sqrt[10/3]{L_{10}} = 12\,100 \sqrt[10/3]{66} = 42\,625 \text{ N} < C_{rA},$$

$$C_{rB\,nec} = P_B \sqrt[10/3]{L_{10}} = 7\,200 \sqrt[10/3]{66} = 25\,304 \text{ N} < C_{rB}.$$

The selected bearings correspond to the operating conditions.

Example no. 13

Operating conditions

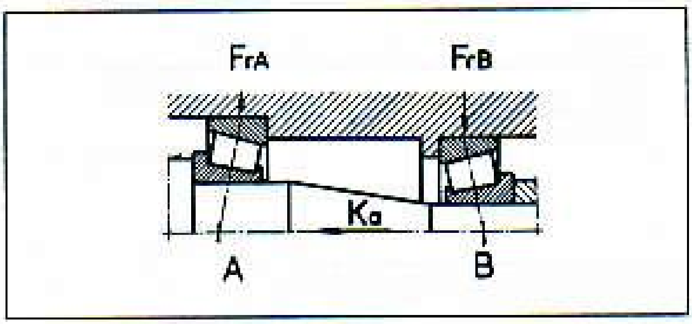
Bearing unit A: bearing 30210A,
Bearing unit B: bearing 32208A,

Loads in bearing units: $F_{rA} = 15\,000$ N,
$F_{rB} = 11\,000$ N,
$K_a = 3\,000$ N.

Shaft speed: $n = 1\,200$ r/min.

Problem to be solved

To determine the minimum rating life for the arrangement in the figure below.



Answer

The characteristics of the used bearings are (see page 382 and 384):

- 30210A: $C_r = 69\,700$ N, $e = 0{,}43$, $Y_A = 1{,}4$.
- 32208A: $C_r = 66\,200$ N, $e = 0{,}37$, $Y_B = 1{,}6$.

We calculate:

$$\frac{F_{rA}}{Y_A} = \frac{15\,000}{1{,}4} = 10\,714,$$

$$\frac{F_{rB}}{Y_B} = \frac{11\,000}{1{,}6} = 6\,875.$$

Since:

$$\frac{F_{rA}}{Y_A} > \frac{F_{rB}}{Y_B} \text{ şi}$$

$$K_a > 0{,}5\left(\frac{F_{rA}}{Y_A} - \frac{F_{rB}}{Y_B}\right) = 0{,}5\left(\frac{15\,000}{1{,}4} - \frac{11\,000}{1{,}6}\right) = 1\,919 \text{ N}$$

it is the case 2b in table 4, page 381.

Total axial loads in the two bearing units can be determinated by the equations:

$$F_{aA} = F_{aB} + K_a = 3\,475{,}5 + 3\,000 = 6\,437 \text{ N},$$

$$F_{aB} = \frac{0{,}5\,F_{rB}}{Y_B} = \frac{0{,}5 \cdot 11\,000}{1{,}6} = 3\,437 \text{ N}.$$

Equivalent dynamic load on bearing unit should be calculated:

$$\frac{F_{aA}}{F_{rA}} = \frac{6\,437}{15\,000} = 0{,}429 < e, \text{ thus for the bearing unit A:}$$

$$P_A = F_{rA} = 15\,000 \text{ N}.$$

$$\frac{F_{aB}}{F_{rB}} = \frac{3\,437}{11\,000} = 0{,}31 < e, \text{ thus for the bearing unit B:}$$

$$P_B = F_{rB} = 11\,000 \text{ N}$$

The rating lives are to be calculated:

$$L_{10A} = \left(\frac{C_r}{P_A}\right)^{10/3} = \left(\frac{69\,700}{15\,000}\right)^{10/3} = 167{,}42 \text{ mil. revolutions},$$

$$L_{10B} = \left(\frac{C_r}{P_B}\right)^{10/3} = \left(\frac{66\,200}{11\,000}\right)^{10/3} = 396{,}47 \text{ mil. revolutions}.$$

thus the requisite rating lives are::

$$L_{10hA} = \frac{10^6\,L_{10A}}{60\,n} = \frac{10^6 \cdot 167{,}42}{60 \cdot 1\,200} = 2\,325{,}3 \text{ hours},$$

$$L_{10hB} = \frac{10^6\,L_{10B}}{60\,n} = \frac{10^6 \cdot 396{,}47}{60 \cdot 1\,200} = 5\,506{,}5 \text{ hours}.$$

Then the minimum rating life of the arrangement is L = 2 325,3 hours.

Example no. 14

Operating conditions:

The bearing units for the drive pinion and the drive gear of a motor car are shown in fig. 1 and 2, respectively.

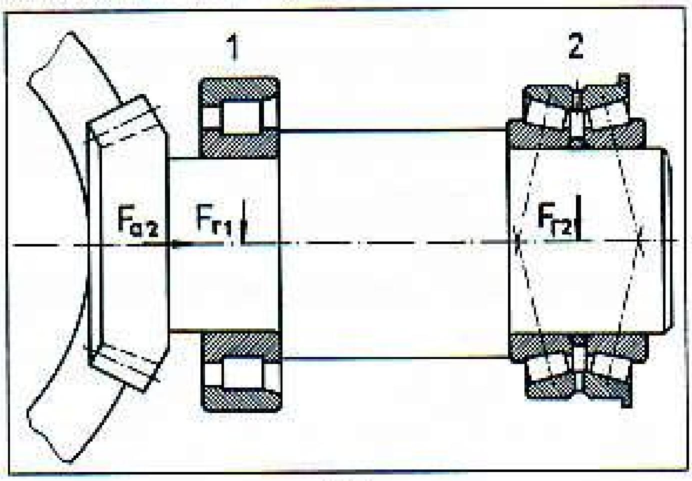


Fig. 1

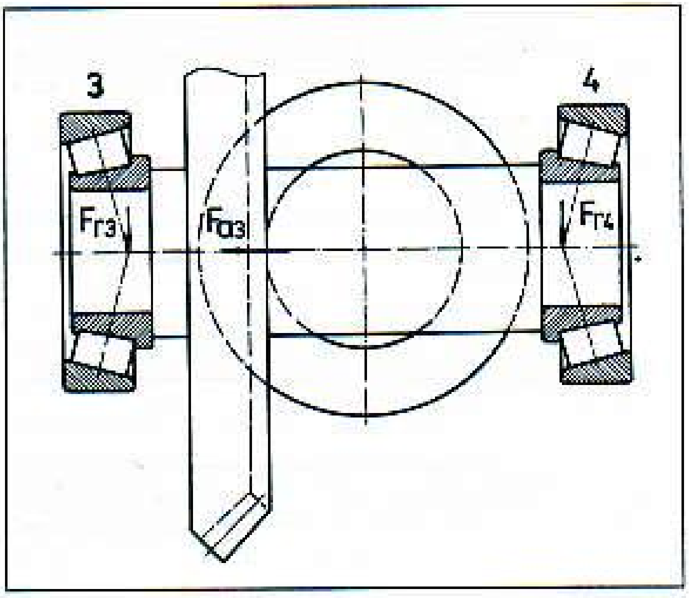


Fig. 2

The following data are known:

- the motor car has 4 velocity steps:

Step	Step operating time	Gear ratio	Median speed (r/min) drive pinion	Median speed (r/min) drive gear
1	0,01	3,615	830	220
2	0,14	2,263	1 300	350
3	0,25	1,480	2 000	530
4	0,60	1,032	3 000	800

- gear ratio for the bevel gearing: 3,777:1

The loads on the bearings will be:

Step	1	2	3	4
F_{r1} (N)	38 120	24 460	16 000	11 170
F_{r2} (N)	18 110	10 080	6 590	4 600
$F_{a2} = F_{a3}$ (N)	23 710	14 830	9 700	6 770
F_{r3} (N)	23 010	14 400	9 420	6 570
F_{r4} (N)	29 740	18 610	12 170	8 490

The bearing bores should meet the condition: $d_1 \geq 30$ mm, $d_2 \geq 25$ mm, $d_3 \geq 35$ mm, $d_4 \geq 35$ mm

Problem to be solved

To determine the dimensions of the bearings that should be selected so that a bearing rating life could be obtained as follows:

Bearing	1	2	3	4
Rating life (number of revolutions)	$35\cdot10^6$	$35\cdot10^6$	$9{,}2\cdot10^6$	$9{,}2\cdot10^6$

Answer

For bearing 1:

Median dynamic load can be determined using the equation on page 25

$$P_m = \sqrt[10/3]{\frac{0{,}01\cdot830\cdot39\,120^{10/3} + 0{,}14\cdot1\,300\cdot24\,480^{10/3} + 0{,}25\cdot2\,000\cdot16\,000^{10/3} + 0{,}60\cdot3\,000\cdot11\,170^{10/3}}{0{,}01\cdot830 + 0{,}14\cdot1\,300 + 0{,}25\cdot2\,000 + 0{,}60\cdot3\,000}} =$$

$$= \sqrt[10/3]{\frac{2{,}02076\cdot10^{17}}{2\,490{,}3}} = 14\,886 \text{ N} \approx 15 \text{ kN}.$$

For bearing 2: Medium dynamic load can be determined using the equation on page 25 and 380:

$$\frac{F_a}{F_r} = 1{,}47 > e = 0{,}83,$$

$$P_2 = 0{,}67\,F_r + Y_2\,F_a.$$

Step	1	2	3	4
P_2 (N)	3 521	2 203	1 813	1 120

$$P_m = \sqrt[10/3]{\frac{0{,}01\cdot830\cdot35\,210^{10/3} + 0{,}14\cdot1\,300\cdot22\,030^{10/3} + 0{,}25\cdot2\,000\cdot18\,130^{10/3} + 0{,}60\cdot3\,000\cdot11\,200^{10/3}}{0{,}01\cdot830 + 0{,}14\cdot1\,300 + 0{,}25\cdot2\,000 + 0{,}60\cdot3\,000}} =$$

$$= \sqrt[10/3]{\frac{2{,}0128\cdot10^{17}}{2\,490{,}3}} = 14\,868 \text{ N} \approx 15 \text{ kN}.$$

For bearing 3: Median dynamic load can be determined using the equation on page 25 and 380;

$$\frac{F_a}{F_r} = 1{,}03 > e = 0{,}37,$$

$$P_3 = 0{,}4\,F_r + Y_3\,F_a.$$

Step	1	2	3	4
P_3 (N)	4 714	2 949	1 929	1 346

$$P_m = \sqrt[10/3]{\frac{0{,}01\cdot220\cdot47\,140^{10/3} + 0{,}14\cdot350\cdot29\,490^{10/3} + 0{,}25\cdot530\cdot19\,290^{10/3} + 0{,}60\cdot800\cdot13\,460^{10/3}}{0{,}01\cdot220 + 0{,}14\cdot350 + 0{,}25\cdot530 + 0{,}60\cdot800}} = \sqrt[10/3]{\frac{1{,}005\cdot10^{17}}{663{,}7}} = 17\,949 \text{ N} \approx$$

≈ 18 kN.

For bearing 4: $P_4 = F_{r4}$,

$$P_m = \sqrt[10/3]{\frac{0{,}01\cdot220\cdot29\,740^{10/3} + 0{,}14\cdot350\cdot18\,610^{10/3} + 0{,}25\cdot530\cdot12\,170^{10/3} + 0{,}60\cdot800\cdot8\,490^{10/3}}{0{,}01\cdot220 + 0{,}14\cdot350 + 0{,}25\cdot530 + 0{,}60\cdot800}} = \sqrt[10/3]{\frac{2{,}1648\cdot10^{17}}{663{,}5}} = 11\,325 \text{ N} \approx$$

$\approx 11{,}5$ kN.

In order to obtain the requisite rating lives, it is necessary to satisfy the conditions in table 2.1, page 18:

Bearing	1	2	3	4
C_r/P_r	2,91	2,91	2	2
C_r requisite (kN)	44	44	38	23

After consulting the bearing tables, a choice could be:

Bearing	1	2	3	4
Type	NF 5306HV	35305 R	30207 A	30207 A
C_r (kN)	55,1	73	50,5	50,5

Note: The bearings 3 and 4 were chosen on constructive reasons.

Example no. 15

Operating conditions

Loads in bearing units: F_a = 30 000 N, F_r = 60 000 N.

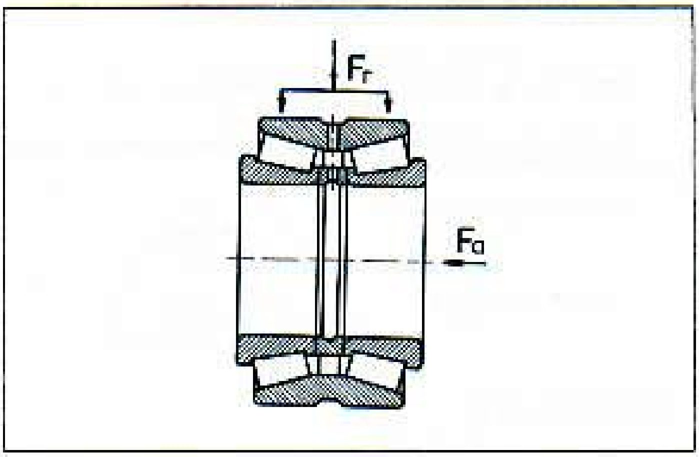
Shaft diameter: d_{min} = 160 mm

Shaft speed: n = 200 r/min.

Requisite rating life: Lh = 20 000 hours

Problem to be solved

Selecting a double row tapered roller bearing.



Answer

For constructive reasons, the bearing 35032, in the catalogue, page 410, with:

d = 160 mm,	C_r = 862 000 N,
D = 240 mm,	e = 0,37,
T = 115 mm,	Y_1 = 1,8,
	Y_2 = 2,7.

Since:

$$\frac{F_a}{F_r} = \frac{30\,000}{60\,000} = 0{,}5 > e,$$

equivalent dynamic radial load will be calculated with the equation:

$$P_r = 0{,}67\,F_r + Y_2\,F_a = 0{,}67 \cdot 60\,000 + 2{,}7 \cdot 30\,000 = 121\,200\ \text{N}$$

The rating life of the bearing can be determined considering the requisite rating life:

$$L_{10} = \frac{60\,n\,L_{10h}}{10^6} = \frac{60 \cdot 200 \cdot 20\,000}{10^6} = 240\ \text{mil. revolutions}$$

Requisite dynamic load carrying capacity should be determined:

$$C_{r\,nec} = P_r \sqrt[10/3]{L_{10}} = 121\,200 \sqrt[10/3]{240} = 627\,431\ \text{N} < C_r.$$

The selected bearings correspond to the operating conditions.

Example no. 16

Operating conditions:

Loads in bearing units: F_a = 10 000 N, F_r = 30 000 N.

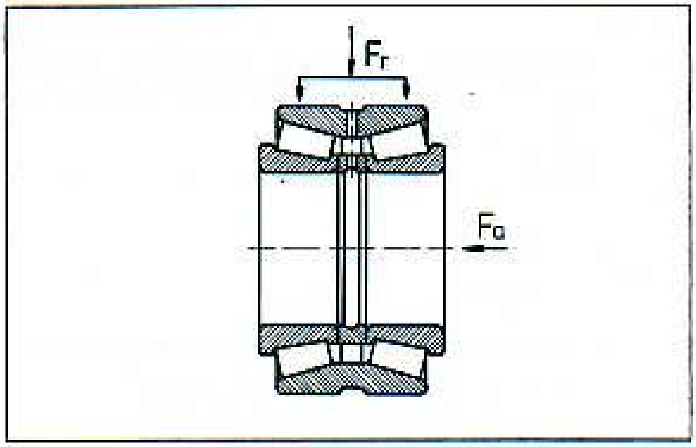
Shaft speed: n = 600 r/min

Bearing operating temperature: t = 200°C

A bearing 35220 has been mounted.

Problem to be solved

To determine the rating life of this tapered roller bearing, double row.



Answer

For bearing 35220, in catalogue, page 412:

d = 100mm,	C_r = 265 000 N,
D = 180 mm,	e = 0,42,
T = 60 mm,	Y_1 = 1,6,
	Y_2 = 2,4.

Since:

$$\frac{F_a}{F_r} = \frac{10\,000}{30\,000} = 0{,}33 < e,$$

equivalent dynamic radial load will be calculated using the equation:

$$P_r = F_r + Y_1\,F_a = 30\,000 + 1{,}6 \cdot 10\,000 = 46\,000\ \text{N}$$

Bearing rating life should be calculated:

$$L_{10} = \left(\frac{C_r}{P_r}\right)^{10/3} = \left(\frac{265\,000}{46\,000}\right)^{10/3} = 342{,}74\ \text{mil. revolutions,}$$

Requisite rating life is calculated using the equation:

$$L_{10h} = f_t \frac{10^6\,L_{10}}{60\,n} = 0{,}73 \frac{10^6 \cdot 342{,}74}{60 \cdot 600} = 6\,950\ \text{hours.}$$

Since the bearing operates at a temperature of 200°C, the rating life is to be adjusted by the temperature factor:

f_t = 0,73 (see table 2.9, page 27)

Example no. 17

Operating conditions

Loads in bearing units: F_r = 450 kN, F_a = 250 kN.

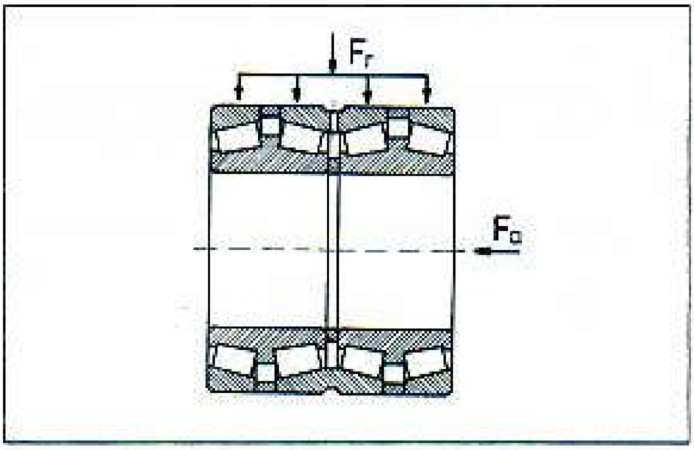
Shaft diameter: d_{min} = 240 mm

Shaft speed: n = 60 r/min

Requisite rating life: L_{10p} = 10 000 hours

Problem to be solved:

Selecting the four-row tapered roller bearing.



Answer

For constructive reasons, the bearing type T-36248 is selected. It has the following characteristics, as shown in the catalogue on page 420:

d = 240 mm C_r = 2 735 kN,
D = 410 mm e = 0,46,
T = 270 mm Y_1 = 1,5,
Y_2 = 2,2.

Since:

$$\frac{F_a}{F_r} = \frac{250}{450} = 0,55 > e,$$

equivalent dynamic radial load can be determined using the equation:

$$P_r = 0,67\ F_r + Y_2\ F_a = 0,67 \cdot 450 + 2,2 \cdot 250 = 851,5\ kN$$

The rating life of the bearing can be determined considering the requisite rating life:

$$L_{10} = \frac{60\ n\ L_{10h}}{10^6} = \frac{60 \cdot 60 \cdot 10\ 000}{10^6} = 36\ \text{mil. revolutions.}$$

Requisite dynamic load carrying capacity should be determined:

$$C_{r\ nec} = P_r \sqrt[10/3]{L_{10}} = 851,5 \sqrt[10/3]{36} = 2\ 495\ kN < C.$$

One can notice that the bearing has been properly selected for the operating conditions.

Example no. 18

Operating conditions

Loads in bearing units: F_r = 123 000 N,
F_{a1} = 175 000 N,
F_{a2} = 19 000 N.

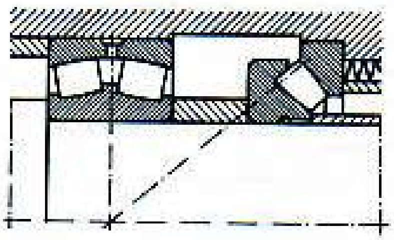
Shaft diameter: d_{min} = 200 mm

Shaft speed: n = 500 r/min

Requisite rating life: L_{10h} = 40 000 hours

Problem to be solved

For constructive reasons, the bearing 23140CAW33 (spherical roller bearing) and 29340 EM (spherical roller thrust bearing), mounted as in the figure below are to be related.



It is necessary to verify the arrangement, considering that the heavier axial load is caried by the spherical roller thrust bearing 29340EM and the lighter load (in the opposite direction) by the spherical roller bearing 23140CAW33.

Answer

The bearing 23140CAW33 characteristics in the catalogue, on page 338, is to be verified under the combined load:

d = 200 mm, C_r = 137 000 N,
D = 340 mm, e = 0,35,
B = 112 mm, Y1 = 1,9,
Y2 = 2,9.

$$\frac{F_{a2}}{F_r} = \frac{19\ 000}{123\ 000} = 0,154 < e,$$

$$P_r = F_r + Y_1\ F_{a2} = 123\ 000 + 1,9 \cdot 19\ 000 = 159\ 100\ N,$$

$$L_{10h} = \frac{1 \cdot 10^6}{60 \cdot 500}\left(\frac{1\ 370\ 000}{159\ 100}\right)^{10/3} = 43\ 623\ \text{hours} > 40\ 000\ \text{hours.}$$

The bearing 29340EM characteristics in the catalogue, on page 476, is to be verified under the pure axial load:

d = 200 mm, C_a = 1 500 000 N,
D = 340 mm, F_r = 0,
H = 85, P_a = F_{a1} = 175 000 N.

$$L_{10h} = \frac{1 \cdot 10^6}{60 \cdot 500}\left(\frac{1\ 500\ 000}{175\ 000}\right)^{10/3} = 42\ 959\ \text{hours} > 40\ 000\ \text{hours.}$$

A similar result is obtained for the rating life of the two bearings, using the data in the table 2.3, page 21, respectively:

For the bearing 23140CAW33: C_r/P_r = 8,61,
n = 500 r/min,
L_{10h} = 43 800 hours.

For the bearing 29340EM: C_a/P_a = 8,57,
n = 500 r/min,
L_{10h} = 43 103 hours.

Example no. 19

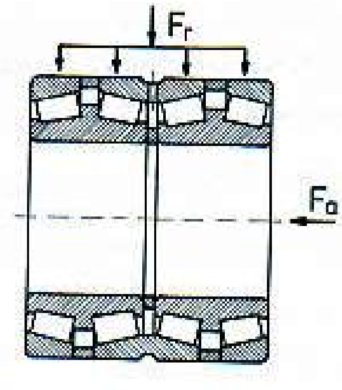
Operating conditions

Loads in bearing units: F_a = 20 kN,
F_r = 70 kN.

Shaft speed: n = 200 r/min.

Problem to be solved

To determine the minimum rating life for the four row tapered bearing T-38428P6W28 type.



Answer

The bearing T-38428P6W28 has the following characteristics, see page 422 in the catalogue:

d = 139,7 mm, C_r = 767 kN,
D = 200,025 mm, e = 0,34,
T = 160,338 mm, Y_1 = 2,0,
Y_2 = 3,0.

Since:

$$\frac{F_a}{F_r} = \frac{20}{70} = 0,285 < e,$$

equivalent dynamic radial load can be calculated using the equation:

$$L_{10} = \left(\frac{C_r}{P_r}\right)^{10/3} = \left(\frac{787}{110}\right)^{10/3} = 647{,}6 \text{ mil. revolutions,}$$

The minimum rating life will be:

$$L_{10h} = \frac{10^6 L}{60\,n} = \frac{10^6 \cdot 647{,}6}{60 \cdot 200} = 54\,000 \text{ hours.}$$

Example no. 20

Operating conditions

The load in the crane clamp-hook F_a = 1 200 000 N

Shaft diameter: d = 260 mm

Bearing speed: n = 0.

Problem to be solved

To select a thrust ball bearingz.

Answer

Under static load, the selection of the bearing depends on the basic static load. From table 2.11, page 29, it is to be selected:

s_0 = 1,5

Since the bearing is only axially loaded, the equivalent load is:

$P_a = F_a$ = 1 200 000 N

Requisite basic static load is:

$C_{0a\ nec} = s_0 P_a$ = 1,5·1 200 000 = 1 800 000 N

The bearing 51252 M, characteristics in the catalogue, page 431, is to be selected:

d = 260 mm,
D = 360 mm,
H = 79 mm,
C_{0a} = 1 967 000 N > $C_{0a\ nec}$ = 1 800 000.

Example no. 21

Operating conditions

Static axial load: F_a = 60 000 N, frequent shock loads

Shaft diameter: d = 40 mm

Bearing speed: n = 0

Problem to be solved

A cylindrical roller thrust bearing, single direction, is to be selected.

Answer

Under a static load, the selection of bearing depends on the basic static load.
From table 2.11, page 29, it is to be selected:

s_0 = 1,6

Since the bearing is axially loaded, the equivalent load is:

$P_a = F_a$ = 60 000 N

Requisite basic static load is:

$C_{0a\ nec} = s_0 P_a$ = 1,6·60 000 = 96 000 N

The bearing 81108, characteristics in the catalogue, page 453, is to be selected:

d = 40 mm,
D = 60 mm,
H = 13 mm,
C_{0a} = 137 kN.

$C_{0a\,nec}$ = 96 000 N < C_{0a} = 137 000 N