

2. Selection of bearing size

The size of a bearing is selected considering the load in the used rolling bearing and also depends on the operational rating life and prescribed operating safety.

Basic load ratings

The basic dynamic load rating C_r is used to calculate bearing dimensions while rotating under load. It expresses the bearing admissible load which will give a basic rating life up to 1000 000 revolutions.

The basic dynamic load ratings of URB bearings have been determined in accordance with national standard STAS 7160 and with the methods prescribed by ISO 281. The values are given in bearing tables.

Considering the basic dynamic load rating, is calculated the service time until the fatigue of the material appears, determining this way the calculated rating life.

Basic static load rating C_{0r} is considered in case of low speeds, low oscillating movements or in the stationary case.

The basic static load rating is defined in accordance with ISO 76 and national standard STAS 7161, as the load acting upon the stationary bearing. It corresponds to a calculated contact stress in the center of the contact area between the most heavily loaded rolling element and the raceway, of:

- 4 600 MPa for self-aligning ball bearings,
- 4 200 MPa for all other ball bearings,
- 4 000 MPa for all roller bearings.

This stress produces a permanent deformation of the rolling element and raceway which is about 0,0001 of the rolling element diameter. The loads are pure radial for radial bearings and pure axial for thrust bearings.

Bearing life

The life of a rolling bearing is defined as the number of revolutions or the number of operating hours, which the bearing is capable to endure, before the first sign of fatigue occurs on one of its rings, on the raceway or the rolling

elements.

If we want to consider only the fatigue on the bearing operating surfaces, the following conditions have to be observed:

1. The forces and speeds considered when calculating the bearing should correspond to the real operating conditions.
2. Proper lubrication should be assured during the entire operating period.
3. If the bearing carries a light load, its failure is generated by the wear.
4. Experience showed that the failure of many bearings was caused by other reasons than fatigue, such as: selection of an inadequate bearing type in a bearing joint, improper operation or lubrication, outer particles in bearing etc.

Basic rating life

The basic rating life of a single bearing or of a group of apparently identical bearings operating under identical conditions, is the life corresponding to a reliability of 90%.

The average life of a group of bearings is approximately five times longer than the basic rating life.

Basic rating life is marked with L_{10} (millions of revolutions) or L_{10h} (operating hours).

L_{10} can be calculated using the equation:

$$L_{10} = \left(\frac{C}{P} \right)^p, \text{ where:}$$

- | | |
|------------|--|
| L_{10} | - basic rating life, millions of revolutions, |
| C | - basic bearing load, kN, |
| P | - equivalent dynamic bearing load, kN, |
| p | - exponent of the life equation with the following values: |
| $p = 3$ | - for ball bearings |
| $p = 10/3$ | - for roller bearings |

The equivalent dynamic bearing load, respectively the radial and axial load, acting simultaneously can be calculated using the following equations (applicable to ball and roller radial bearings):

$$P_r = F_r, \text{ kN,} \quad \text{- for pure radial load}$$

$$P_r = XF_r + YF_a, \text{ kN,} \quad \text{- for combined load}$$

For thrust ball bearings, the following equations can be used:

$$P_a = F_a, \text{ kN,} \quad \text{- for pure axial load}$$

$$P_a = XF_r + YF_a, \text{ kN,} \quad \text{- for combined load}$$

where:

F_r = the radial component of the load, kN
 F_a = the axial component of the load, kN

In the texts preceding the bearing tables, for some groups of bearings there are given details for determining the equivalent load. Values of the coefficients X and Y can be found in tables.

For bearings operating at constant speed, the basic rating life expressed in operating hours can be calculated using the equation:

$$L_{10h} = \frac{1\,000\,000}{60n} (C/P)^p \text{ sau } L_{10h} = \frac{16\,666}{n} (C/P)^p$$

where:

n = rotational speed, r/min

Values of the basic rating life L_{10} (millions of revolutions) as a function of the ratio C/P can be found in the table 2.1.

Values of the basic rating life L_{10h} (operating hours) as a function of the ratio C/P and speed n can be found in table 2.2 for ball bearings and table 2.3 for roller bearings.

When determining the bearing size it is necessary to base the calculations on the rating life corresponding to the purpose of operation.

It usually depends on the machine type, service life and the requirements regarding operational safety.

Approximate values of the service life for various classes of machines and equipments for general purposes are given in table 2.4

The basic rating life L_{10h} of the bearings can be determined as a function of service life, using the life calculation chart on page 22.

Load ratio C/P for various life values L_{10}
(millions of revolutions)

Table 2.1

L_{10}	C/P		L_{10}	C/P	
	Ball bearings	Roller bearings		Ball bearings	Roller bearings
0,5	0,793	0,812	600	8,43	8,61
0,75	0,909	0,917	650	8,66	8,98
1	1	1	700	8,88	9,14
1,5	1,14	1,13	750	9,09	9,29
2	1,26	1,24	800	9,28	9,43
3	1,44	1,39	850	9,47	9,58
4	1,58	1,52	900	9,65	9,7
5	1,71	1,62	950	9,83	9,82
6	1,82	1,71	1 000	10	9,94
8	2	1,87	1 100	10,3	8,17
10	2,15	2	1 200	10,6	8,39
12	2,29	2,11	1 300	10,9	8,59
14	2,41	2,21	1 400	11,2	8,79
16	2,52	2,3	1 500	11,4	8,97
18	2,62	2,38	1 600	11,7	9,15
20	2,71	2,46	1 700	11,9	9,31
25	2,92	2,63	1 800	12,2	9,48
30	3,11	2,77	1 900	12,4	9,63
35	3,27	2,91	2 000	12,6	9,78
40	3,42	3,02	2 200	13	10,1
45	3,56	3,13	2 400	13,4	10,3
50	3,68	3,23	2 600	13,8	10,6
60	3,91	3,42	2 800	14,1	10,8
70	4,12	3,58	3 000	14,4	11
80	4,31	3,72	3 200	14,7	11,3
90	4,48	3,86	3 400	15	11,5
100	4,64	3,98	3 600	15,3	11,7
120	4,93	4,2	3 800	15,8	11,9
140	5,19	4,4	4 000	15,9	12
160	5,43	4,58	4 500	16,5	12,5
180	5,65	4,75	5 000	17,1	12,9
200	5,85	4,9	5 500	17,7	13,2
220	6,04	5,04	6 000	18,2	13,6
240	6,21	5,18	6 500	18,7	13,9
260	6,38	5,3	7 000	19,1	14,2
280	6,54	5,42	7 500	19,6	14,5
300	6,69	5,54	8 000	20	14,6
320	6,84	5,64	8 500	20,4	15,1
340	6,96	5,75	9 000	20,8	15,4
360	7,11	5,85	9 500	21,2	15,6
380	7,24	5,94	10 000	21,5	15,8
400	7,37	6,03	12 000	22,9	16,7
420	7,49	6,12	14 000	24,1	17,5
440	7,61	6,21	16 000	25,2	18,2
460	7,72	6,29	18 000	26,2	18,9
480	7,83	6,37	20 000	27,1	19,5
500	7,94	6,45	25 000	29,2	20,9
550	8,19	6,64	30 000	31,1	22

Ball bearings - load ratio C/P for various basic rating lives L_{10h} (operating hours) at various speeds n (r/min)

Table 2.2

L_{10h}	C/P when $n =$ 50	100	150	200	250	300	400	500	750	1 000	1 500
100	0,67	0,84	0,97	1,06	1,14	1,22	1,34	1,44	1,65	1,82	2,08
500	1,14	1,44	1,65	1,82	1,96	2,08	2,29	2,47	2,82	3,11	3,56
1 000	1,44	1,82	2,08	2,29	2,47	2,62	2,88	3,11	3,56	3,91	4,48
1 250	1,55	1,96	2,24	2,47	2,68	2,82	3,11	3,35	3,83	4,22	4,83
1 600	1,69	2,13	2,43	2,68	2,88	3,07	3,37	3,63	4,16	4,58	5,24
2 000	1,82	2,29	2,62	2,88	3,11	3,30	3,63	3,91	4,48	4,93	5,65
2 500	1,96	2,47	2,82	3,11	3,35	3,56	3,91	4,22	4,83	5,31	6,08
3 200	2,13	2,68	3,07	3,37	3,63	3,86	4,25	4,58	5,24	5,77	6,60
4 000	2,29	2,88	3,30	3,63	3,91	4,16	4,58	4,93	5,65	6,21	7,11
5 000	2,47	3,11	3,56	3,91	4,22	4,48	4,93	5,31	6,08	6,69	7,66
6 300	2,68	3,36	3,84	4,23	4,55	4,84	5,33	5,74	6,57	7,23	8,28
8 000	2,88	3,63	4,16	4,58	4,93	5,24	5,77	6,21	7,11	7,63	8,96
10 000	3,11	3,91	4,48	4,93	5,31	5,65	6,21	6,69	7,66	8,43	9,65
12 500	3,35	4,22	4,83	5,31	5,72	6,08	6,69	7,21	8,25	9,09	10,4
16 000	3,63	4,58	5,24	5,77	6,21	6,60	7,27	7,83	8,96	9,66	11,3
20 000	3,91	4,93	5,65	6,21	6,69	7,11	7,83	8,43	9,65	10,6	12,2
25 000	4,22	5,31	6,08	6,69	7,21	7,66	8,43	9,09	10,4	11,4	13,1
32 000	4,58	5,77	6,60	7,27	7,83	8,32	9,16	9,86	11,3	12,4	14,2
40 000	4,93	6,21	7,11	7,83	8,43	8,96	9,86	10,6	12,2	13,4	15,3
50 000	5,31	6,69	7,66	8,43	9,09	9,65	10,6	11,4	13,1	14,4	16,5
63 000	5,74	7,23	8,28	9,11	9,81	10,4	11,5	12,4	14,2	15,6	17,8
80 000	6,21	7,83	8,96	9,86	10,6	11,3	12,4	13,4	15,3	16,9	19,3
100 000	6,69	8,43	9,65	10,6	11,4	12,2	13,4	14,4	16,5	18,2	20,8
200 000	8,43	10,6	12,2	13,4	14,4	15,3	16,9	18,2	20,8	22,9	26,2

L_{10h}	C/P when $n =$ 2 000	2 500	3 000	4 000	5 000	6 000	8 000	10 000	15 000	20 000	30 000
100	2,29	2,47	2,62	2,88	3,11	3,30	3,63	3,91	4,48	4,93	5,65
500	3,91	4,22	4,48	4,93	5,31	5,65	6,21	6,69	7,66	8,43	9,65
1 000	4,93	5,31	5,65	6,21	6,69	7,11	7,83	8,43	9,65	10,6	12,2
1 250	5,31	5,72	6,08	6,69	7,21	7,66	8,43	9,09	10,4	11,4	13,1
1 600	5,77	6,21	6,60	7,27	7,83	8,32	9,16	9,86	11,3	12,4	14,2
2 000	6,21	6,69	7,11	7,83	8,43	8,96	9,86	10,6	12,2	13,4	15,3
2 500	6,69	7,21	7,66	8,43	9,09	9,65	10,6	11,4	13,1	14,4	16,5
3 200	7,27	7,83	8,32	9,16	9,86	10,5	11,5	12,4	14,2	15,7	17,9
4 000	7,83	8,43	8,96	9,86	10,6	11,3	12,4	13,4	15,3	16,9	19,3
5 000	8,43	9,09	9,65	10,6	11,4	12,2	13,4	14,4	16,5	18,2	20,8
6 300	9,11	9,81	10,4	11,5	12,4	13,1	14,5	15,6	17,8	19,6	22,5
8 000	9,86	10,6	11,3	12,4	13,4	14,2	15,7	16,9	19,3	21,3	24,3
10 000	10,6	11,4	12,2	13,4	14,4	15,3	16,9	18,2	20,8	22,9	26,2
12 500	11,4	12,3	13,1	14,4	15,5	16,5	18,2	19,6	22,4	24,7	28,2
16 000	12,4	13,4	14,2	15,7	16,9	17,9	19,7	21,3	24,3	26,8	30,7
20 000	13,4	14,4	15,3	16,9	18,2	19,3	21,3	22,9	26,2	28,8	33,0
25 000	14,4	15,5	16,5	18,2	19,6	20,8	22,9	24,7	28,2	31,1	35,8
32 000	15,7	16,9	17,8	19,7	21,3	22,6	24,9	26,8	30,7	33,7	38,6
40 000	16,9	18,2	19,3	21,3	22,9	24,3	26,8	28,8	33,0	36,3	41,6
50 000	18,2	19,6	20,8	22,9	24,7	26,1	28,8	31,1	35,6	39,1	44,8
63 000	19,6	21,1	22,5	24,7	26,6	28,3	31,2	33,6	38,4	42,3	48,4
80 000	21,3	22,9	24,3	26,8	28,8	30,7	33,7	36,3	41,6	45,8	52,4
100 000	22,9	24,7	26,2	28,8	31,1	33,0	36,3	39,1	44,8	49,3	56,5
200 000	28,8	31,1	33,0	36,3	39,1	41,6	45,8	49,3	56,5	62,1	71,1

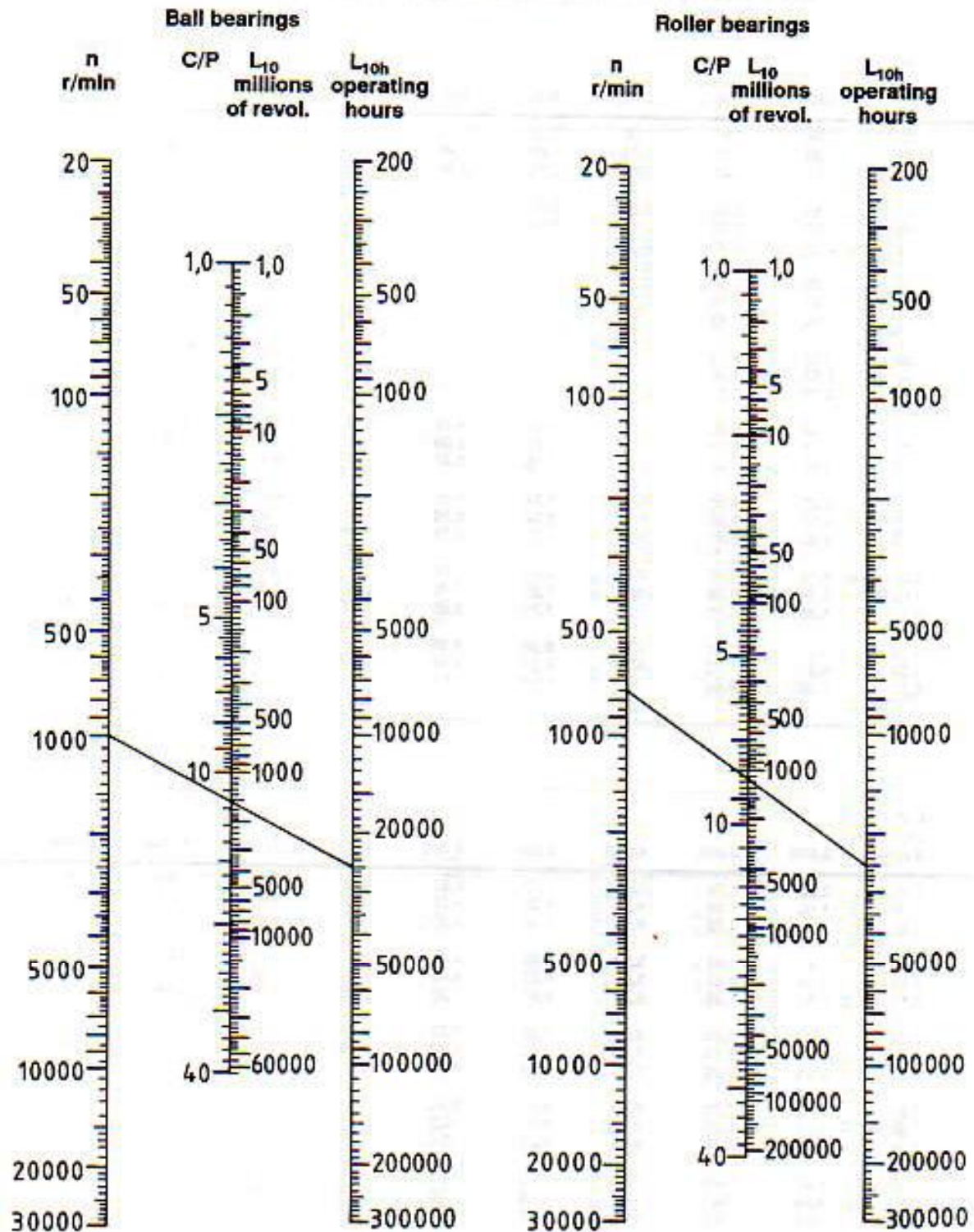
Roller bearings - load ratio C/P for various basic rating lives L_{10h} (operating hours) at various speeds n (r/min)

Table 2.3

L_{10h}	C/P when $n =$ 50	100	150	200	250	300	400	500	750	1 000	1 500
100	0,70	0,86	0,97	1,06	1,13	1,19	1,30	1,39	1,57	1,71	1,83
500	1,13	1,39	1,57	1,71	1,83	1,93	2,11	2,25	2,54	2,77	3,13
1 000	1,39	1,71	1,83	2,11	2,25	2,38	2,59	2,77	3,13	3,42	3,86
1 250	1,48	1,83	2,07	2,25	2,41	2,54	2,77	2,97	3,35	3,65	4,12
1 600	1,60	1,97	2,23	2,43	2,59	2,74	2,99	3,19	3,61	3,93	4,44
2 000	1,71	2,11	2,38	2,59	2,77	2,93	3,19	3,42	3,86	4,20	4,75
2 500	1,83	2,25	2,54	2,77	2,97	3,13	3,42	3,65	4,12	4,50	5,06
3 200	1,97	2,43	2,74	2,99	3,19	3,37	3,68	3,93	4,44	4,84	5,47
4 000	2,11	2,59	2,93	3,19	3,42	3,61	3,93	4,20	4,75	5,16	5,85
5 000	2,25	2,77	3,13	3,42	3,65	3,86	4,20	4,50	5,06	5,54	6,25
6 300	2,42	2,97	3,36	3,66	3,91	4,13	4,51	4,82	5,44	5,93	6,70
8 000	2,59	3,19	3,61	3,93	4,20	4,44	4,84	5,16	5,85	6,37	7,20
10 000	2,77	3,42	3,86	4,20	4,50	4,75	5,16	5,54	6,25	6,81	7,70
12 500	2,97	3,65	4,12	4,50	4,81	5,06	5,54	5,92	6,68	7,29	8,23
16 000	3,19	3,93	4,44	4,84	5,16	5,47	5,96	6,37	7,20	7,85	8,86
20 000	3,42	4,20	4,75	5,16	5,54	5,85	6,37	6,81	7,70	8,39	9,48
25 000	3,65	4,50	5,06	5,54	5,92	6,25	6,81	7,29	8,23	8,97	10,1
32 000	3,93	4,84	5,47	5,96	6,37	6,73	7,34	7,85	8,86	9,66	10,9
40 000	4,20	5,16	5,85	6,37	6,81	7,20	7,85	8,39	9,48	10,3	11,7
50 000	4,50	5,54	6,25	6,81	7,29	7,70	8,39	8,97	10,1	11,0	12,5
63 000	4,82	5,93	6,70	7,30	7,81	8,25	8,99	9,61	10,9	11,8	13,4
80 000	5,16	6,37	7,20	7,85	8,39	8,86	9,66	10,3	11,7	12,7	14,4
100 000	5,54	6,81	7,70	8,39	8,97	9,48	10,3	11,0	12,5	13,6	15,4
200 000	6,81	8,39	9,48	10,3	11,0	11,7	12,7	13,6	15,4	16,7	18,9

L_{10h}	C/P when $n =$ 2 000	2 500	3 000	4 000	5 000	6 000	8 000	10 000	15 000	20 000	30 000
100	2,11	2,25	2,38	2,59	2,77	2,93	3,19	3,42	3,86	4,20	4,75
500	3,42	3,65	3,86	4,20	4,50	4,75	5,16	5,54	6,25	6,81	7,70
1 000	4,20	4,50	4,75	5,16	5,54	5,85	6,37	6,81	7,70	8,39	9,48
1 250	4,50	4,81	5,06	5,54	5,92	6,25	6,81	7,29	8,23	8,97	10,1
1 600	4,84	5,16	5,47	5,96	6,37	6,73	7,34	7,85	8,86	9,66	10,9
2 000	5,16	5,54	5,85	6,37	6,81	7,20	7,85	8,39	9,48	10,3	11,7
2 500	5,54	5,92	6,25	6,81	7,29	7,70	8,39	8,97	10,1	11,0	12,5
3 200	5,96	6,37	6,73	7,34	7,85	8,29	9,03	9,66	10,9	11,9	13,4
4 000	6,37	6,81	7,20	7,85	8,39	8,86	9,66	10,3	11,7	12,7	14,4
5 000	6,81	7,29	7,70	8,39	8,97	9,48	10,3	11,0	12,5	13,6	15,4
6 300	7,30	7,81	8,25	8,99	9,61	10,2	11,1	11,8	13,4	14,6	16,5
8 000	7,85	8,39	8,86	9,66	10,3	10,9	11,9	12,7	14,4	15,7	17,7
10 000	8,39	8,97	9,48	10,3	11,0	11,7	12,7	13,6	15,4	16,7	18,9
12 500	8,97	9,59	10,1	11,0	11,8	12,5	13,6	14,5	16,4	17,9	20,2
16 000	9,66	10,3	10,9	11,9	12,7	13,4	14,6	15,7	17,7	19,3	21,8
20 000	10,3	11,0	11,7	12,7	13,6	14,4	15,7	16,7	18,9	20,6	23,3
25 000	11,0	11,8	12,5	13,6	14,5	15,4	16,7	17,9	20,2	22,0	24,9
32 000	11,9	12,7	13,4	14,6	15,7	16,5	18,0	19,3	21,8	23,7	26,8
40 000	12,7	13,6	14,4	15,7	16,7	17,7	19,3	20,6	23,3	25,4	28,7
50 000	13,6	14,5	15,4	16,7	17,9	18,9	20,6	22,0	24,9	27,1	30,6
63 000	14,6	15,6	16,5	17,9	19,2	20,3	22,1	23,6	26,7	29,1	32,8
80 000	15,7	16,7	17,7	19,3	20,6	21,8	23,7	25,4	28,7	31,2	35,3
100 000	16,7	17,9	18,9	20,6	22,0	23,3	25,4	27,1	30,6	33,4	37,7
200 000	20,6	22,0	23,3	25,4	27,1	28,7	31,2	33,4	37,7	41,1	46,4

Basic rating life calculation chart



Example:

1. It is required to determine the size of a deep groove ball bearing single row, considering the following conditions:

- Basic rating life $L_{10h} = 25\ 000$ operating hours
- Rotational speed $n = 1\ 000$ r/min
- Load in bearing $F_r = 5$ kN

The chart shows that $C/P = 11,6$; $C = 11,6 \cdot P = 11,6 \cdot 5 = 58$ kN, in the catalogue on page 133, you can select the bearing 6310 type with the following characteristics: $C_r = 61,8$ kN; $n = 7\ 000$ r/min.

2. What is the basic rating life of the bearing NU 210E which is operating under a radial load of 7,7 kN at a rotational speed $n = 750$ r/min?

See page 236 in the catalogue and you will find for the bearing, NU 210E type, the following values: $C_r = 63,7$ kN, $n = 8\ 000$ r/min. From the chart, for a bearing operated at a rotational speed of 750 r/min and $C_r/P_r = 63,7/7,7 = 8,3$, a basic rating life $L_{10h} = 25\ 000$ operating hours is determined.

Recommended basic rating lives for general purpose machines

Table 2.4

Application	Recommended basic rating life L _{10h} (operating hours)
Household machines, technical apparatus for medical use, instruments, agricultural machines:	300...3 000
Machines used for short periods or intermittently: electric hand tools, cranes, lifting tackles in workshops, building machines:	3 000...8 000
Machines used intermittently or for short periods with high operational reliability: lifts, small cranes:	8 000...12 000
Machines for use 8 hours/day but not always at full capacity: machines for general purposes, electric motors for industrial use, rotary crushers, gear drives for general purposes:	10 000...25 000
Machines operating 8 hours/day at full capacity: machine tools, woodworking machines, large cranes, printing equipment, ventilators, separators, centrifuges:	20 000...30 000
Machines for continuous use 24 hours/day: Rolling mill gear units, medium sized electrical machinery, compressors, pumps, textile machines, mine hoists:	40 000...50 000
Hydraulic machines, rotary furnaces, capstans, propulsion machinery for sea vessels (propellers for sea vessels):	50 000...10 0000
Machines for continuous use 24 hours/day with high reliability: large electric machinery, mine pumps and mine ventilators, power station plants, machines for cellulose industry, pumping units:	100 000...

The basic rating life of road and rail vehicle bearings, for wheel - axle bearings, is expressed as a function of the wheel diameter and covered distance (km), using the equation:

$$L_{10} = \frac{1\,000}{\pi D} L_{10s}, \text{ respectively: } L_{10s} = \frac{\pi D}{1\,000} L_{10}$$

where:

- L₁₀ - basic rating life, millions of revolutions
- L_{10s} - service life distance, millions of kilometers
- D - wheel diameter, m

Approximate values for the service life distance (kilometers covered), in case of light loaded cars and rail vehicles are given in table 2.5.

Values for basic rating life L_{10s}

Table 2.5

Type of vehicle	L _{10s} /10 ⁶ km
Wheel hub bearings for road vehicles	
- light loaded cars	0,3
- trucks, buses	0,6
Axlebox bearings for rail vehicles:	
goods wagons (according to UIC)	0,8
suburban vehicles, trams	1,5
long distance passenger carriages	3
motorailers	3-4
Diesel and electric locs	3-4

In case of bearings which do not rotate but oscillate from a central position through an angle, as shown in fig.1, basic rating life can be determined as follows:

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

where:

Complete oscillation = 4γ from point 0 to point 4

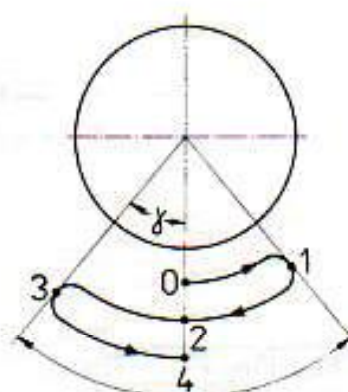


Fig. 1

- L_{10osc} - basic rating life, millions of cycles
- γ - oscillation amplitude (angle of maximum deviation from center position), degrees.

If the amplitude of oscillation is very small, it can be ignored for basic rating life determination.

Fluctuating dynamic load and speeds

In many cases, in operation speed and magnitude of load fluctuate. Therefore, a mean dynamic load is to be calculated.

The load acting on the bearing can vary as shown in fig. 2-a and 2-b.

In this case, the mean load can be determined using the equation:

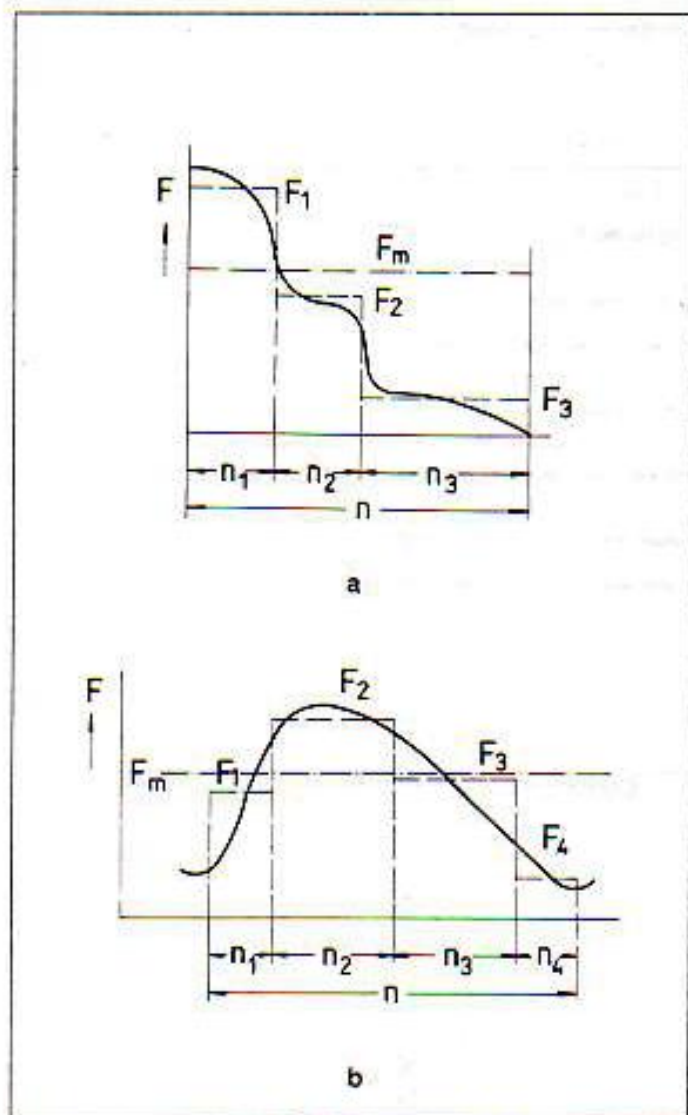


Fig. 2

$$F_m = \sqrt[p]{\frac{F_1^p n_1 + F_2^p n_2 + \dots + F_n^p n_n}{n}}$$

where:

- F_m - constant mean load, kN
- $F_1, F_2, \dots, F_n$ - constant load during $n_1, n_2, \dots, n_n$ revolutions, kN
- n - total number of revolutions ($n = n_1 + n_2 + \dots$) during which loads $F_1, F_2, \dots$ act
- p - exponent -3 - for ball bearings,
-10/3 - for roller bearings.

If the bearing speed is constant and the magnitude of the load is between the minimum value F_{min} and a maximum value F_{max} as shown in fig. 3 a and b, the mean load can be obtained from:

$$F_m = \frac{F_{min} + 2F_{max}}{3}, \text{ kN}$$

If the external radial load consists of a load F_1 which is constant in magnitude and direction and a load F_2 which is variable in direction and constant in magnitude (F_1 and F_2 acting in the same plane) as shown in fig. 4, the mean

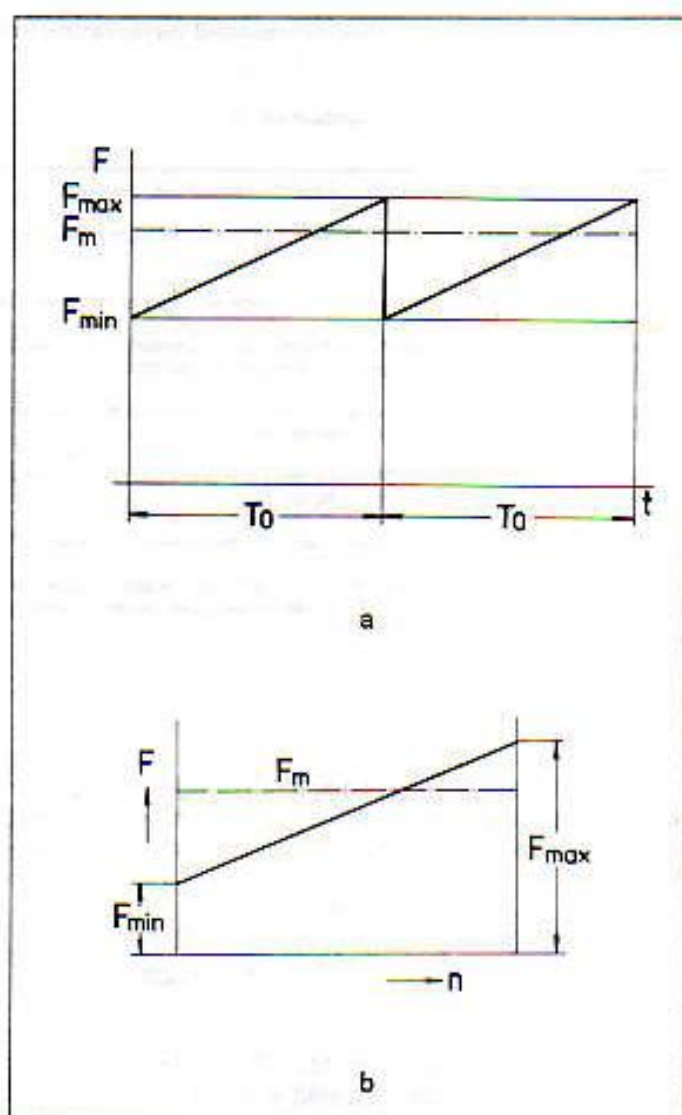


Fig. 3

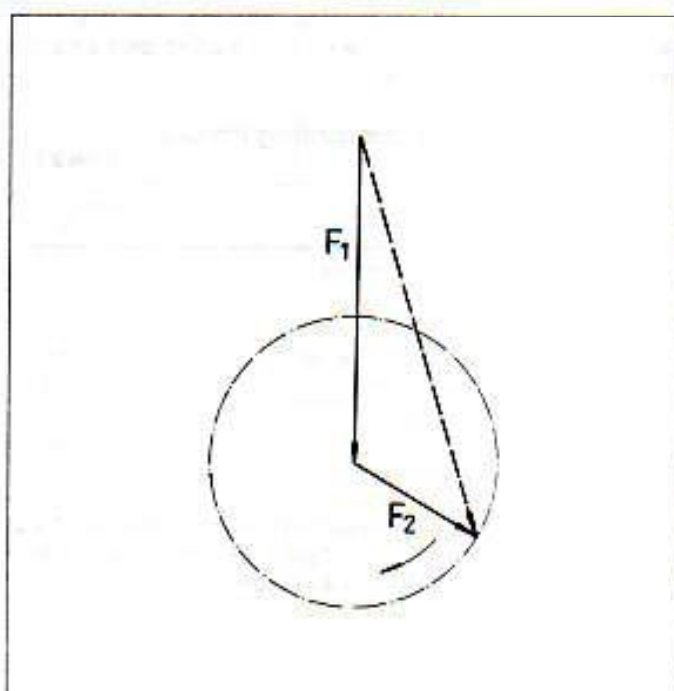


Fig. 4

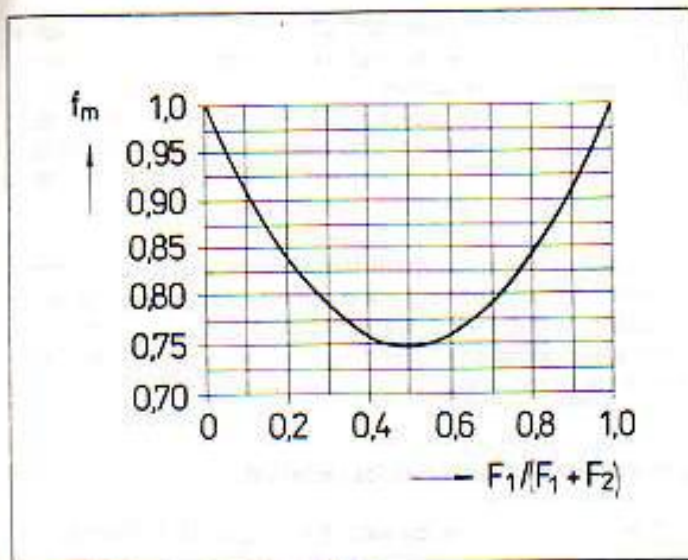


Fig. 5

load can be determined using the equation:

$$F_m = f_m (F_1 + F_2), \text{ kN}$$

Values for the factor f_m can be obtained from fig. 5.

In case of sinusoidal movement as it is shown in fig. 6, the mean load can be obtained from:

$$F_m = \sqrt{\frac{4}{3\pi}} F_{\max}, \text{ kN}$$

$$F_m = 0.75 F_{\max}, \text{ kN, for ball bearings}$$

$$F_m \approx 0.77 F_{\max}, \text{ kN, for roller bearings}$$

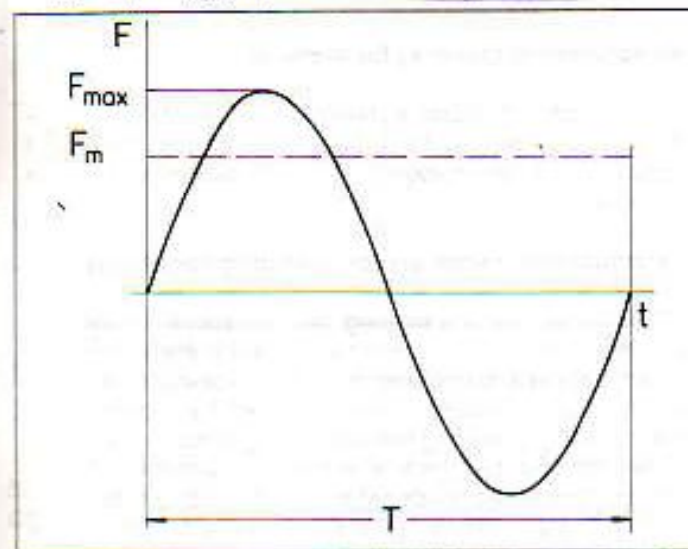


Fig. 6

In case of oscillating movements with oscillating angle γ , as shown in fig. 7, equivalent mean load can be calculated with the equation:

$$F_m = \sqrt{\frac{\gamma}{90^\circ}} F_r, \text{ kN}$$

If the fluctuating load acts in a pure radial direction for radial bearings and in a pure axial direction for thrust bearings, the equivalent dynamic bearing load will be:

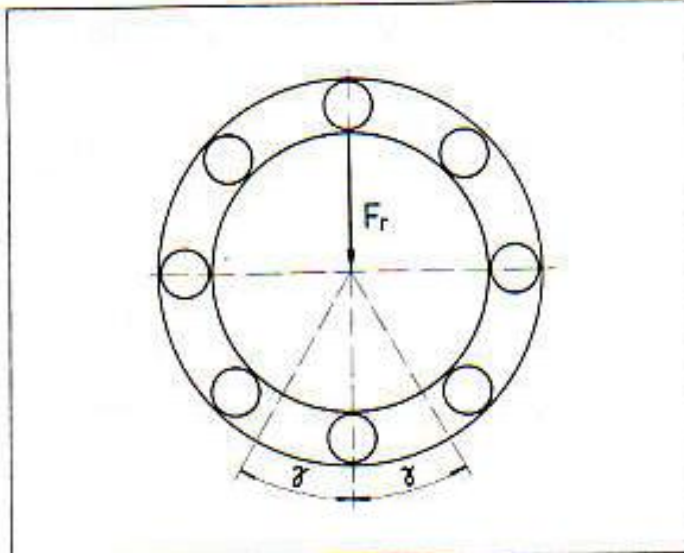


Fig. 7

$$P_r = F_m$$

For combined loads, with radial load F_r and axial load F_a constant in direction and magnitude, the equivalent dynamic load can be calculated using the equation

$$P_r = X F_r + Y F_a, \text{ kN}$$

In case of combined loads, with radial and axial loads changing in time, ratio F_r/F_a being constant, the equivalent dynamic load can be calculated by:

$$P_m = X F_{r,m} + Y F_{a,m}$$

where:

- P_m - equivalent mean dynamic load, kN,
- $F_{r,m}$ - radial mean load, kN,
- $F_{a,m}$ - axial mean load, kN,
- X, Y - factors of radial and axial load.

In case the direction and magnitude of the load change in time and speeds fluctuate in time, the equivalent mean dynamic load will be calculated using the equation:

$$P_m = \sqrt[p]{\frac{P_1^p n_1 + P_2^p n_2 + \dots + P_n^p n_n}{n}}$$

where:

- P_m - equivalent mean dynamic load, kN
- P_1 - equivalent dynamic load for n_1 revolutions, kN
- P_2 - equivalent dynamic load for n_2 revolutions, kN
- P_n - equivalent dynamic load for n_n revolutions, kN
- n_1 - number of revolutions for load P_1
- n_2 - number of revolutions for load P_2
- n_n - number of revolutions for load P_n
- n - number of revolutions ($n = n_1 + n_2 + \dots + n_n$)
- p - exponent: -3 - for ball bearings, -10/3 - for roller bearings

Basic dynamic load of a bearing group

In case of ball and roller bearings especially, a bearing group of the same type mounted close together is required, so that heavy radial loads can be carried.

In order to take over the load uniformly these bearings should be mounted in order to equal the diameter deviations to the radial clearances.

These deviations must be kept below 1/2 of the admitted tolerance class.

Basic dynamic load for a bearing group as a function of the basic load of the single bearing can be calculated using the equation:

$$C_{ri} = C_r i^n$$

where:

- C_{ri} - basic dynamic load of the bearing group, kN,
- C_r - basic dynamic load of the single bearing, selected from the tables,
- i - number of bearings of the same type, mounted close together,
- n - exponent depending on the bearing type:
0,7 - for ball bearings
7/9 - for roller bearings

Values of i^n are given in table 2.6.

Values for i^n

Table 2.6

i	$i^{0,7}$	$i^{7/9}$
2	1,62	1,71
3	2,16	2,35
4	2,84	2,94

The equivalent dynamic load for each group of bearings is calculated considering the specifications in the introductory text preceding the respective group.

Adjusted rating life

Basic rating life L_{10h} is often satisfactory for bearing performances. This life means a reliability of 90% for material and a modern and usual manufacturing technology, as well as for conventional operating conditions.

For a reliability over 90% (100-n)%, ISO recommends steels elaborated in better conditions, high level manufacturing technologies and specific operating conditions. In this case, adjusted rating life can be calculated as follows:

$$L_{na} = a_1 a_2 a_3 L_{10}$$

$$L_{na} = a_1 a_2 a_3 \left(\frac{C}{P} \right)^p$$

where:

- L_{na} - adjusted rating life, millions of revolutions
- a_1 - life adjustment factor considering reliability
- a_2 - life adjustment factor considering the material and manufacturing conditions
- a_3 - life adjustment factor considering the operating conditions.

In case of life adjustment factors a_1, a_2, a_3 greater than 1, when calculating adjusted rating life, prudence and familiarity with bearing manufacturing and operating conditions, including shaft bending and housing stiffness are recommended.

Life adjustment factor a_1 for reliability

The bearing failure caused by fatigue is subjected to certain statistic laws. Therefore, this fact is recommended to be considered when calculating the bearing life.

Values of the life adjustment factor a_1 for reliabilities over than 90% are given in table 2.7.

Values for factor a_1

Table 2.7

Reliability, %	L_{na}	a_1
90	L_{10a}	1
95	L_{5a}	0,62
96	L_{4a}	0,53
97	L_{3a}	0,44
98	L_{2a}	0,33
99	L_{1a}	0,21

Life adjustment factor a_2 for material

Life adjustment factor a_2 takes into account the properties of the material, heat treatment of the steel and manufacturing technologies. For URB bearings, $a_2 = 1$ is recommended.

Life adjustment factor a_{23} for operating conditions

The longest life of a bearing can be reached in case of hydrodynamic lubrication, namely where there is no direct contact between rolling elements and raceway due to the lubricant film. In this field, many studies have been done by world leading bearing manufacturing companies. These studies showed that there is relationship between life adjustment factor a_2 for material and life adjustment factor a_3 for operating conditions. Preferably these factors should be unified, obtaining factor a_{23} . In this case, adjusted rating life would be:

$$L_{na} = a_1 a_{23} L_{10} \text{ or } L_{na} = a_1 a_{23} L_{10h}$$

The values of a_{23} coefficient depend on the lubricant used for bearing lubrication, namely on the ratio of the oil viscosity at $+40^\circ\text{C}$, ν (initial value) to the viscosity required for adequate lubrication at the operating temperature ν_1 . The values are given in table 2.8.

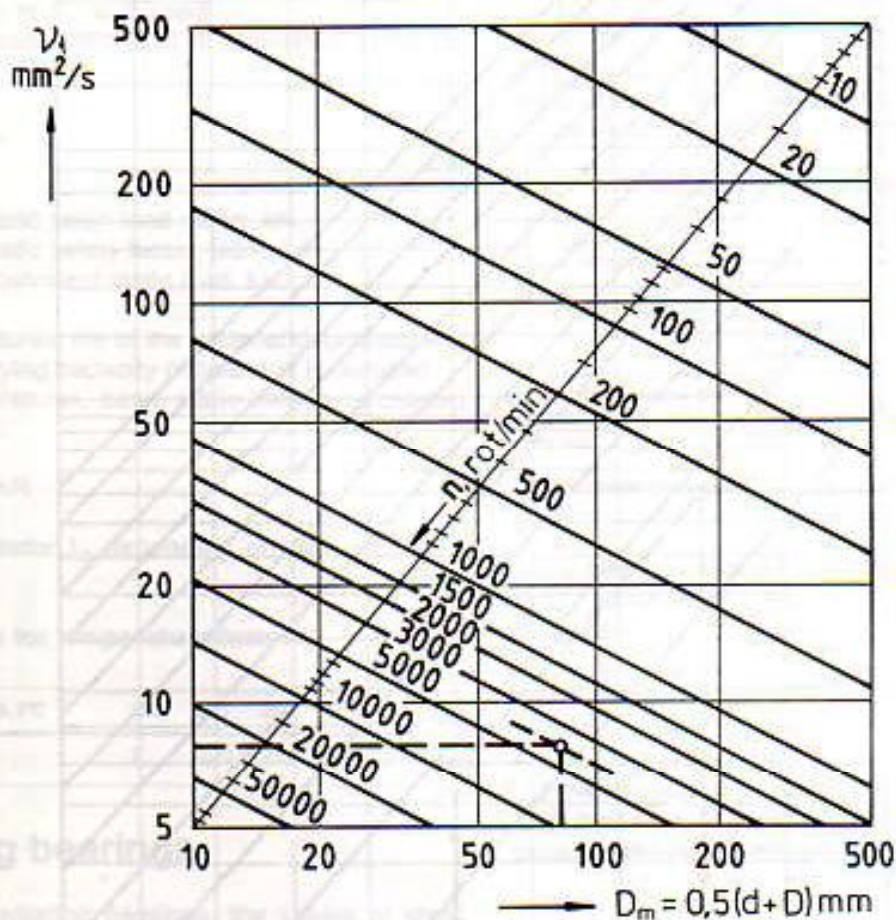


Fig. 8

Values for factor a_{23}

Table 2.9

$\frac{\nu}{\nu_1}$	0,1	0,2	0,5	1	1,5	2	3	4	5
a_{23}	0,45	0,55	0,75	1	1,3	1,6	2	2,5	2,5

The values of viscosity ν_1 as a function of the mean bearing diameter and operating speed are given in the diagram fig. 8.

Kinematic viscosity ν at the temperature of $+40^\circ\text{C}$ can be determined from the diagram fig. 9 in accordance with ISO, if the bearing operating temperature is known.

In case of grease lubrication, calculation should be done considering the basic oil viscosity and the value of the life adjustment factor a_{23} will be smaller than 1.

Example of oil kinematic viscosity calculation for bearing lubrication:
The bearing 6212 operates at a speed of 3500 r/min and a temperature of $+70^\circ\text{C}$.

Mean diameter will be:

$$0,5 (d + D) = 0,5 (80 + 110) = 85 \text{ mm.}$$

From the diagram fig. 9, at a temperature of $+70^\circ\text{C}$, for a viscosity $\nu_1 = 8 \text{ mm}^2/\text{s}$, the viscosity at $+40^\circ\text{C}$ is $20 \text{ mm}^2/\text{s}$ (cSt).

In this case should be selected an oil in accordance with ISO VG22 with kinematic viscosity limits: $\nu_{\min} = 19,8 \text{ mm}^2/\text{s}$ (cSt) and $\nu_{\max} = 24,2 \text{ mm}^2/\text{s}$ (cSt).

In case of bearing operating at temperatures higher than $+150^\circ\text{C}$, an adjustment factor f_t for temperature should be added to the life adjustment factor a_{23} . Adjusted rating life will be:

$$L_{na} = a_1 a_{23} f_t L_{10} \text{ or } L_{na} = a_1 a_{23} f_t L_{10h}$$

Values for the life adjustment factor f_t for temperature are given in table 2.9.

Values for operating temperature factor f_t

Table 2.9

Operating temperature, $t^\circ\text{C}$	150	200	250	300
f_t	1	0,73	0,42	0,22

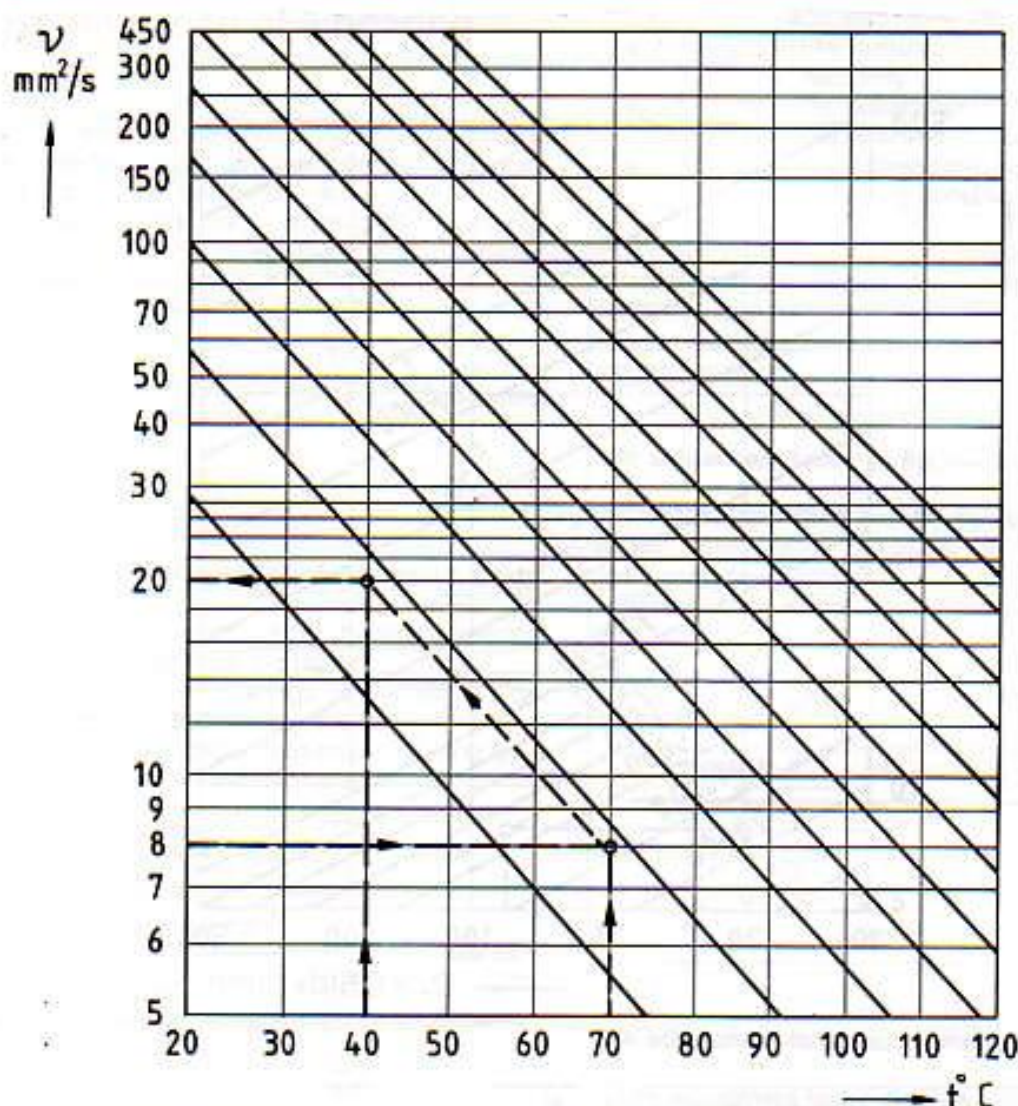


Fig. 9

Static load

When the bearing is stationary or rotates at slow movements or very low speeds (lower than 10 r/min), basic static load is not determined by the material fatigue but by permanent deformation caused at the rolling element/raceway contact.

It is also the case of rotating bearings when they have to sustain heavy shock loads which act during a fraction of their revolution.

Generally, the value of the load may increase up to the value of the basic static load C_0 , without altering the bearing operating properties.

Equivalent static load

Combined static load (radial and axial load acting simultaneously on bearing) must be converted into an equivalent static bearing load. This is defined as the load (radial for radial bearings and axial for thrust bearings) which if applied, would cause the same permanent deformation in the bearing as the real load operating upon it.

Equivalent static load is obtained from the general equation:

$$P_0 = X_0 F_r + Y_0 F_a, \text{ kN},$$

where:

- P_0 - equivalent static bearing load, kN,
- F_r - radial component of the heaviest static load, kN,
- F_a - axial component of the heaviest static load, kN,
- X_0 - radial load factor of the bearing,
- Y_0 - axial load factor of the bearing.

Data needed to calculate equivalent static load can be found in text and in bearing tables.

Requisite basic static load rating

When determining bearing size on the basis of the static load, a static safety factor s_0 is used.

The requisite basic static load is calculated using the equation:

$$C_{0r} = s_0 P_{0r}, \text{ kN},$$

where:

- C_{0r} - basic static load rating, kN,
- s_0 - static safety factor, table 2.11,
- P_{0r} - equivalent static load, kN.

At high temperatures, life of the material decreases and the static load carrying capacity of bearings is reduced.

For high temperatures, basic static load is calculated using the equation:

$$C_{0r} = f_{0t} s_0 P_{0r}, \text{ kN}$$

The values of factor f_{0t} depending on temperature is given in table 2.10

Values for temperature factor f_{0t}

Table 2.10

Operating temperature, °C	150	200	250	300
f_{0t}	1	0,85	0,85	0,75

Non-rotating bearings

In case of non-rotating bearings, the values of static safety factor s_0 for certain applications are given in table 2.11. These values are also valid for bearings with oscillating movements.

Values for static safety factor s_0

Table 2.11

Application	s_0
Variable pitch propeller for aircraft	0,5
Gates for barrages, dams, sluices	1
Opening bridges	1,5
Crane hooks for:	
- large cranes without additional loads	1,5
- small cranes with additional dynamic loads	1,8

Rotating bearings

In case of fluctuating or oscillating loads and especially when heavy shock loads are acting during a fraction of revolution, it is necessary to check if the bearing has the proper static load carrying capacity.

Heavy shock loads higher than the basic static bearing load produce permanent deformations not uniformly distributed on raceway, which influence negatively upon bearing running.

Generally, heavy shock loads cannot be exactly calculated and in certain cases they produce deformations of bearing housing and consequently an unfavorable load

distribution in bearing.

When a bearing rotates under maximum load, raceway becomes uniformly deformed on all its outer surface without any imprint.

For various operating conditions, maximum load acting upon the bearing is calculated with static safety factor s_0 , depending on the vibrations and shock loads.

The values of static safety factor are given in table 2.12.

Values for static safety factor s_0

Table 2.12

Type of operation	Requirements regarding quiet running					
	Unimportant		Normal		High	
	Ball bearings	Roller bearings	Ball bearings	Roller bearings	Ball bearings	Roller bearings
Smooth, vibration-free	0,5	1	1	1,5	2	3
Normal	0,5	1	1	1,5	2	3,5
Heavy shock loads	> 1,5	> 2,5	> 1,5	> 3	> 2	> 4

For bearings with a known equivalent static load, static safety factor s_0 is necessary to be checked using the equation:

$$s_0 = \frac{C_{0r}}{P_{0r}}$$

If the value of s_0 is less than that recommended in table 2.12, then a bearing with a higher basic static load carrying capacity should be selected.

Basic static load for a group of bearings

Where more bearings of the same type are mounted close together to take over a static load, the load magnitude supported by these bearings will be calculated from:

$$C_{0ri} = C_{0r} i,$$

where:

- C_{0ri} - basic static load of the bearing group,
- C_{0r} - basic static load of the single bearing (from tables),
- i - number of bearings.