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SELECTION OF BEARING SIZE

Basic load ratings

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.

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 the bearings have been determined in accordance with 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, 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 live

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} (milions of revolutions) or L_{10h} (operating hours).

L_{10} can be calculated using the equation:

$L_{10} = (C/P)^p$, where:

L_{10} - basic rating life, milions 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):

$P = F_r$, kN - for pure radial load,
$P = XF_r + YF_a$, kN - for combined load,

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

$P = F_a$, kN - for pure radial load,
$P = XF_r + YF_a$, kN - for combined load,

where:
F_r - the radial component of the load, kN,
F_a - the axial component of the load, kN,
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:

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

where:
n =rotational speed, r/min.
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 1.

Table 1

Application	**Recommended basic rating life L_{10h} (operating hours)**
Household machines, technical apparata 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 crushes, 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 fumaces, capstans, propulsion machinery for sea vessels (propellers for sea vessels):	50 000...100 000
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:

$L_{10} = (1000/pD)L_{10s}$, respectively: $L_{10s} = (pD/1000)L_{10}$.

where:
L_{10} - basic rating life, millions of revolutions
L_{10s} - service live 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

Table 2

Type of vehicle	$L_{10s}/10^6$, km
Wheel hub bearings for road vehicles	
- lightly 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	3-5

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

$L_{10OSC} = (180/2g)L_{10}$

where:

L_{10osc} - basic rating life, millions of cycles
g - 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.

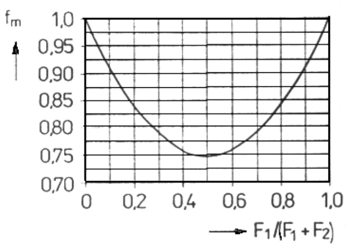

Figure 1

Dynamic load and variable speed

In many operation cases, the size of the load and rotational speed are variable, when an average constant radial F_{mr} or axial F_{ma} load must be calculated for the calculus of the dynamic equivalent load.

1) If at constant rotational speed the force acting on the rolling bearing linearly varies between a minimum value F_{mr}, a_{min} and a maximum value F_{mr}, a_{max}, keeping its direction within a certain interval of time, the medium load results from the following relation:

$$F_{mr,n} = (F_{r,amin} + 2 \cdot F_{r,amax})/3, \quad [KN]$$

2) If the radial load that acts on a rolling bearing is made of a force F_{r1} which is constant in size and direction (for example the weight of a rotor) and a constant rotation force F_{r2} (for example the unbalancing phenomena), the average load results from

$$F_{rm} = f_m(F_{r1} + F_{r2}), \quad [KN]$$

The values for fm coefficient are obtained from the figure 1:

3) For a radial load, F_r applied on bearing which oscillates from a central position through an angle 2g(see figure 2), the average radial load is done by the following relation:

$$F_{mr} = f_0F_r, \text{ [KN]}$$

with values for f_0 coefficient given in table 1 according to the oscillation angle g and the exponent of the life formula, p.

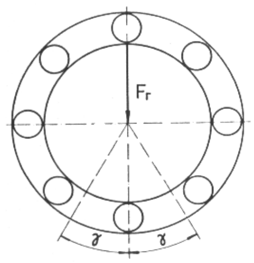

Figure2

Table. 1

γ^0	f_o	
	p=3	p=10/3
10	0,47	0,53
20	0,61	0,65
30	0,69	0,72
45	0,79	0,81
60	0,87	0,89
75	0,94	0,95
90	1,0	1,0

For variable loads in size, time and direction and for different rotational speeds, the average dynamic loads given by the following formula:

$$F_{mr,a} = [\ \Sigma(F_{ir,a}{}^{p} \cdot n_i)/n]^{1/p},\ [KN]$$

where: $F_{mr,a}$ - average constant load, radial or axial, [KN]
$F_{ir,a}$ - constant loads applied on the duration of effecting of rotations n_i, [KN]
n_i - the no. of rotations corresponding to $F_{ir,a}$ loads
$n = \Sigma\ n_i$, rot/min
p = 3 for ball bearings and
p = 10/3 for roller bearings

Basic dynamic load of a bearing group

Assembling two or even more identical bearings, the base dynamic load of the *i* bearings assembly being calculated with the following relation:

$C_r = i^{0.7}\ C_{ri}$ [KN] for punctual contact bearings;
$C_r = i^{7/9}\ C_{ri}$ [KN] for linear contact bearings.

To take evenly the loads, these bearings must be paired so that the diameter and radial clearance deviations are max. 1/2 of the allowed tolerance field. Relation which refers to the basic dynamic load of the roller bearing indicated in roller bearing tables depends on “basic rating life” (L_{10}) which, according to ISO 281 means the life attained or exceeded by 90% of the bearing group of the same type dimension operating in the same conventional conditions (good mounting, protection against foreign particles penetration, correct lubrication, correct loading, non exposure to extreme speeds and temperatures).

Adjusted rating life

After bearing selection (according to the basic dynamic load), it is recommended to determine its effective life (adjusted rating life for conditions different from those mentioned in ISO 281) with the following relation:

$$L_n = a_1 a_2 a_3 f_t (C_r/P_r)^p$$

where: L_n – adjusted rating life (mil. of rotations),
a_1 - correction factor that takes into account the reliability (table 1);
a_2 - correction factor that takes into account the quality of the material and manufacturing technology (for materials and technologies used for manufacturing URB bearings a_2 = 1)
a_3 - correction factor that takes into account the operating conditions and lubrication quality.
f_t – correction factor according to the operation temperature (table 3)

The connection between these two last connection factors leads to their fusion into a single factor, a_{23}, whose value is given in table. 2 and depends on the ratio between the cinematic viscosity of the oil at 40°C, ν initial in cSt or mm²/s (see figure1) and the viscosity required for a correct lubrication at the operation temperature, ν_1 see figure 2.

Table. 1

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

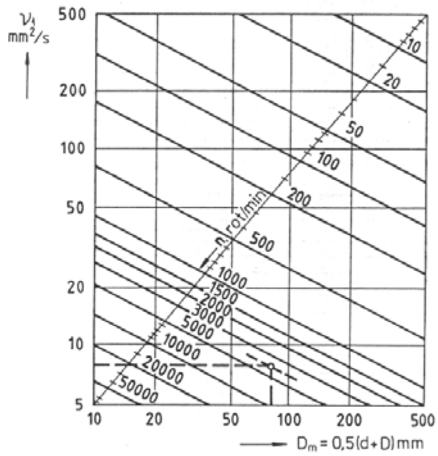

Figure 1

Example of calculation of the kinematic viscosity of the oil:

For a bearing with D_m = 85 mm which operates at a rotational speed of 3500 rot/min, it results from figure 2, ν = 8 mm²/s. From figure 2 results that for the operating temperature of 70°C to obtain ν_1 viscosity it is required an initial viscosity of ν= 20 mm²/s.

Table 2

ν/ν_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

Table 3

Running temperature [°C]	150	200	250	300
f_t	1	0,73	0,42	0,22

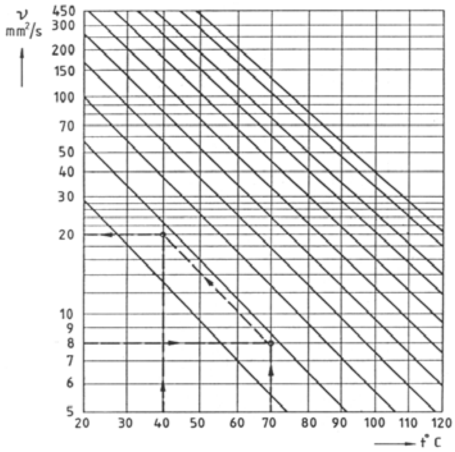

Figure 2

Static load

a) Basic static load

Basic static load, C_{or}, is given in the bearings catalogues for every size and it is taken in consideration when the bearing is stationary, has slow oscillations, low speed (n<10 rot/min) or when during the rotating these must support heavy shock loads. In this case, the operation safety is determined by the size of the deformations of the raceway of the bearing.

Basic static load is determined according to ISO 76 and represents the load that produces a permanent deformation of 0.0001 from the diameter of the rolling element, the load being purely radial for radial bearings and purely axial for thrust bearings.

The combined static load (radial and axial loads that are acting simultaneous on a bearing) must be converted into an equivalent load which results from the general formula:

$$P_0 = X_0F_r + Y_0F_a \text{ , KN}$$

where:
- P_o equivalent static load of the roller bearing, KN
- F_r the radial component of the heavy static load in KN
- F_a the axial component of the heavy static load in KN
- X_o the radial load factor of the bearing
- Y_o the axial load factor of the bearing

X_o and Y_o are given in the bearings tables and catalogues according to the type of the bearing and ratio F_a/F_r

Knowing the shaft diameter “d”, the size of the bearing is determined from the condition of inequality:

$$C_or \geq s_of_{ot}P_o \text{ , KN}$$

where: s_o is a static safety factor coefficient chosen according to table. 1 (for the non-rotating bearings or for the bearings with oscillating movements) and table 2 (for rotating-bearings subject to oscillating loads or heavy shock loads with short duration).

The heavy shock loads that are higher than the basic static load of the bearing are producing remanent deformations not uniformly distributed on raceway which negatively influence the good operation of the roller bearing.

At high operating temperatures C_{or} is corrected with the following factor:

f_{ot} = - 1 for a temperature of 150 °C
-0,95 for a temperature of 200 °C
-0,85 for a temperature of 250 °C
-0,75 for a temperature of 300 °C

Table 1

Application	s_0
Adjustable pitch airscrew for planes	0,5
Gates of barrages, dams, flood gates	1
Mobile bridges	1,5
Crane hooks for:	
- small cranes, with additional dynamic loads	1,6
- large cranes, without additional loads	1,5

Table 2

Load type	Silent running requirements (without noise)					
	Low		Normal		High	
	Bearings		Bearings		Bearings	
	balls	roller	balls	roller	balls	roller
Smooth, without vibrations	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

In the situation when more bearings of the same type are mounted close together, the amount of the static load supported by them will be determined with the following relation:

$$C_{0ri} = C_{0r} \cdot i, \text{ KN,}$$

where: C_{0ri} - basic static load of the bearing group, KN
C_{0r} - basic static load of the single bearing taken from tables, KN
i - number of bearings.