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Rolling bearings — Dynamic load ratings and rating life

Roulements — Charges dynamiques de base et durée nominale

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 281 was prepared by Technical Committee ISO/TC 4, *Rolling bearings*, Subcommittee SC 8, *Load ratings and life*.

This second edition cancels and replaces the first edition (ISO 281:1990), ISO 281:1990/Amd. 1:2000, ISO 281:1990/Amd. 2:2000 and ISO/TS 16799:1999, which have been technically revised.

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Introduction

It is often impractical to establish the suitability of a bearing selected for a specific application by testing a sufficient number of bearings in that application. However, life, as defined in 3.1, is a primary representation of the suitability. A reliable life calculation is therefore considered to be an appropriate and convenient substitute for testing. The purpose of this International Standard is to provide the required basis for life calculation.

Since ISO 281 was published in 1990, additional knowledge has been gained regarding the influence on bearing life of contamination, lubrication, internal stresses from mounting, stresses from hardening, fatigue load limit of the material, etc. In ISO 281:1990/Amd. 2:2000, a general method was presented to consider such influences in the calculation of a modified rating life of a bearing. This amendment is incorporated in this International Standard, which also provides a practical method to consider the influence on bearing life of lubrication condition, contaminated lubricant and fatigue load of bearing material.

ISO/TS 16281 [1] introduced advanced calculation methods which enable the user to take into account the influence on bearing life of bearing-operating clearance and misalignment under general loading conditions. The user can also consult the bearing manufacturer for recommendations and evaluation of equivalent load and life for these operation conditions and other influences as, for example, rolling element centrifugal forces or other high-speed effects.

Calculations according to this International Standard do not yield satisfactory results for bearings subjected to such application conditions and/or of such internal design which result in considerable truncation of the area of contact between the rolling elements and the ring raceways. Unmodified calculation results are thus not applicable, for example, to ball bearings with filling slots that project substantially into the ball/raceway contact area when the bearing is subjected to axial loading in the application. Bearing manufacturers should be consulted in such cases.

The life modification factors for reliability, a_1, have been slightly changed and extended to 99,95 % reliability.

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Revisions of this document will be required from time to time, as the result of new developments or in the light of new information concerning specific bearing types and materials.

Background information regarding the derivation of equations and factors in this document is given in ISO/TR 8646[1)] and ISO/TR 1281-2[2].

1) Under revision. Will be published under the reference ISO/TR 1281-1.

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Rolling bearings — Dynamic load ratings and rating life

1 Scope

This International Standard specifies methods of calculating the basic dynamic load rating of rolling bearings within the size ranges shown in the relevant ISO publications, manufactured from contemporary, commonly used, high quality hardened bearing steel, in accordance with good manufacturing practice and basically of conventional design as regards the shape of rolling contact surfaces.

This document also specifies methods of calculating the basic rating life, which is the life associated with 90 % reliability, with commonly used high quality material, good manufacturing quality and with conventional operating conditions. In addition, it specifies methods of calculating the modified rating life, in which various reliabilities, lubrication condition, contaminated lubricant and fatigue load of the bearing are taken into account.

This International Standard does not cover the influence of wear, corrosion and electrical erosion on bearing life.

This document is not applicable to designs where the rolling elements operate directly on a shaft or housing surface, unless that surface is equivalent in all respects to the bearing ring (or washer) raceway it replaces.

Double-row radial bearings and double-direction thrust bearings are, when referred to in this document, presumed to be symmetrical.

Further limitations concerning particular types of bearings are included in the relevant clauses.

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 76, *Rolling bearings — Static load ratings*

ISO 5593, *Rolling bearings — Vocabulary*

ISO/TR 8646:1985, *Explanatory notes on ISO 281/1-1977*[2)]

ISO 15241, *Rolling bearings — Symbols for quantities*

2) Under revision. Will be published under the reference ISO/TR 1281-1.

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5593 and the following apply.

3.1
life
〈of an individual rolling bearing〉 number of revolutions which one of the bearing rings or washers makes in relation to the other ring or washer before the first evidence of fatigue develops in the material of one of the rings or washers or one of the rolling elements

NOTE Life may also be expressed in number of hours of operation at a given constant speed of rotation.

3.2
reliability
〈in the context of bearing life〉 for a group of apparently identical rolling bearings, operating under the same conditions, the percentage of the group that is expected to attain or exceed a specified life

NOTE The reliability of an individual rolling bearing is the probability that the bearing will attain or exceed a specified life.

3.3
rating life
predicted value of life based on a basic dynamic radial load rating or a basic dynamic axial load rating

3.4
basic rating life
rating life associated with 90 % reliability for bearings manufactured with commonly used high quality material, of good manufacturing quality, and operating under conventional operating conditions

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3.5
modified rating life
rating life modified for 90 % or other reliability, bearing fatigue load, and/or special bearing properties, and/or contaminated lubricant, and/or other non-conventional operating conditions

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NOTE The term “modified rating life” is new in this document and replaces “adjusted rating life”.

3.6
basic dynamic radial load rating
constant stationary radial load which a rolling bearing can theoretically endure for a basic rating life of one million revolutions

NOTE In the case of a single-row angular contact bearing, the radial load rating refers to the radial component of that load which causes a purely radial displacement of the bearing rings in relation to each other.

3.7
basic dynamic axial load rating
constant centric axial load which a rolling bearing can theoretically endure for a basic rating life of one million revolutions

3.8
dynamic equivalent radial load
constant stationary radial load under the influence of which a rolling bearing would have the same life as it would attain under the actual load conditions

3.9
dynamic equivalent axial load
constant centric axial load under the influence of which a rolling bearing would have the same life as it would attain under the actual load conditions

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3.10
fatigue load limit
bearing load under which the fatigue stress limit, σ_u, is just reached in the most heavily loaded raceway contact

3.11
roller diameter
⟨applicable in the calculation of load ratings⟩ theoretical diameter in a radial plane through the middle of the roller length for a symmetrical roller

NOTE 1 For a tapered roller, the applicable diameter is equal to the mean value of the diameters at the imaginary sharp corners at the large end and at the small end of the roller.

NOTE 2 For an asymmetrical convex roller, the applicable diameter is an approximation of the diameter at the point of contact between the roller and the ribless raceway at zero load.

3.12
effective roller length
⟨applicable in the calculation of load ratings⟩ theoretical maximum length of contact between a roller and that raceway where the contact is shortest

NOTE This is normally taken to be either the distance between the theoretically sharp corners of the roller minus the roller chamfers or the raceway width, excluding the grinding undercuts, whichever is the smaller.

3.13
nominal contact angle
angle between a plane perpendicular to a bearing axis (a radial plane) and the nominal line of action of the resultant of the forces transmitted by a bearing ring or washer to a rolling element

NOTE For bearings with asymmetrical rollers, the nominal contact angle is determined by the contact with the non-ribbed raceway.

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3.14
pitch diameter of ball set
diameter of the circle containing the centres of the balls in one row in a bearing

3.15
pitch diameter of roller set
diameter of the circle intersecting the roller axes at the middle of the rollers in one row in a bearing

3.16
conventional operating conditions
conditions which may be assumed to prevail for a bearing which is properly mounted and protected from foreign matter, adequately lubricated, conventionally loaded, not exposed to extreme temperature and not run at exceptionally low or high speed

3.17
viscosity ratio
actual kinematic oil viscosity at operating temperature divided by the reference kinematic viscosity for adequate lubrication

3.18
film parameter
ratio of lubricant film thickness to composite r.m.s. surface roughness, used to estimate the influence of lubrication on bearing life

3.19
pressure-viscosity coefficient
parameter characterizing the influence of oil pressure on the oil viscosity in the rolling element contact

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3.20
viscosity index
index characterizing the degree of influence of temperature on the viscosity of lubricating oils

4 Symbols

For the purposes of this document, the symbols given in ISO 15241 and the following apply.

a_{ISO} life modification factor, based on a systems approach of life calculation

a_1 life modification factor for reliability

b_m rating factor for contemporary, commonly used, high quality hardened bearing steel in accordance with good manufacturing practices, the value of which varies with bearing type and design

C_a basic dynamic axial load rating, in newtons

C_r basic dynamic radial load rating, in newtons

C_u fatigue load limit, in newtons

C_{0a} basic static axial load rating[3)], in newtons

C_{0r} basic static radial load rating[3)], in newtons

D bearing outside diameter, in millimetres

D_{pw} pitch diameter of ball or roller set, in millimetres

D_w nominal ball diameter, in millimetres

D_{we} roller diameter applicable in the calculation of load ratings, in millimetres

d bearing bore diameter, in millimetres

e limiting value of F_a/F_r for the applicability of different values of factors X and Y

e_C contamination factor

F_a bearing axial load (axial component of actual bearing load), in newtons

F_r bearing radial load (radial component of actual bearing load), in newtons

f_c factor which depends on the geometry of the bearing components, the accuracy to which the various components are made, and the material

f_0 factor for calculation of basic static load rating[3)]

i number of rows of rolling elements

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3) For definitions, calculation methods and values of C_{0a}, C_{0r} and f_0, see ISO 76.

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L_{nm} modified rating life, in million revolutions

L_{we} effective roller length applicable in the calculation of load ratings, in millimetres

L_{10} basic rating life, in million revolutions

n speed of rotation, in revolutions per minute

n subscript for probability of failure, in percent

P dynamic equivalent load, in newtons

P_a dynamic equivalent axial load, in newtons

P_r dynamic equivalent radial load, in newtons

S reliability (probability of survival), in percent

X dynamic radial load factor

Y dynamic axial load factor

Z number of rolling elements in a single-row bearing; number of rolling elements per row of a multi-row bearing with the same number of rolling elements per row

α nominal contact angle, in degrees

κ viscosity ratio, ν / ν_1

Λ film parameter

ν actual kinematic viscosity at the operating temperature, in square millimetres per second

ν_1 reference kinematic viscosity, required to obtain adequate lubrication condition, in square millimetres per second

σ (real) stress, used in fatigue criterion, in newtons per square millimetre

σ_u fatigue stress limit of raceway material, in newtons per square millimetre

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5 Radial ball bearings

5.1 Basic dynamic radial load rating

5.1.1 Basic dynamic radial load rating for single bearings

The basic dynamic radial load rating for radial ball bearings is given by the equations

$$C_r = b_m f_c (i \cos\alpha)^{0,7} Z^{2/3} D_w^{1,8} \quad (1)$$

for $D_w \leqslant 25,4$ mm

$$C_r = 3,647\, b_m f_c (i \cos\alpha)^{0,7} Z^{2/3} D_w^{1,4} \quad (2)$$

for $D_w > 25,4$ mm

where the values of b_m and f_c are given in Tables 1 and 2 respectively. They apply to bearings with a cross-sectional raceway groove radius not larger than 0,52 D_w in radial and angular contact ball bearing inner rings and not larger than 0,53 D_w in radial and angular contact ball bearing outer rings and self-aligning ball bearing inner rings.

The load-carrying ability of a bearing is not necessarily increased by the use of a smaller groove radius, but it is reduced by the use of a groove radius larger than those indicated in the previous paragraph. In the latter case, a correspondingly reduced value of f_c shall be used. Calculation of this reduced value of f_c can be carried out by means of Equation (3–15) given in ISO/TR 8646:1985.

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Table 1 — Values of b_m for radial ball bearings

Bearing type	b_m
Radial and angular contact ball bearings (except filling slot bearings), insert bearings and self-aligning ball bearings	1,3
Filling slot bearings	1,1

5.1.2 Basic dynamic radial load rating for bearing combinations

5.1.2.1 Two single-row radial contact ball bearings operating as a unit

When calculating the basic dynamic radial load rating for two similar single-row radial contact ball bearings mounted side by side on the same shaft, such that they operate as a unit (paired mounting), the pair is considered as one double-row radial contact ball bearing.

5.1.2.2 Back-to-back and face-to-face arrangements of single-row angular contact ball bearings

When calculating the basic dynamic radial load rating for two similar single-row angular contact ball bearings mounted side by side on the same shaft, such that they operate as a unit (paired mounting) in a back-to-back or a face-to-face arrangement, the pair is considered as one double-row angular contact ball bearing.

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Table 2 — Values of factor f_c for radial ball bearings

$\frac{D_w \cos\alpha}{D_{pw}}$ [a]	Factor f_c			
	Single-row radial contact ball bearings and single-row and double-row angular contact ball bearings	Double-row radial contact ball bearings	Single-row and double-row self-aligning ball bearings	Single-row radial contact separable ball bearings (magneto bearings)
0,01	29,1	27,5	9,9	9,4
0,02	35,8	33,9	12,4	11,7
0,03	40,3	38,2	14,3	13,4
0,04	43,8	41,5	15,9	14,9
0,05	46,7	44,2	17,3	16,2
0,06	49,1	46,5	18,6	17,4
0,07	51,1	48,4	19,9	18,5
0,08	52,8	50	21,1	19,5
0,09	54,3	51,4	22,3	20,6
0,1	55,5	52,6	23,4	21,5
0,11	56,6	53,6	24,5	22,5
0,12	57,5	54,5	25,6	23,4
0,13	58,2	55,2	26,6	24,4
0,14	58,8	55,7	27,7	25,3
0,15	59,3	56,1	28,7	26,2
0,16	59,6	56,5	29,7	27,1
0,17	59,8	56,7	30,7	27,9
0,18	59,9	56,8	31,7	28,8
0,19	60	56,8	32,6	29,7
0,2	59,9	56,8	33,5	30,5
0,21	59,8	56,6	34,4	31,3
0,22	59,6	56,5	35,2	32,1
0,23	59,3	56,2	36,1	32,9
0,24	59	55,9	36,8	33,7
0,25	58,6	55,5	37,5	34,5
0,26	58,2	55,1	38,2	35,2
0,27	57,7	54,6	38,8	35,9
0,28	57,1	54,1	39,4	36,6
0,29	56,6	53,6	39,9	37,2
0,3	56	53	40,3	37,8
0,31	55,3	52,4	40,6	38,4
0,32	54,6	51,8	40,9	38,9
0,33	53,9	51,1	41,1	39,4
0,34	53,2	50,4	41,2	39,8
0,35	52,4	49,7	41,3	40,1
0,36	51,7	48,9	41,3	40,4
0,37	50,9	48,2	41,2	40,7
0,38	50	47,4	41	40,8
0,39	49,2	46,6	40,7	40,9
0,4	48,4	45,8	40,4	40,9

[a] Values of f_c for intermediate values of $\frac{D_w \cos\alpha}{D_{pw}}$ are obtained by linear interpolation.

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Table 3 — Values of X and Y for radial ball bearings

Bearing type		"Relative axial load" [a, b]		Single-row bearing				Double-row bearings				e
				$\frac{F_a}{F_r} \leqslant e$		$\frac{F_a}{F_r} > e$		$\frac{F_a}{F_r} \leqslant e$		$\frac{F_a}{F_r} > e$		
				X	Y	X	Y	X	Y	X	Y	
Radial contact ball bearings		$\frac{f_0 F_a}{C_{0r}}$ [c]	$\frac{F_a}{i Z D_w^2}$									
		0,172	0,172				2,3				2,3	0,19
		0,345	0,345				1,99				1,99	0,22
		0,689	0,689				1,71				1,71	0,26
		1,03	1,03				1,55				1,55	0,28
		1,38	1,38	1	0	0,56	1,45	1	0	0,56	1,45	0,3
		2,07	2,07				1,31				1,31	0,34
		3,45	3,45				1,15				1,15	0,38
		5,17	5,17				1,04				1,04	0,42
		6,89	6,89				1				1	0,44
Angular contact ball bearings		$\frac{f_0 i F_a}{C_{0r}}$ [c]	$\frac{F_a}{Z D_w^2}$									
	$\alpha = 5°$	0,173	0,172			For this type, use the X, Y and e values applicable to single-row radial contact ball bearings.			2,78		3,74	0,23
		0,346	0,345						2,4		3,23	0,26
		0,692	0,689						2,07		2,78	0,3
		1,04	1,03						1,87		2,52	0,34
		1,38	1,38	1	0			1	1,75	0,78	2,36	0,36
		2,08	2,07						1,58		2,13	0,4
		3,46	3,45						1,39		1,87	0,45
		5,19	5,17						1,26		1,69	0,5
		6,92	6,89						1,21		1,63	0,52
	$\alpha = 10°$	0,175	0,172				1,88		2,18		3,06	0,29
		0,35	0,345				1,71		1,98		2,78	0,32
		0,7	0,689				1,52		1,76		2,47	0,36
		1,05	1,03				1,41		1,63		2,29	0,38
		1,4	1,38	1	0	0,46	1,34	1	1,55	0,75	2,18	0,4
		2,1	2,07				1,23		1,42		2	0,44
		3,5	3,45				1,1		1,27		1,79	0,49
		5,25	5,17				1,01		1,17		1,64	0,54
		7	6,89				1		1,16		1,63	0,54
	$\alpha = 15°$	0,178	0,172				1,47		1,65		2,39	0,38
		0,357	0,345				1,4		1,57		2,28	0,4
		0,714	0,689				1,3		1,46		2,11	0,43
		1,07	1,03				1,23		1,38		2	0,46
		1,43	1,38	1	0	0,44	1,19	1	1,34	0,72	1,93	0,47
		2,14	2,07				1,12		1,26		1,82	0,5
		3,57	3,45				1,02		1,14		1,66	0,55
		5,35	5,17				1		1,12		1,63	0,56
		7,14	6,89				1		1,12		1,63	0,56
	$\alpha = 20°$	—	—			0,43	1		1,09	0,7	1,63	0,57
	$\alpha = 25°$	—	—			0,41	0,87		0,92	0,67	1,41	0,68
	$\alpha = 30°$	—	—			0,39	0,76		0,78	0,63	1,24	0,8
	$\alpha = 35°$	—	—	1	0	0,37	0,66	1	0,66	0,6	1,07	0,95
	$\alpha = 40°$	—	—			0,35	0,57		0,55	0,57	0,93	1,14
	$\alpha = 45°$	—	—			0,33	0,5		0,47	0,54	0,81	1,34
Self-aligning ball bearings				1	0	0,4	0,4 cotα	1	0,42 cotα	0,65	0,65 cot α	1,5 tanα
Single-row radial contact separable ball bearings (magneto bearings)				1	0	0,5	2,5	—	—	—	—	0,2

[a] Permissible maximum value depends on the bearing design (internal clearance and raceway groove depth). Use the first or second column depending on available information.

[b] Values of X, Y and e for intermediate "relative axial loads" and/or contact angles are obtained by linear interpolation.

[c] For values of f_0, see ISO 76.

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5.1.2.3 Tandem arrangement

The basic dynamic radial load rating, for two or more similar single-row radial contact ball bearings or two or more similar angular contact ball bearings mounted side by side on the same shaft, such that they operate as a unit (paired or stack mounting) in a tandem arrangement, is the number of bearings to the power of 0,7 times the rating of one single-row bearing. The bearings need to be properly manufactured and mounted for equal load distribution between them.

5.1.2.4 Independently replaceable bearings

If, for some technical reason, the bearing arrangement is regarded as a number of single-row specially manufactured bearings which are replaceable independently of each other, then 5.1.2.3 does not apply.

5.2 Dynamic equivalent radial load

5.2.1 Dynamic equivalent radial load for single bearings

The dynamic equivalent radial load for radial and angular contact ball bearings, under constant radial and axial loads, is given by

$$P_{\mathrm{r}} = X F_{\mathrm{r}} + Y F_{\mathrm{a}} \tag{3}$$

where the values of factors X and Y are given in Table 3. These factors apply to bearings with cross-sectional groove radii according to 5.1.1. For other groove radii, calculation of X and Y can be carried out by means of 4.2 in ISO/TR 8646:1985.

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5.2.2 Dynamic equivalent radial load for bearing combinations

5.2.2.1 Back-to-back and face-to-face arrangements of single-row angular contact ball bearings

When calculating the equivalent radial load for two similar single-row angular contact ball bearings mounted side by side on the same shaft, such that they operate as a unit (paired mounting) in a back-to-back or a face-to-face arrangement, the pair is considered as one double-row angular contact ball bearing.

NOTE If two similar single-row radial contact ball bearings are operating in back-to-back or face-to-face arrangement, the user should consult the bearing manufacturer about calculation of equivalent radial load.

5.2.2.2 Tandem arrangement

When calculating the equivalent radial load for two or more similar single-row radial contact ball bearings or two or more similar single-row angular contact ball bearings mounted side by side on the same shaft, such that they operate as a unit (paired or stack mounting) in a tandem arrangement, the values of X and Y for a single-row bearing shall be used.

The “relative axial load” (see Table 3) is established by using $i = 1$ and F_{a} and $C_{0\mathrm{r}}$ values which both refer to one of the bearings only (even though the F_{r} and F_{a} values referring to the total loads are used for the calculation of the equivalent load for the complete arrangement).

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