INTERNATIONAL STANDARD

ISO 281

First edition
1990-12-01

Rolling bearings — Dynamic load ratings and rating life

Roulements — Charges dynamiques de base et durée nominale

Reference number
ISO 281 : 1990 (E)

Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

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.

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.

International Standard ISO 281 was prepared by Technical Committee ISO/TC 4, *Rolling bearings*.

This first edition of ISO 281 cancels and replaces the first edition of ISO 281-1 : 1977, of which it constitutes a technical revision.

Annex A of this International Standard is for information only.

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.

The present state of knowledge does not enable this International Standard to include specific values of the life adjustment factors for special bearing properties and operating conditions. Values of these factors must therefore be decided on the basis of experience, usually in consultation with the bearing manufacturer.

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 groove ball bearings with filling slots which project substantially into the ball/raceway contact area when the bearing is subjected to load in the application.

Calculations according to this International Standard do not yield satisfactory results for bearings subjected to such application conditions which cause deviations from a normal load distribution in the bearing, for example misalignment, housing or shaft deflection, rolling element centrifugal forces or other high speed effects, and preload or extra large clearance in radial bearings. Where there is reason to assume that such conditions prevail, the user should consult the bearing manufacturer for recommendations and evaluation of equivalent load and life.

Revisions of this International Standard 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.

Detailed background information regarding the derivation of formulae and factors given in this International Standard may be found in ISO/TR 8646.

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, good quality hardened steel in accordance with good manufacturing practice and basically of conventional design as regards the shape of rolling contact surfaces.

This International Standard also specifies methods of calculating the basic rating life, which is the life associated with 90 % reliability, with commonly used material and manufacturing quality, and with conventional operating conditions. In addition, it specifies methods of calculating adjusted rating life, in which various reliabilities, special bearing properties and specific operating conditions are taken into account by means of life adjustment factors.

This International Standard 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 International Standard, presumed to be symmetrical.

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 76 : 1987, *Rolling bearings — Static load ratings*.

ISO 5593 : 1984, *Rolling bearings — Vocabulary*.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 5593, together with the following, apply.

3.1 life: For an individual rolling bearing, the 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 rolling elements.

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.

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

3.3 basic rating life: For an individual rolling bearing, or a group of apparently identical rolling bearings operating under the same conditions, the life associated with 90 % reliability, with contemporary, commonly used material and manufacturing quality, and under conventional operating conditions.

3.4 adjusted rating life: The rating life obtained by adjustment of the basic rating life for a desired reliability level, special bearing properties and specific operating conditions.

3.5 basic dynamic radial load rating: That constant stationary radial load which a rolling bearing could theoretically endure for a basic rating life of one million revolutions.

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.

3.6 basic dynamic axial load rating: That constant centric axial load which a rolling bearing could theoretically endure for a basic rating life of one million revolutions.

3.7 dynamic equivalent radial load: That constant stationary radial load under the influence of which a rolling bearing would have the same life as it will attain under the actual load conditions.

3.8 dynamic equivalent axial load: That constant centric axial load under the influence of which a rolling bearing would have the same life as it will attain under the actual load conditions.

3.9 roller diameter applicable in the calculation of load ratings: The diameter at the middle of the roller.

NOTE — For a tapered roller this is equal to the mean value of the diameters at the theoretically sharp corners at the large end and at the small end of the roller.

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

3.10 roller length applicable in the calculation of load ratings: The 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.

3.11 nominal contact angle: The angle between a plane perpendicular to the bearing axis and the nominal line of action of the resultant of the forces transmitted by a bearing ring to a rolling element.

3.12 pitch diameter of a ball set: The diameter of the circle containing the centres of the balls in one row in a bearing.

3.13 pitch diameter of a roller set: The diameter of the circle intersecting the roller axes at the middle of the rollers in one row in a bearing.

3.14 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.

4 Symbols

C_r = basic dynamic radial load rating, in newtons

C_a = basic dynamic axial load rating, in newtons

C_{or} = basic static radial load rating[1)], in newtons

C_{oa} = basic static axial load rating[1)], in newtons

D_w = ball diameter, in millimetres

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

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

F_r = bearing radial load = radial component of actual bearing load, in newtons

F_a = bearing axial load = axial component of actual bearing load, in newtons

L_{10} = basic rating life, in million revolutions

L_{na} = adjusted rating life, in million revolutions

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

P_r = dynamic equivalent radial load, in newtons

P_a = dynamic equivalent axial load, in newtons

X = dynamic radial load factor

Y = dynamic axial load factor

Z = number of balls or rollers in a single row bearing; number per row of a multi-row bearing with the same number of balls or rollers per row

a_1 = life adjustment factor for reliability (see 9.3)

a_2 = life adjustment factor for special bearing properties (see 9.4)

a_3 = life adjustment factor for operating conditions (see 9.5)

b_m = rating factor for contemporary, normally used material and manufacturing quality, the value of which varies with bearing type and design

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

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_o = factor which depends on the geometry of the bearing components and on the applicable stress level[1)]

i = number of rows of balls or rollers in a bearing

α = nominal contact angle of a bearing, in degrees

5 Radial ball bearings

5.1 Basic dynamic radial load rating

The basic dynamic radial load rating, C_r, for radial and angular contact ball bearings is given by

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

for $D_w \leqslant 25,4$ mm

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

for $D_w > 25,4$ mm

Values of b_m are given in table 1. Values of f_c are given in table 2. They apply to bearings with a cross-sectional raceway groove radius not larger than 0,52 D_w in radial and angular contact groove ball bearing inner rings and 0,53 D_w in radial and angular contact groove 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 larger radii than those indicated above.

1) For definition, calculation method and values, see ISO 76.

Table 1 — Values of b_m for radial ball bearings

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

5.1.1 Bearing combinations

5.1.1.1 When calculating the basic radial load rating for two similar single row radial contact groove 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 bearing.

5.1.1.2 When calculating the basic 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 "back-to-back" or "face-to-face" arrangement, the pair is considered as one double row angular contact bearing.

5.1.1.3 The basic radial load rating for 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 "tandem" arrangement, properly manufactured and mounted for equal load distribution, is the number of bearings to the power of 0,7, times the rating of one single row bearing.

5.1.1.4 If, for some technical reason, the bearing arrangement is regarded as a number of single row bearings which are replaceable independently of each other, then 5.1.1.3 does not apply.

5.2 Dynamic equivalent radial load

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

$$P_r = XF_r + YF_a$$

Values of X and Y are given in table 3.

5.2.1 Bearing combinations

5.2.1.1 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 "back-to-back" or "face-to-face" arrangement, the pair is considered as one double row angular contact bearing.

5.2.1.2 When calculating the equivalent radial load for two or more similar single row ball bearings mounted side-by-side on the same shaft such that they operate as a unit (paired or stack mounting) in "tandem" arrangement, the values of X and Y for a single row bearing are used. The "relative axial load" (see table 3) is established by using $i = 1$ and the F_a and C_{or} 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).

5.3 Basic rating life

5.3.1 The basic rating life, L_{10}, for a radial ball bearing is given by

$$L_{10} = \left(\frac{C_r}{P_r}\right)^3$$

The values of C_r and P_r are calculated in accordance with 5.1 and 5.2.

This life formula is also used for the evaluation of the life of two or more single row bearings operating as a unit, as referred to in 5.1.1. In this case, the load rating C_r is calculated for the complete bearing arrangement and the equivalent load P_r is calculated for the total loads acting on the arrangement, using the values of X and Y indicated in 5.2.1.2.

5.3.2 The life formula gives satisfactory results for a broad range of bearing loads. However, extra-heavy loads may cause detrimental plastic deformations at the ball/raceway contacts. The user should therefore consult the bearing manufacturer to establish the applicability of the life formula in cases where P_r exceeds C_{or} or 0,5 C_r, whichever is the smaller.

Table 2 — Values of f_c for radial ball bearings

$\frac{D_w \cos\alpha}{D_{pw}}$ [1)]	f_c			
	Single row radial contact groove ball bearings and single and double row angular contact groove ball bearings	Double row radial contact groove 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

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

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

Bearing type		"Relative axial load" 1), 2)		Single row bearings				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 groove ball bearings		$\frac{f_0 F_a}{C_{0r}}$ 3)	$\frac{F_a}{iZD_w^2}$									
		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 groove ball bearings		$\frac{f_0 iF_a}{C_{0r}}$ 3)	$\frac{F_a}{ZD_w^2}$									
	$\alpha = 5°$	0,173	0,172			For this type use the X, Y and e values applicable to single row radial contact groove 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
		3,50	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
	$\alpha = 30°$	—	—	1	0	0,39	0,76	1	0,78	0,63	1,24	0,8
	$\alpha = 35°$	—	—			0,37	0,66		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 cot α	1	0,42 cot α	0,65	0,65 cot α	1,5 tan α
Single row radial contact separable ball bearings (magneto bearings)				1	0	0,5	2,5	—	—	—	—	0,2

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

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

3) For values of f_0, see ISO 76.