INTERNATIONAL STANDARD 281/I

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION •МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Rolling bearings — Dynamic load ratings and rating life — Part I : Calculation methods

Roulements — Charges dynamiques de base et durée nominale — Partie I : Méthodes de calcul

First edition — 1977-03-15

UDC 621.822 Ref. No. ISO 281/I-1977 (E)

Descriptors : rolling bearings, ball bearings, roller bearings, thrust ball bearings, roller thrust bearings, dynamic loads, ratings, life (durability), rules of calculation.

Price based on 10 pages

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 281/I was developed by Technical Committee ISO/TC 4, *Rolling bearings*, and was circulated to the member bodies in January 1976.

It has been approved by the member bodies of the following countries :

Australia	Italy	Sweden
Bulgaria	Japan	Switzerland
Canada	Korea, Rep. of	Turkey
Chile	Mexico	United Kingdom
Czechoslovakia	Netherlands	U.S.A.
France	Poland	U.S.S.R.
Germany	Romania	Yugoslavia
Hungary	South Africa, Rep. of	
India	Spain	

The member body of the following country expressed disapproval of the document on technical grounds :

Austria

This International Standard cancels and replaces ISO Recommendation R 281-1962, of which it constitutes a technical revision.

Printed in Switzerland

In the Introductory Note to ISO/R 281-1962, *Rolling bearings – Methods of evaluating dynamic load ratings*, it was stated that "it is recognised that revisions of the calculations may be required from time to time as the result of improvements and new developments".

Since the 1950s, when ISO/R 281 was drawn up, experience has shown that a theoretical difference between the case where the inner ring rotates in relation to the load and that where the outer ring rotates in relation to the load can be disregarded in practice. Thus, the rotation factor can be deleted from a standardized calculation. In addition, the evaluation of bearing life for reliabilities greater than 90 % has become of more frequent interest. Finally, in cases where material with properties deviating from those of conventional bearing steel is used and/or where the lubrication is not quite adequate, it has been found justified to adjust the rating life.

In this International Standard, the developments indicated above have been considered.

Part I, Calculation methods, contains the body of this International Standard, whilst Part II, Explanatory notes, gives supplementary background information regarding the derivation of formulae and factors given in Part I.

CONTENTS

Page

Rolling bearings — Dynamic load ratings and rating life — Part I : Calculation methods

0 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. Other methods are therefore required to establish this suitability.

Life, as defined in sub-clause 2.1, represents the period of unimpaired performance of a rolling bearing when the bearing is properly mounted, adequately lubricated, protected from foreign matter and not otherwise subjected to extreme operating conditions. A reliable life calculation is therefore considered to be a suitable and advantageous substitute for testing.

The purpose of this International Standard is to provide the required basis for this life calculation.

1 SCOPE AND FIELD OF APPLICATION

This International Standard sets out methods of calculating the basic dynamic load rating and rating life of rolling bearings within the size ranges shown in the relevant ISO publications, manufactured from 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 adjusted rating life to take into account various reliabilities, materials and operating conditions.

The present state of the art does not permit the inclusion in this International Standard of specifications such as, for example, that of the characteristics of good quality, hardened steel (analysis, inclusions, structure, hardness, etc.), or the inclusion of specific values of life adjustment factors for material and operating conditions. Revisions of this International Standard will therefore be required from time to time as the result of new developments or in the light of new information concerning specific bearing types.

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.

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 DEFINITIONS

2.1 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.

2.2 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.

2.3 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.

2.4 basic dynamic radial load rating : That constant stationary radial load which a rolling bearing can 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.

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

2.6 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.

2.7 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.

2.8 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 theoretical sharp corners at the large end and the small end of the roller.

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

2.9 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 theoretical sharp corners of the roller minus the roller chamfers or the raceway width excluding the grinding undercuts, whichever is the smaller.

2.10 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 SYMBOLS

C_r = basic dynamic radial load rating, newtons

C_a = basic dynamic axial load rating, newtons

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

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

D_w = ball diameter, millimetres

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

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

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

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

L_{10} = basic rating life, million revolutions

L_n = adjusted rating life for a reliability of $(100 - n)$ %, million revolutions

L_{10a} = adjusted rating life for non-conventional material properties and operating conditions, million revolutions

L_{na} = adjusted rating life for non-conventional material properties and operating conditions and for a reliability of $(100 - n)$ %, million revolutions

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

P_r = dynamic equivalent radial load, newtons

P_a = dynamic equivalent axial load, newtons

X = radial load factor

Y = axial load factor

Z = number of balls or rollers in a single row bearing, number per row of a multi-row bearing with equal number of balls or rollers per row

a_1 = life adjustment factor for a reliability other than 90 %

a_2 = life adjustment factor for non-conventional material properties

a_3 = life adjustment factor for non-conventional operating conditions

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

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

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

α = nominal contact angle of a bearing, degrees

4 RADIAL BALL BEARINGS

4.1 Basic dynamic radial load rating

The basic dynamic load rating for radial and angular contact ball bearings is :

for $D_w \leqslant 25{,}4$ mm :

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

for $D_w > 25{,}4$ mm :

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

Values of factor f_c are given in table 1. They apply to bearings with a cross-sectional raceway groove radius not larger than 0,52 D_w in radial and angular contact groove

1) For definition and calculation method, refer to ISO 76, *Rolling bearings — Static load ratings.* (At present at the stage of draft : revision of ISO/R 76.)

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 is reduced by the use of a larger radius than those indicated above.

4.1.1 *Bearing combinations*

a) 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.

b) 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.

c) 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 0,7 power times the rating of one single row bearing.

If for some technical reason the bearing arrangement is regarded as a number of single row bearings which are replaceable independent of each other, the above paragraph does not apply.

TABLE 1 — **Factor f_c for radial ball bearings**

$\frac{D_w \cos \alpha}{D_{pw}}$	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)**
0,05	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	50,0	21,1	19,5
0,09	54,3	51,4	22,3	20,6
0,10	55,5	52,6	23,4	21,5
0,12	57,5	54,5	25,6	23,4
0,14	58,8	55,7	27,7	25,3
0,16	59,6	56,5	29,7	27,1
0,18	59,9	56,8	31,7	28,8
0,20	59,9	56,8	33,5	30,5
0,22	59,6	56,5	35,2	32,1
0,24	59,0	55,9	36,8	33,7
0,26	58,2	55,1	38,2	35,2
0,28	57,1	54,1	39,4	36,6
0,30	56,0	53,0	40,3	37,8
0,32	54,6	51,8	40,9	38,9
0,34	53,2	50,4	41,2	39,8
0,36	51,7	48,9	41,3	40,4
0,38	50,0	47,4	41,0	40,8
0,40	48,4	45,8	40,4	40,9

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

TABLE 2 — **Factors *X* and *Y* for radial ball bearings**

Bearing type		"Relative axial load"[1]		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		$\frac{F_a}{C_{or}}$	$\frac{F_a}{i Z D_w^2}$									
		0,014	0,172				2,30				2,30	0,19
		0,028	0,345				1,99				1,99	0,22
		0,056	0,689				1,71				1,71	0,26
		0,084	1,03				1,55				1,55	0,28
		0,11	1,38	1	0	0,56	1,45	1	0	0,56	1,45	0,30
		0,17	2,07				1,31				1,31	0,34
		0,28	3,45				1,15				1,15	0,38
		0,42	5,17				1,04				1 04	0,42
		0,56	6,89				1,00				1,00	0,44
Angular contact groove ball bearings	α	$\frac{i F_a}{C_{or}}$	$\frac{F_a}{Z D_w^2}$									
	5°	0,014	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
		0,028	0,345						2,40		3,23	0,26
		0,056	0,689						2,07		2,78	0,30
		0,085	1,03						1,87		2,52	0,34
		0,11	1,38	1	0			1	1,75	0,78	2,36	0,36
		0,17	2,07						1,58		2,13	0,40
		0,28	3,45						1,39		1,87	0,45
		0,42	5,17						1,26		1,69	0,50
		0,56	6,89						1,21		1,63	0,52
	10°	0,014	0,172				1,88		2,18		3,06	0,29
		0,029	0,345				1,71		1,98		2,78	0,32
		0,057	0,689				1,52		1,76		2,47	0,36
		0,086	1,03				1,41		1,63		2,29	0,38
		0,11	1,38	1	0	0,46	1,34	1	1,55	0,75	2,18	0,40
		0,17	2,07				1,23		1,42		2,00	0,44
		0,29	3,45				1,10		1,27		1,79	0,49
		0,43	5,17				1,01		1,17		1,64	0,54
		0,57	6,89				1,00		1,16		1,63	0,54
	15°	0,015	0,172				1,47		1,65		2,39	0,38
		0,029	0,345				1,40		1,57		2,28	0,40
		0,058	0,689				1,30		1,46		2,11	0,43
		0,087	1,03				1,23		1,38		2,00	0,46
		0,12	1,38	1	0	0,44	1,19	1	1,34	0,72	1,93	0,47
		0,17	2,07				1,12		1,26		1,82	0,50
		0,29	3,45				1,02		1,14		1,66	0,55
		0,44	5,17				1,00		1,12		1,63	0,56
		0,58	6,89				1,00		1,12		1,63	0,56
	20°	–	–			0,43	1,00		1,09	0,70	1,63	0,57
	25°	–	–			0,41	0,87		0,92	0,67	1,41	0,68
	30°	–	–	1	0	0,39	0,76	1	0,78	0,63	1,24	0,80
	35°	–	–			0,37	0,66		0,66	0,60	1,07	0,95
	40°	–	–			0,35	0,57		0,55	0,57	0,93	1,14
	45°	–	–			0,33	0,50		0,47	0,54	0,81	1,34
Self-aligning ball bearings				1	0	0,40	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 bearing design (internal clearance and raceway groove depth).

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

4.2 Dynamic equivalent radial load

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

$$P_r = X F_r + Y F_a$$

Values of factors X and Y are given in table 2.

4.2.1 *Bearing combinations*

a) 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.

b) 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 2) is established by using $i = 1$ and the F_a and C_o values which both refer to one of the bearings only (even through 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).

4.3 Basic rating life

The basic rating life for a radial ball bearing is

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

The values of C_r and P_r are calculated in accordance with 4.1 and 4.2.

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 4.1.1. 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 4.2.1.

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.

5 THRUST BALL BEARINGS

5.1 Basic dynamic axial load rating

5.1.1 *Single row bearings*

The basic dynamic axial load rating for single row, single or double direction thrust ball bearings is

for $D_w \leqslant 25{,}4$ mm $\alpha = 90°$:

$$C_a = f_c Z^{2/3} D_w^{1,8}$$

for $D_w \leqslant 25{,}4$ mm $\alpha \neq 90°$:

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

for $D_w > 25{,}4$ mm $\alpha = 90°$:

$$C_a = 3{,}647 f_c Z^{2/3} D_w^{1,4}$$

for $D_w > 25{,}4$ mm $\alpha \neq 90°$:

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

Z is the number of balls carrying load in one direction.

Values of factor f_c are given in table 3 and apply to bearings with a cross-sectional raceway groove radius not larger than 0,54 D_w. The load carrying ability of a bearing is not necessarily increased by the use of a smaller groove radius, but is reduced by the use of a larger groove radius than that indicated above.

5.1.2 *Bearings with two or more rows of balls*

The basic dynamic axial load rating for thrust ball bearings, with two or more rows of similar balls carrying load in the same direction, is

$$C_a = (Z_1 + Z_2 + \ldots + Z_n) \times$$

$$\times \left[\left(\frac{Z_1}{C_{a1}}\right)^{10/3} + \left(\frac{Z_2}{C_{a2}}\right)^{10/3} + \ldots + \left(\frac{Z_n}{C_{an}}\right)^{10/3}\right]^{-3/10}$$

The load ratings $C_{a1}, C_{a2}, \ldots, C_{an}$ for the rows with $Z_1, Z_2, \ldots, Z_n$ balls are calculated from the appropriate single row bearing formula in 5.1.1.

Values of f_c for $\frac{D_w}{D_{pw}}$ or $\frac{D_w \cos\alpha}{D_{pw}}$ and/or contact angles other than shown in the table are obtained by linear interpolation or extrapolation.