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Rolling bearings — Load ratings for hybrid bearings with rolling elements made of ceramic —

Part 2:
Static load ratings

Roulements — Charges de base pour roulements hybrides avec éléments roulants en céramique —

Partie 2: Charges statiques

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

A list of all the parts in the ISO 20056 series can be found on the ISO website.

Introduction

Hybrid bearings are rolling bearings with raceways consisting of commonly used rolling bearing steel and rolling elements made from silicon nitride (for definitions, see ISO 5593). Due to the higher modulus of elasticity of the ceramic rolling elements, hybrid bearings have a noticeably smaller contact ellipse at the same load than rolling bearings with rolling elements made of rolling bearing steel. This will lead to higher contact stresses at the same load.

Since the second edition of ISO 76 in 1987, the static capacity of rolling bearings is defined by a permissible Hertzian contact stress in the highest loaded contact. In rolling bearings made of steel, this contact stress will lead to a permanent plastic deformation at raceway and rolling element of approximately 1/10 000th of the rolling element diameter. In hybrid bearings, no significant plastic deformation will occur at the rolling element, resulting in a smaller total plastic deformation in the rolling contact. Therefore, in accordance with industrial practice, slightly higher permissible Hertzian stresses are defined for hybrid bearings. The guideline values of the static safety factor, S_0, have been increased accordingly to maintain the same overall safety for the raceway.

Rolling bearings — Load ratings for hybrid bearings with rolling elements made of ceramic —

Part 2: Static load ratings

1 Scope

This document specifies methods of calculating the static load ratings for hybrid bearings with bearing rings made of contemporary, commonly used, high quality hardened bearing steel, in accordance with good manufacturing practice, and a full set of rolling elements made of silicon nitride (Si_3N_4) in contemporary, commonly used material and manufacturing quality. For balls, ISO 26602,[4] together with ISO 3290-2,[1] is applicable. For rollers, ISO 12297-2[2] is applicable, and ISO 26602[4] is applicable in an analogous way.

For applications where hybrid bearings are used, guideline values of the static safety factor, S_0, according to Table 1 and Table 2 are observed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 76:2006, *Rolling bearings — Static load ratings*

ISO 5593, *Rolling bearings — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5593 and ISO 76, and the following, apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
basic static radial load rating
C_{0r}
radial load which corresponds to a calculated contact stress at the centre of the most heavily loaded rolling element/raceway contact of

— 4 600 MPa for all radial ball bearings including radial self-aligning ball bearings, and

— 4 200 MPa for all radial roller bearings

Note 1 to entry: 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.

Note 2 to entry: The contact stress limits given in this subclause are only valid for rolling elements made of silicon nitride with a modulus of elasticity of 300 000 MPa or higher. For rolling elements made of ceramics with a lower modulus of elasticity, the contact stress limits per ISO 76 should be applied.

3.2
basic static axial load rating
C_{0a}
static centric axial load which corresponds to a calculated contact stress at the centre of the most heavily loaded rolling element/raceway contact of

— 4 600 MPa for all thrust ball bearings, and

— 4 200 MPa for all thrust roller bearings

Note 1 to entry: 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 to entry: 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.

Note 3 to entry: The contact stress limits given are only valid for rolling elements made of silicon nitride with a modulus of elasticity of 300 000 MPa or higher. For rolling elements made of ceramics with a lower modulus of elasticity, the contact stress limits according to ISO 76 should be applied.

4 Symbols

C_0	basic static load rating, in N
C_{0a}	basic static axial load rating, in N
C_{0r}	basic static radial load rating, in N
D_{pw}	pitch diameter of ball or roller set, in mm
D_w	nominal ball diameter, in mm
D_{we}	roller diameter applicable in the calculation of load ratings, in mm
E_{Ce}	modulus of elasticity of ceramic rolling elements, in MPa (E_{Ce} = 300 000 MPa)
E_{St}	modulus of elasticity of rolling bearing steel, in MPa (E_{St} = 207 000 MPa, according to ISO 76)
$E(\chi)$	complete elliptic integral of the second kind
F_a	bearing axial load (axial component of actual bearing load), in N
F_r	bearing radial load (radial component of actual bearing load), in N
$F(\rho)$	relative curvature difference
f_0	factor for calculation of basic static load rating
i	number of rows of rolling elements
$K(\chi)$	complete elliptic integral of the first kind
L_{we}	effective roller length applicable in the calculation of load ratings, in mm
P_{0a}	static equivalent axial load, in N
P_{0r}	static equivalent radial load, in N

r_e	cross-sectional raceway groove radius of outer ring or housing washer, in mm
r_i	cross-sectional raceway groove radius of inner ring or shaft washer, in mm
S_0	static safety factor
w	correction factor for different material combinations
X_0	static radial load factor
Y_0	static 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
γ	auxiliary parameter, $\gamma = D_w \times \cos\ \alpha / D_{pw}$
ν_{Ce}	Poisson's ratio of ceramic rolling elements (ν_{Ce} = 0,26)
ν_{St}	Poisson's ratio of bearing steel (ν_{St} = 0,30, according to ISO 76)
$\sum\rho$	curvature sum, in mm^{-1}
ϕ	angular position of rolling element, in degrees
χ	ratio of semi major to semi minor axis of the contact ellipse

5 Static load rating

5.1 General

The static load ratings for hybrid bearings are calculated using Formulae (1) to (12). These formulae and the contact stress limits given in 3.1 and 3.2 are only valid for rolling elements made of silicon nitride with a modulus of elasticity of 300 000 MPa or higher. For rolling elements made of ceramics with a lower modulus of elasticity, the contact stress limits according to ISO 76 should be applied.

5.2 Basic static radial load rating of radial ball bearings

The basic static radial load rating for a radial ball bearing with a ceramic ball set is given by Formula (1):

$$C_{0r} = f_0 \times i \times Z \times D_w{}^2 \times \cos\ \alpha \tag{1}$$

with Formula (2):

$$f_0 = \min\left\{ f_{0,i}, f_{0,e} \right\} \tag{2}$$

and Formulae (3) and (4):

$$f_{0,i} = 2{,}295\,96 \times \chi_i \times \left(\frac{E(\chi_i)}{2 + \dfrac{\gamma}{1-\gamma} - \dfrac{D_w}{2 \times r_i}} \right)^2 \tag{3}$$

$$f_{0,e} = 2{,}295\,96 \times \chi_e \times \left(\frac{E(\chi_e)}{2 - \frac{\gamma}{1+\gamma} - \frac{D_w}{2 \times r_e}} \right)^2 \quad (4)$$

The calculation of the Hertzian parameters χ and $E(\chi)$ is described in Annex A. Guide values of the factor f_0 are given in Annex B, Table B.1.

The basic static radial load rating for a radial self-aligning ball bearing with a ceramic ball set is given by Formula (5):

$$C_{0r} = f_0 \times i \times Z \times {D_w}^2 \times \cos\alpha \quad (5)$$

with Formula (6):

$$f_0 = 2{,}295\,96 \times \left[\frac{\pi}{4} \times (1+\gamma) \right]^2 \quad (6)$$

Guide values of the factor f_0 are given in Annex B, Table B.1.

5.3 Basic static axial load rating of thrust ball bearings

The basic static axial load rating for a thrust ball bearing with a ceramic ball set is given by Formula (7):

$$C_{0a} = f_0 \times Z \times {D_w}^2 \times \sin\alpha \quad (7)$$

with Formula (8):

$$f_0 = \min\left\{ f_{0,i}, f_{0,e} \right\} \quad (8)$$

and Formulae (9) and (10):

$$f_{0,i} = 11{,}479\,8 \times \chi_i \times \left(\frac{E(\chi_i)}{2 + \frac{\gamma}{1-\gamma} - \frac{D_w}{2 \times r_i}} \right)^2 \quad (9)$$

$$f_{0,e} = 11{,}479\,8 \times \chi_e \times \left(\frac{E(\chi_e)}{2 - \frac{\gamma}{1+\gamma} - \frac{D_w}{2 \times r_e}} \right)^2 \quad (10)$$

where

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

The calculation of the Hertzian parameters χ and $E(\chi)$ is described in Annex A. Guide values of the factor f_0 are given in Annex B, Table B.1.

5.4 Basic static radial load rating of radial roller bearings

The basic static radial load rating for a radial roller bearing with a ceramic roller set is given by Formula (11):

$$C_{0r} = 41{,}586\,2 \times \left(1 - \frac{D_{we} \times \cos\alpha}{D_{pw}}\right) \times i \times Z \times L_{we} \times D_{we} \times \cos\alpha \tag{11}$$

5.5 Basic static axial load rating of thrust roller bearings

The basic static axial load rating for a thrust roller bearing with a ceramic roller set is given by Formula (12):

$$C_{0a} = 207{,}931 \times \left(1 - \frac{D_{we} \times \cos\alpha}{D_{pw}}\right) \times Z \times L_{we} \times D_{we} \times \sin\alpha \tag{12}$$

where

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

5.6 Discontinuities in load ratings

For information for discontinuities in load ratings, see Annex C.

5.7 Consideration of special material properties

For information on consideration of special material properties, see Annex D.

6 Static equivalent load

6.1 General

The derivation of the static radial load factor, X_0, and the static axial load factor, Y_0, is described in ISO/TR 10657:1991[5], Clause 4. The equation set used there is almost independent of the modulus of elasticity and Poisson's ratio of rolling elements and raceways, therefore the values obtained by this derivation is valid also for hybrid bearings with ceramic rolling elements.

6.2 Radial ball bearings

For the calculation of the static equivalent load, the factors and formulae given in ISO 76:2006, 5.2 apply.

6.3 Thrust ball bearings

For the calculation of the static equivalent load, the factors and formulae given in ISO 76:2006, 6.2 apply.

6.4 Radial roller bearings

For the calculation of the static equivalent load, the factors and formulae given in ISO 76:2006, 7.2 apply.

6.5 Thrust roller bearings

For the calculation of the static equivalent load, the factors and formulae given in ISO 76:2006, 8.2 apply.

7 Static safety factor

It is advisable to check that the basic static load rating is adequate for attaining the performance requirements of the application by calculation of the static safety factor S_0 according to ISO 76:2006, Formula (14) and (15).

The guideline values of S_0 given in Tables 1 and 2 for various types of operation and application requirements regarding smooth and vibration-free running are applicable to rotating bearings and are based on experience.

For other specific operating conditions, the bearing manufacturer should be consulted for guidance on the applicable S_0 values.

Table 1 — Guideline values of static safety factor S_0 for hybrid ball bearings

Type of operation	S_0 min.
Quiet-running applications: smooth-running, vibration-free[a], high rotational accuracy	2,6
Normal-running applications: smooth-running, vibration-free[a], normal rotational accuracy	1,3
Applications subjected to shock loads: pronounced shock loads[b]	2

[a] Technically there is no completely vibration-free rolling bearing.

[b] Where the magnitude of the shock load is not known, values of S_0 which are at least 2 should be used. If the magnitude of the shock loads is known exactly, smaller values of S_0 can be applied.

Table 2 — Guideline values of static safety factor S_0 for hybrid roller bearings

Type of operation	S_0 min.
Quiet-running applications: smooth-running, vibration-free[a], high rotational accuracy	3,3
Normal-running applications: smooth-running, vibration-free[a], normal rotational accuracy	1,7
Applications subjected to shock loads: pronounced shock loads[b]	3,3

[a] Technically there is no completely vibration-free rolling bearing.

[b] Where the magnitude of the shock load is not known, values of S_0 which are at least 3,3 should be used. If the magnitude of the shock loads is known exactly, smaller values of S_0 can be applied.

Annex A
(informative)

Calculation of the Hertzian parameters for point contact

The ratio of semi major to semi minor axis of the contact ellipse, χ, is independent of the modulus of elasticity and Poisson's ratio of the contacting bodies. It can be obtained by iteratively finding the solution of Formula (A.1):

$$1-\frac{2}{\chi^2-1}\times\left(\frac{K(\chi)}{E(\chi)}-1\right)-F(\rho)=0 \tag{A.1}$$

The complete elliptic integral of the first kind, $K(\chi)$, is shown by Formula (A.2):

$$K(\chi)=\int_0^{\frac{\pi}{2}}\left[1-\left(1-\frac{1}{\chi^2}\right)\times(\sin\phi)^2\right]^{-\frac{1}{2}}\mathrm{d}\phi \tag{A.2}$$

and the complete elliptic integral of the second kind, $E(\chi)$, is shown by Formula (A.3):

$$E(\chi)=\int_0^{\frac{\pi}{2}}\left[1-\left(1-\frac{1}{\chi^2}\right)\times(\sin\phi)^2\right]^{\frac{1}{2}}\mathrm{d}\phi \tag{A.3}$$

The curvature sum of the inner ring [shaft washer] raceway contacts is shown by Formula (A.4):

$$\sum\rho_\mathrm{i}=\frac{2}{D_\mathrm{w}}\times\left(2+\frac{\gamma}{1-\gamma}-\frac{D_\mathrm{w}}{2\times r_\mathrm{i}}\right) \tag{A.4}$$

The curvature sum of the outer ring [housing washer] raceway contacts is shown by Formula (A.5):

$$\sum\rho_\mathrm{e}=\frac{2}{D_\mathrm{w}}\times\left(2-\frac{\gamma}{1+\gamma}-\frac{D_\mathrm{w}}{2\times r_\mathrm{e}}\right) \tag{A.5}$$

The relative curvature difference of the inner ring (shaft washer) raceway contacts is shown by Formula (A.6):

$$F_\mathrm{i}(\rho)=\frac{\frac{\gamma}{1-\gamma}+\frac{D_\mathrm{w}}{2\times r_\mathrm{i}}}{2+\frac{\gamma}{1-\gamma}-\frac{D_\mathrm{w}}{2\times r_\mathrm{i}}} \tag{A.6}$$

The relative curvature difference of the outer ring (housing washer) raceway contacts is shown by Formula (A.7):

$$F_\mathrm{e}(\rho)=\frac{\frac{-\gamma}{1+\gamma}+\frac{D_\mathrm{w}}{2\times r_\mathrm{e}}}{2-\frac{\gamma}{1+\gamma}-\frac{D_\mathrm{w}}{2\times r_\mathrm{e}}} \tag{A.7}$$

Annex B
(informative)

Guide values of the factor f_0 for ball bearings

Guideline values of the factor f_0 for ball bearings are given in Table B.1.

Table B.1 — Guide values of factor f_0 for ball bearings

$\frac{D_w \times \cos\alpha}{D_{pw}}$ [a]	Factor f_0		
	Radial and angular contact ball bearings	Self-aligning ball bearings	Thrust ball bearings
0	14,1	1,4	59,0
0,01	14,3	1,4	58,2
0,02	14,5	1,5	57,3
0,03	14,6	1,5	56,6
0,04	14,8	1,5	55,8
0,05	15,0	1,6	55,0
0,06	15,2	1,6	54,3
0,07	15,4	1,6	53,5
0,08	15,6	1,7	52,7
0,09	15,8	1,7	52,0
0,1	15,7	1,7	51,2
0,11	15,4	1,7	50,4
0,12	15,2	1,8	49,7
0,13	14,9	1,8	49,0
0,14	14,7	1,8	48,2
0,15	14,5	1,9	47,5
0,16	14,3	1,9	46,7
0,17	14,1	1,9	45,9
0,18	13,8	2,0	45,3
0,19	13,6	2,0	44,5
0,2	13,4	2,0	43,7
0,21	13,1	2,1	43,1
0,22	12,9	2,1	42,3
0,23	12,6	2,1	41,6
0,24	12,4	2,2	40,9
0,25	12,3	2,2	40,1
0,26	12,0	2,2	39,4
0,27	11,8	2,3	38,8
0,28	11,6	2,3	38,0
0,29	11,3	2,4	37,3
0,3	11,1	2,4	36,6
0,31	10,9	2,4	35,9
0,32	10,7	2,5	35,2

Table B.1 *(continued)*

$\frac{D_w \times \cos\alpha}{D_{pw}}$ [a]	Factor f_0		
	Radial and angular contact ball bearings	**Self-aligning ball bearings**	**Thrust ball bearings**
0,33	10,4	2,5	34,5
0,34	10,2	2,5	33,8
0,35	10,1	2,6	33,1
0,36	9,9	2,6	—
0,37	9,6	2,7	—
0,38	9,4	2,7	—
0,39	9,2	2,7	—
0,4	9,0	2,8	—

NOTE 1 This table is based on the Hertzian point contact equation with elastic properties of the ball and raceways as given in the notes in Clause 4.

NOTE 2 It is assumed that the load distribution results in a maximum ball load of $\frac{5 \times F_r}{Z \times \cos\alpha}$ for radial ball bearings and a maximum ball load of $\frac{F_a}{Z \times \sin\alpha}$ for thrust ball bearings.

NOTE 3 Values in this table were obtained by using raceway cross-sectional groove radii of 0,52 D_w and 0,53 D_w at the inner and outer ring contact of radial bearings and 0,54 D_w for thrust bearings.

[a] Values of f_0 for intermediate values of $\frac{D_w \times \cos\alpha}{D_{pw}}$ are obtained by linear interpolation.

Annex C
(informative)

Discontinuities in the calculation of basic static load ratings

The factors used for the calculation of basic static load ratings C_{0r} and C_{0a} according to this document are slightly different for radial and thrust angular contact ball bearings.

Therefore, there is a discontinuity in the calculated static axial load rating (C_{0a}) when a bearing with the contact angle α = 45° is both calculated as a radial bearing ($C_{0a} = C_{0r}/Y_0$) and as a thrust bearing.

ISO 76:2006, Annex A explains why the load rating factors are different, and shows how the load ratings can be recalculated in order to bring about correct comparisons under the same conditions.