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

Part 1:
Dynamic load ratings

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

Partie 1: Charges dynamiques de base

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Foreword

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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 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 steel rolling bearings 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 theoretically to a reduction of the dynamic load-carrying capacity.

In practice, hybrid bearings are used in numerous industrial applications, where these bearings show at least the same service life as conventional rolling bearings with steel rolling elements. Thus for the typical range of application of hybrid bearings, the theoretical reduction of the dynamic load rating is not observed in actual applications. The smaller contact ellipse and the material combination of ceramic-steel will lead to noticeably lower surface shear stress in the rolling contact, which again will lead to a higher load-carrying ability. This is reflected by defining a higher b_m factor compared to steel bearings, which compensates for the higher contact stress under the same load.

Therefore, the formulae specified in this document give the same dynamic load ratings as defined per ISO 281 for rolling bearings with identical internal geometry and rolling elements made of steel.

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

Part 1: Dynamic load ratings

1 Scope

This document specifies methods of calculating the dynamic 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 rolling elements made from silicon nitride in contemporary, commonly used, high material and manufacturing quality and surface finish. For balls, ISO 26602[6] together with ISO 3290-2[2] are applicable. For rollers, ISO 12297-2[3] is applicable and ISO 26602[6] is applicable in an analogous way.

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 281, *Rolling bearings — Dynamic load ratings and rating life*

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 281 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/

4 Symbols

For the purpose of this document, the following symbols apply.

b_m	rating factor for contemporary, commonly used, high quality hardened bearing steel in accordance with good manufacturing practice, the value of which varies with bearing type and design
C_a	basic dynamic axial load rating, in N
C_r	basic dynamic radial load rating, in N
C_u	fatigue load limit, in N (see Annex A)
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 281)

$E(\chi)$ complete elliptic integral of the second kind

f_c 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 rolling elements

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

Q_u fatigue load limit of a single contact, 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

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, $\gamma = D_w \times \cos\alpha / D_{pw}$ for ball bearings with $\alpha \neq 90°$

$\gamma = D_w / D_{pw}$ for ball bearings with $\alpha = 90°$

$\gamma = D_{we} \times \cos\alpha / D_{pw}$ for roller bearings with $\alpha \neq 90°$

$\gamma = D_{we} / D_{pw}$ for roller bearings with $\alpha = 90°$

η reduction factor for thrust bearings

λ reduction factor

ν adjustment factor for exponent variation

ν_{Ce} Poisson's ratio of ceramic rolling elements (ν_{Ce} = 0,26)

ν_{St} Poisson's ratio of rolling bearing steel (ν_{St} = 0,30, according to ISO 281)

$\sum\rho$ curvature sum, in mm^{-1}

σ_{Hu} Hertzian contact stress at which the fatigue limit of the raceway is reached, in MPa

χ ratio of semi-major to semi-minor axis of the contact ellipse

5 Dynamic load rating

5.1 Ball bearings

5.1.1 Basic dynamic radial load rating

The basic dynamic radial load rating of a hybrid ball bearing is given by Formulae (1), (2) and (3):

$$C_r = b_m \times f_c \times (i \times \cos \alpha)^{0,7} \times Z^{2/3} \times D_w{}^{1,8} \text{ for } D_w \leq 25{,}4 \text{ mm} \tag{1}$$

and

$$C_r = 3{,}647 \times b_m \times f_c \times (i \times \cos \alpha)^{0,7} \times Z^{2/3} \times D_w{}^{1,4} \text{ for } D_w > 25{,}4 \text{ mm} \tag{2}$$

with

$$f_c = 29{,}038\ 580 \times \lambda \times \left(\frac{2 \times r_i}{2 \times r_i - D_w}\right)^{0,41} \times \gamma^{0,3} \times \frac{(1-\gamma)^{1,39}}{(1+\gamma)^{1/3}} \times \left\{1 + \left[1{,}04 \left(\frac{1-\gamma}{1+\gamma}\right)^{1,72} \times \left(\frac{r_i}{r_e} \times \frac{2 \times r_e - D_w}{2 \times r_i - D_w}\right)^{0,41}\right]^{\frac{10}{3}}\right\}^{\frac{-3}{10}} \tag{3}$$

Tabulated guide values for the factor f_c are given in Annex B. The values of f_c given in Table B.1 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.

5.1.2 Basic dynamic axial load rating

5.1.2.1 Thrust ball bearings with contact angle α < 90°

The basic dynamic axial load rating of a hybrid thrust ball bearing with contact angle α < 90° is given by Formulae (4), (5) and (6):

$$C_a = b_m \times f_c \times (\cos \alpha)^{0,7} \times \tan \alpha \times Z^{2/3} \times D_w{}^{1,8} \text{ for } D_w \leq 25{,}4 \text{ mm} \tag{4}$$

and

$$C_a = 3{,}647 \times b_m \times f_c \times (\cos \alpha)^{0,7} \times \tan \alpha \times Z^{2/3} \times D_w{}^{1,4} \text{ for } D_w > 25{,}4 \text{ mm} \tag{5}$$

with

$$f_c = 70{,}825\ 8060 \times \lambda \times \eta \times \left(\frac{2 \times r_i}{2 \times r_i - D_w}\right)^{0,41} \times \gamma^{0,3} \times \frac{(1-\gamma)^{1,39}}{(1+\gamma)^{1/3}} \times \left\{1 + \left[\left(\frac{1-\gamma}{1+\gamma}\right)^{1,72} \times \left(\frac{r_i}{r_e} \times \frac{2 \times r_e - D_w}{2 \times r_i - D_w}\right)^{0,41}\right]^{\frac{10}{3}}\right\}^{\frac{-3}{10}} \tag{6}$$

where

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

Tabulated guide values for the factor f_c are given in Annex B. The values of f_c given in Table B.2 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 it is reduced by the use of a groove radius larger than those indicated in the previous paragraph.

5.1.2.2 Thrust ball bearings with contact angle α = 90°

The basic dynamic axial load rating of a hybrid thrust ball bearing with contact angle α = 90° is given by Formulae (7), (8) and (9):

$$C_a = b_m \times f_c \times Z^{2/3} \times D_w^{1,8} \text{ for } D_w \leq 25{,}4 \text{ mm} \quad (7)$$

and

$$C_a = 3{,}647 \times b_m \times f_c \times Z^{2/3} \times D_w^{1,4} \text{ for } D_w > 25{,}4 \text{ mm} \quad (8)$$

with

$$f_c = 70{,}825\,8060 \times \lambda \times \eta \times \left(\frac{2 \times r_i}{2 \times r_i - D_w} \right)^{0,41} \times \gamma^{0,3} \times \left\{ 1 + \left[\left(\frac{r_i}{r_e} \times \frac{2 \times r_e - D_w}{2 \times r_i - D_w} \right)^{0,41} \right]^{\frac{10}{3}} \right\}^{\frac{-3}{10}} \quad (9)$$

where

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

Tabulated guide values for the factor f_c are given in Annex B. The values of f_c given in Table B.2 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 it is reduced by the use of a groove radius larger than those indicated in the previous paragraph.

5.1.3 Rating and reduction factors for hybrid ball bearings

The values for the factors b_m, λ and η used in Formulae (1) to (9) for the different kinds of hybrid ball bearings are given in Table 1.

Table 1 — Rating and reduction factors for hybrid ball bearings

Bearing type	b_m	λ	η
Single row radial deep groove ball bearing	1,8	0,95	—
Single row and double row angular contact ball bearing			—
Double row radial deep groove ball bearing	1,8	0,9	—
Self-aligning ball bearings	1,8	1	—
Thrust ball bearing	1,8	0,9	$1 - \frac{\sin \alpha}{3}$

5.2 Roller bearings

5.2.1 Basic dynamic radial load rating

The basic dynamic radial load rating of a hybrid radial roller bearing is given by Formulae (10) and (11):

$$C_r = b_m \times f_c \times (i \times L_{we} \times \cos\alpha)^{7/9} \times Z^{3/4} \times D_{we}^{29/27} \tag{10}$$

with

$$f_c = 142{,}846\ 97 \times \lambda \times \nu \times \frac{\gamma^{2/9} \times (1-\gamma)^{29/27}}{(1+\gamma)^{1/4}} \times \left\{ 1 + \left[1{,}04 \times \left(\frac{1-\gamma}{1+\gamma} \right)^{\frac{143}{108}} \right]^{\frac{9}{2}} \right\}^{\frac{-2}{9}} \tag{11}$$

Tabulated guide values for the factor f_c are given in Annex B.

5.2.2 Basic dynamic axial load rating

5.2.2.1 Thrust roller bearings with contact angle α < 90°

The basic dynamic axial load rating of a hybrid thrust roller bearing with contact angle α < 90° is given by Formulae (12) and (13):

$$C_a = b_m \times f_c \times (L_{we} \times \cos\alpha)^{7/9} \times \tan\alpha \times Z^{3/4} \times D_{we}^{29/27} \tag{12}$$

with

$$f_c = 380{,}092\ 23 \times \lambda \times \nu \times \eta \times \frac{\gamma^{2/9} \times (1-\gamma)^{29/27}}{(1+\gamma)^{1/4}} \times \left\{ 1 + \left[\left(\frac{1-\gamma}{1+\gamma} \right)^{\frac{143}{108}} \right]^{\frac{9}{2}} \right\}^{\frac{-2}{9}} \tag{13}$$

Tabulated guide values for the factor f_c are given in Annex B.

5.2.2.2 Thrust roller bearings with contact angle α = 90°

The basic dynamic axial load rating of a hybrid thrust roller bearing with contact angle α = 90° is given by Formulae (14) and (15):

$$C_a = b_m \times f_c \times L_{we}^{7/9} \times Z^{3/4} \times D_{we}^{29/27} \tag{14}$$

with

$$f_c = 326{,}830\ 26 \times \lambda \times \nu \times \eta \times \gamma^{2/9} \tag{15}$$

where

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