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Spherical plain bearings — Derivation of the load rating factors

Rotules lisses — Explication sur le calcul des charges 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*.

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Introduction

Different calculating methods for static and dynamic load ratings of spherical plain bearings have been used in different countries, thus making it difficult to compare different solutions. A unified method for the calculation of static and dynamic load ratings has been standardized in ISO 20015.

ISO 20015 leaves the load rating factors to the manufacturers to determine because they are dependent on design and material. Bearing manufacturers don't have unified methods to determine these factors themselves. This document gives the supplementary background information regarding the derivation of factors in ISO 20015.

Spherical plain bearings — Derivation of the load rating factors

1 Scope

This document gives supplementary background information regarding the derivation of factors given in ISO 20015.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

A	contact area on bearing sliding surface, in square millimetres (mm^2)
B	inner ring width, in millimetres (mm)
C	outer ring width, in millimetres (mm)
$\bar{C}$	effective width of distribution of contact load, in millimetres (mm)
$\bar{C}(\theta)$	effective width of distribution of contact load function versus θ, in millimetres (mm)
C_a	dynamic axial load rating, in newtons (N)
C_r	dynamic radial load rating, in newtons (N)
C_{0a}	static axial load rating, in newtons (N)
C_{0r}	static radial load rating, in newtons (N)
D	outside diameter, in millimetres (mm)
D_{S1}	smallest diameter of sliding contact surface of the outer ring, in millimetres (mm)
D_{S2}	largest diameter of sliding contact surface of the outer ring, in millimetres (mm)
d	bore diameter, in millimetres (mm)
d_k	sphere diameter, in millimetres (mm)
F_a	axial load, in newtons (N)

F_r	radial load, in newtons (N)
f_a	factor for the calculation of dynamic axial load ratings of the sliding contact area, which depends on design and material, in newtons per square millimetre (MPa)
$f_a(\tau)$	factor for the calculation of axial load ratings of the sliding contact area for angular contact radial spherical plain bearings and angular contact thrust spherical plain bearings, function versus τ, in newtons per square millimetre (MPa)
$f_{ar}(\theta_0, \tau)$	factor for the calculation of radial load ratings of the sliding contact area for angular contact radial spherical plain bearings, function versus θ_0 and τ, in newtons per square millimetre (MPa)
f_{0a}	factor for the calculation of static axial load ratings of the sliding contact area, which depends on design and material, in newtons per square millimetre (MPa)
f_r	factor for the calculation of dynamic radial load ratings of the sliding contact area, which depends on design and material, in newtons per square millimetre (MPa)
$f_r(\varepsilon)$	factor for the calculation of radial load ratings of the sliding contact area for radial spherical plain bearing, function versus ε, in newtons per square millimetre (MPa)
f_{0r}	factor for the calculation of static radial load ratings of the sliding contact area, which depends on design and material, in newtons per square millimetre (MPa)
$g_a(\beta)$	axial contact stress distribution dimensionless function versus β
$g_{ar}(\theta,\zeta)$	contact stress distribution dimensionless function versus θ and ζ for angular contact radial spherical plain bearing
$g_r(\theta)$	radial contact stress distribution dimensionless function versus θ
$I(\theta_0)$	surface integral of radial contact stress distribution dimensionless function versus θ_0
$J(\tau)$	surface integral of axial contact stress distribution dimensionless function versus τ
k	factor affecting the accuracy for manufacturing ($k \le 1$)
$p(\theta)$	contact stress function versus θ, in newtons per square millimetre (MPa)
$p(\beta)$	contact stress function versus β, in newtons per square millimetre (MPa)
$p(\theta, \beta)$	contact stress function versus θ and β, in newtons per square millimetre (MPa)
$p(\theta, \varphi)$	contact stress function versus θ and φ, in newtons per square millimetre (MPa)
$p_a(\theta)$	axial contact stress function versus θ, in newtons per square millimetre (MPa)
$p_a(\beta)$	axial contact stress function versus β, in newtons per square millimetre (MPa)
$p_a(\theta, \beta)$	axial contact stress function versus θ and β, in newtons per square millimetre (MPa)
$p_r(\theta)$	radial contact stress function versus θ, in newtons per square millimetre (MPa)
$p_r(\beta)$	radial contact stress function versus β, in newtons per square millimetre (MPa)
$p_r(\theta, \beta)$	radial contact stress function versus θ and β, in newtons per square millimetre (MPa)
$p_r(\theta, \zeta)$	radial contact stress function versus θ and ζ, in newtons per square millimetre (MPa)
$\bar{p}$	allowable contact stress of bearing material, in newtons per square millimetre (MPa)

r variable of integration of radius of contact area

S width of contact area in spherical surface direction, in millimetres (mm)

s variable of integration of width of contact area in spherical surface direction

T bearing width, in millimetres (mm)

z coordinate variable along z axis

α variable angle in arising contact area, in radians (rad) (see Figure 3)

β variable angle in arising contact area, in radians (rad) (see Figure 3)

ε dimensionless parameter of radial internal clearance ratio versus sphere diameter

ζ dimensionless variable ($\zeta = z/\bar{C}$)

$\zeta_0(\theta)$ boundary value of dimensionless variable ζ versus θ

θ variable of integration of load distribution angle along the circumferential direction, in radians (rad)

θ_0 maximum angle of load distribution along the circumferential direction, in radians (rad)

μ factor of effective contact width of outer ring of bearing

τ bearing nominal contact angle, in radians (rad)

τ_{S1} smallest contact angle to diameter of sliding contact surface, in radians (rad)

τ_{S2} largest contact angle to diameter of sliding contact surface, in radians (rad)

φ variable of integration of load distribution angle perpendicular to the circumferential direction, in radians (rad)

φ_{max} maximum angle of load distribution perpendicular to the circumferential direction, in radians (rad)

5 General

The calculation of the radial load rating and the axial load rating for radial spherical plain bearings, angular contact thrust spherical plain bearings and angular contact radial spherical plain bearings is explained in Formulas (1) to (42).

6 Radial spherical plain bearings

6.1 Bearing load distribution on the sliding contact area

When the bearing supports a radial load F_r, the radial load distribution on the bearing sliding contact area is shown in Figures 1 and 2.

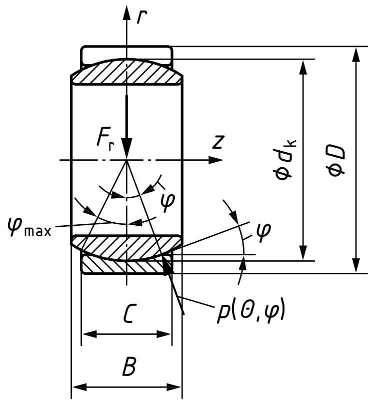

Figure 1 — Radial spherical plain bearing under radial load F_r

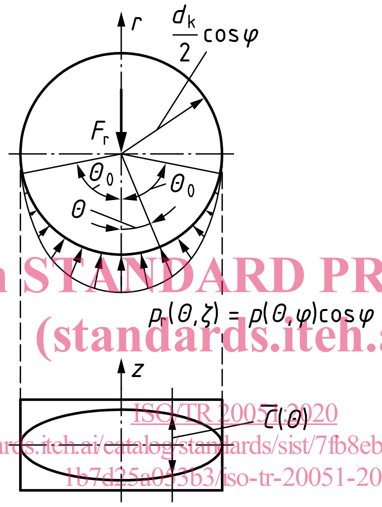

Figure 2 — Radial load distribution and projected contact area on the bearing contact area along a circumferential direction under radial load F_r

The contact distributed load $p(\theta,\varphi)$ is a function of θ and φ. The radial load F_r is the integral of the component of the distributed load $p(\theta,\varphi)$ acting in the direction of the radial load F_r on the bearing contact area along the circumferential direction.

$$\int_A p(\theta,\varphi)\cos\theta\cos\varphi \mathrm{d}A = F_r \tag{1}$$

where

$$\mathrm{d}A = \frac{\mathrm{d}z}{\cos\varphi}\frac{d_k}{2}\cos\varphi \mathrm{d}\theta = \frac{d_k}{2}\mathrm{d}\theta \mathrm{d}z \tag{2}$$

The limits of integration area A of contact stress is set by

$$-\theta_0 \le \theta \le \theta_0, \quad -\frac{\bar{C}(\theta)}{2} \le z \le \frac{\bar{C}(\theta)}{2} \tag{3}$$

Then, Formula (1) can be changed as

$$\begin{aligned}\int_A p(\theta,\varphi)\cos\theta\cos\varphi \mathrm{d}A &= \int_{-\theta_0}^{\theta_0}\int_{-\bar{C}(\theta)/2}^{\bar{C}(\theta)/2} p(\theta,\varphi)\cos\theta\cos\varphi\frac{d_k}{2}\mathrm{d}\theta \mathrm{d}z \\ &= \frac{d_k}{2}\int_{-\theta_0}^{\theta_0}\cos\theta d\theta\int_{-\bar{C}(\theta)/2}^{\bar{C}(\theta)/2} p(\theta,\varphi)\cos\varphi \mathrm{d}z = F_r\end{aligned} \tag{4}$$

If we set $p_r(\theta,\zeta) = p(\theta,\varphi)\cos\varphi$ and $\zeta = z/\bar{C}$, $-\zeta_0(\theta) \le \zeta \le \zeta_0(\theta)$, then

$$\int_{-\bar{C}(\theta)/2}^{\bar{C}(\theta)/2} p(\theta,\varphi)\cos\varphi \mathrm{d}z = \bar{C}\int_{-\zeta_0(\theta)}^{\zeta_0(\theta)} p_r(\theta,\zeta)\mathrm{d}\zeta \tag{5}$$

Thus Formula (1) becomes

$$\int_A p(\theta,\varphi)\cos\theta\cos\varphi \mathrm{d}A = \bar{C}\frac{d_k}{2}\int_{-\theta_0}^{\theta_0}\int_{-\zeta_0(\theta)}^{\zeta_0(\theta)} p_r(\theta,\zeta)\cos\theta \mathrm{d}\theta \mathrm{d}\zeta = F_r \tag{6}$$

Formula (6) is the basis of calculating the radial load ratings of the radial spherical plain bearings.

6.2 Bearing load rating

When the radial load reaches the load rating, and if we set

$$p_r(\theta,\zeta) = \bar{p}g_r(\theta,\zeta) \tag{7}$$

Then the Formula (6) becomes

$$\bar{C}\frac{d_k}{2}\bar{p}\int_{-\theta_0}^{\theta_0}\int_{-\zeta_0(\theta)}^{\zeta_0(\theta)} g_r(\theta,\zeta)\cos\theta \mathrm{d}\theta \mathrm{d}\zeta = C_r \tag{8}$$

If we set

$$I(\theta_0) = \frac{1}{2}\int_{-\theta_0}^{\theta_0}\int_{-\zeta_0(\theta)}^{\zeta_0(\theta)} g_r(\theta,\zeta)\cos\theta \mathrm{d}\theta \mathrm{d}\zeta \tag{9}$$

Then the radial load rating is

$$C_r = \bar{C}d_k\bar{p}I(\theta_0) \tag{10}$$