INTERNATIONAL STANDARD

ISO 15312

Second edition
2018-02

Rolling bearings — Thermal speed rating — Calculation

Roulements — Vitesse de référence thermique — Calculs

Reference number
ISO 15312:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Published in Switzerland

Contents

Page

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 15312:2003), of which it constitutes a minor revision with the following changes:

a) the term “coefficients” has been deleted from the title;

b) the normative references have been updated and modified;

c) Formula (11) has been corrected;

d) Clause 7 has been moved to a new informative Annex B;

e) content from Annex B has been moved to a new informative Annex C.

Rolling bearings — Thermal speed rating — Calculation

1 Scope

This document defines the thermal speed rating for oil bath lubricated rolling bearings and defines calculation principles for the determination of this parameter. The parameter determined in accordance with this document applies to rolling bearings of the given series and sizes of standard design or of a design that, from a frictional point of view, can be related to a standard design bearing.

In most cases of standard assembly, the permissible temperature determines the maximum operating speed. Heating of the assembly is then generated by the bearing.

Thrust ball bearings are excluded from this document as kinematic effects do not allow the thermal speed rating defined in this document to be applied.

NOTE 1 In Annex A mean values for the coefficients f_{0r} and f_{1r} are given — for for calculating viscous losses of oil bath lubricated bearings and f_{1r} for calculating frictional losses of bearings.

NOTE 2 Explanatory notes on the limiting criterion are given in Annex B.

NOTE 3 In Annex C the reference conditions for grease lubrication are defined. The reference conditions are chosen such that the thermal speed rating for grease lubrication is identical to that for oil bath lubrication.

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, *Rolling bearings — Static load ratings*

ISO 1132-1, *Rolling bearings — Tolerances — Part 1: Terms and definitions*

ISO 5593, *Rolling bearings — Vocabulary*

ISO 5753-1, *Rolling bearings — Internal clearance — Part 1: Radial internal clearance for radial bearings*

ISO 15241, *Rolling bearings — Symbols for physical quantities*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1132-1 and ISO 5593, 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
thermal speed rating
inner ring or shaft washer rotational speed at which equilibrium is reached between the heat generated by the friction in the bearing and the heat flow emitted through the bearing seating (shaft and housing) under the reference conditions

Note 1 to entry: The thermal speed rating is one among various criteria which permit comparison of the different rolling bearing types and sizes with regard to their suitability for operation at high speed.

Note 2 to entry: Mechanical and kinematic criteria which could lead to further speed limitations are not taken into account by the thermal speed rating.

3.2
reference conditions
conditions for the thermal speed rating related to

a) the mean temperature of the stationary outer ring or housing washer of the bearing, i.e. the reference temperature, and the mean environmental temperature, i.e. the reference ambient temperature;

b) the factors determining the friction losses in the bearing, such as:

   — the magnitude and direction of the bearing load;

   — the method of lubrication, type of lubricant, its kinematic viscosity and quantity;

   — other general reference conditions;

c) the heat flow emitted from the rolling bearing defined as the product of the "heat emitting reference surface area of the rolling bearing" and the "reference heat flow density specific to the rolling bearing".

Note 1 to entry: The heat emission under the reference conditions is based on empirical values and represents the heat emission of the real bearing arrangement. It is, however, independent of the real design of the bearing arrangement.

3.3
heat emitting reference surface area
sum of the contact areas, between inner ring (shaft washer) and shaft and between outer ring (housing washer) and housing, through which the heat flow is emitted

3.4
reference load
bearing load, determined by the reference conditions, which causes the load-dependent frictional moment

3.5
reference heat flow
heat flow, emitted by thermal conduction through the heat emitting reference surface, and caused by frictional resistance, when the bearing is operating under the reference conditions

3.6
reference heat flow density
reference heat flow divided by the heat emitting reference surface area

3.7
reference ambient temperature
mean environmental temperature of the bearing arrangement under the reference conditions

3.8
reference temperature
mean temperature of the stationary outer ring or housing washer of the bearing under the reference conditions

4 Symbols and units

For the purposes of this document, the symbols given in ISO 15241 and the following apply.

Table 1 — Symbols and units

Symbol	Term	Unit
A_r	Heat emitting reference surface area	mm^2
B	Width of rolling bearing	mm
C_{0a}	Basic static axial load rating in accordance with ISO 76	N
C_{0r}	Basic static radial load rating in accordance with ISO 76	N
D	Bearing outside diameter	mm
D_1	Inside diameter of the outer ring of thrust spherical roller bearing	mm
d	Bearing bore diameter	mm
d_m	Mean diameter of rolling bearing $d_m = 0{,}5 \times (D + d)$	mm
d_1	Outside diameter of the inner ring of thrust spherical roller bearing	mm
f_{0r}	Coefficient for the load-independent frictional moment for the reference conditions	1
f_{1r}	Coefficient for the load-dependent frictional moment for the reference conditions	1
M_0	Load-independent frictional moment	N·mm
M_{0r}	Load-independent frictional moment under the reference conditions at the thermal speed rating, $n_{\theta r}$	N·mm
M_1	Load-dependent frictional moment	N·mm
M_{1r}	Load-dependent frictional moment under the reference conditions at the thermal speed rating, $n_{\theta r}$	N·mm
N_r	Bearing power loss under the reference conditions at the thermal speed rating, $n_{\theta r}$	W
$n_{\theta r}$	Thermal speed rating	min^{-1}
P_{1r}	Reference load	N
q_r	Reference heat flow density	W/mm^2
T	Total width of tapered roller bearing	mm
ν_r	Kinematic viscosity of the lubricant under the reference conditions (at the reference temperature, θ_r, of the rolling bearing)	mm^2/s
α	Contact angle	°
θ_{Ar}	Reference ambient temperature	°C
θ_r	Reference temperature	°C
Φ_r	Reference heat flow	W

5 Reference conditions

5.1 General

The reference conditions in this document are mainly based on the operating conditions of the most frequently used bearing types and sizes.

5.2 Reference conditions determining the frictional heat generation

5.2.1 Reference temperatures

Reference temperature of the bearing on the stationary outer ring or housing washer: $\theta_r = 70$ °C.

Reference temperature of the bearing environment: $\theta_{Ar} = 20$ °C.

5.2.2 Reference load

5.2.2.1 Radial bearings with contact angle $0° \leq \alpha \leq 45°$

5 % of the basic static radial load rating C_{0r} as pure radial load.

In the case of a single-row angular contact bearing, the reference load refers to the radial component of that load which causes a purely radial displacement of the bearing rings in relation to each other.

$$P_{1r} = 0{,}05 \times C_{0r}$$

5.2.2.2 Thrust roller bearings with contact angle $45° < \alpha \leq 90°$

2 % of the basic static axial load rating C_{0a} as centrically acting axial load.

$$P_{1r} = 0{,}02 \times C_{0a}$$

5.2.3 Lubrication

5.2.3.1 Lubricant

A mineral oil without EP additives having the following kinematic viscosity, ν_r, at $\theta_r = 70$ °C:

a) Radial bearings $\nu_r = 12$ mm^2/s (ISO VG 32);

b) Thrust roller bearings $\nu_r = 24$ mm^2/s (ISO VG 68).

5.2.3.2 Method of lubrication

Oil bath lubrication with an oil level up to the centre of the rolling element in the lowest position.

5.2.4 Other reference conditions

5.2.4.1 Bearing characteristics

size range	standard type bearings up to and including a bore diameter of 1 000 mm
internal clearance	complying with group “N” as specified in ISO 5753-1
seals	not provided with contacting seals
double row radial bearings and double direction thrust bearings	presumed to be symmetrical
rolling bearings where the rolling elements operate directly on the shaft or in the housing	presumed that the running surface of the shaft or housing is equivalent in all respects to the raceway of the bearing ring or washer which it replaces

5.2.4.2 Arrangement of the bearing

bearing rotational axis	horizontal

NOTE For thrust cylindrical roller and needle roller bearings, care should be taken to supply oil to the upper rolling elements.

outer ring or housing washer	stationary
angular contact bearing setting	zero operating clearance

5.3 Reference conditions determining the heat emission

5.3.1 Heat emitting reference surface area

The following surface areas are defined as the heat emitting reference surface area A_r.

a) For radial bearings with the exception of tapered roller bearings, see Figure 1 and Formula (1).

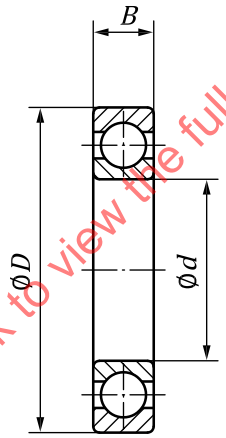
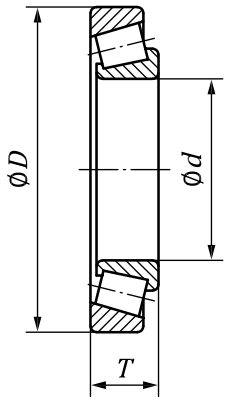


Figure 1 — Radial bearings with the exception of tapered roller bearings

$$A_r = \pi \times B(D+d) \tag{1}$$

b) For tapered roller bearings, see Figure 2 and Formula (2).



NOTE The total width of the bearing has been used instead of the individual ring widths to give results that align more correctly with empirical data.

Figure 2 — Tapered roller bearings

$$A_r = \pi \times T\left(d + D\right) \tag{2}$$

c) For thrust cylindrical roller bearings and thrust needle roller bearings, see Figure 3 and Formula (3).

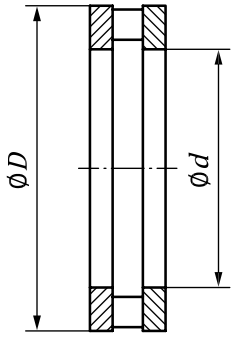


Figure 3 — Thrust cylindrical roller bearings and thrust needle roller bearings

$$A_r = 0{,}5 \times \pi\left(D^2 - d^2\right) \tag{3}$$

d) For thrust spherical roller bearings, see Figure 4 and Formula (4).

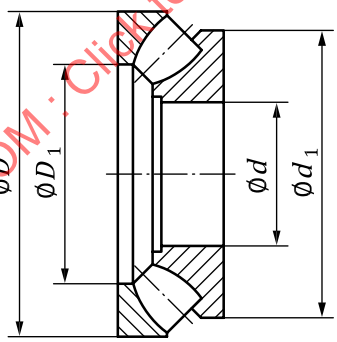


Figure 4 — Thrust spherical roller bearings

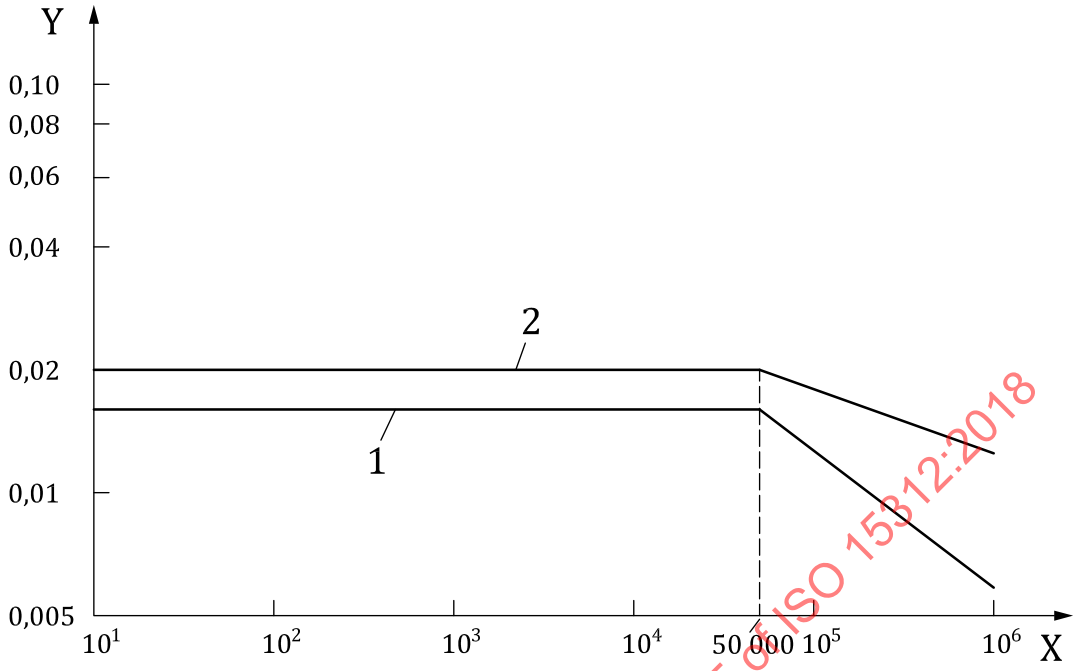
$$A_r = 0{,}25 \times \pi\left(D^2 + d_1^2 - D_1^2 - d^2\right) \tag{4}$$

5.3.2 Reference heat flow density

The reference heat flow density, q_r, is defined as:

$$q_r = \frac{\Phi_r}{A_r} \tag{5}$$

For normal applications the following values for the heat flow density q_r may be assumed, when the temperature difference $\theta_r - \theta_{Ar}$ equals 50 °C:



Radial bearings (see Figure 5, curve 1)

— for $A_r \leq 50\,000$ mm^2

$q_r = 0{,}016$ W/mm^2

— $A_r > 50\,000$ mm^2

$$q_r = 0{,}016 \times \left(\frac{A_r}{50\,000} \right)^{-0{,}34} \text{ W/mm}^2$$

Thrust bearings (see Figure 5, curve 2)

— for $A_r \leq 50\,000$ mm^2

$q_r = 0{,}020$ W/mm^2

— for $A_r > 50\,000$ mm^2

$$q_r = 0{,}020 \times \left(\frac{A_r}{50\,000} \right)^{-0{,}16} \text{ W/mm}^2$$

Key

X heat emitting reference surface, A_r, mm^2
Y reference heat flow density, q_r, W/mm^2
1 radial bearings
2 thrust bearings

Figure 5 — Curves related to radial and thrust bearings

6 Calculation of the thermal speed rating

The calculation of the thermal speed rating is based on the energy balance in the rolling bearing system under the reference conditions. The frictional heat generated in the bearing under the reference conditions and at the thermal speed rating equals the heat flow emitted from the bearing:

$$N_r = \Phi_r \tag{6}$$

The frictional heat of a bearing running at the thermal speed rating under the reference conditions is calculated as follows:

$$N_r = \frac{\pi \times n_{\theta r}}{30 \times 10^3} \left(M_{0r} + M_{1r} \right) \tag{7}$$

$$M_{0r} = 10^{-7} \times f_{0r} \left(v_r \times n_{\theta r}\right)^{\frac{2}{3}} \times d_m^3 \tag{8}$$

$$M_{1r} = f_{1r} \times P_{1r} \times d_m \tag{9}$$

The heat flow emitted from the rolling bearing under the reference conditions is calculated from the reference heat flow density, q_r, and the heat emitting reference surface area, A_r:

$$\Phi_r = q_r \times A_r \tag{10}$$

With Formulae (7), (8) and (9) for the frictional heat generated and Formula (10) for the heat flow emitted, the equation for the determination of the thermal speed rating $n_{\theta r}$ is given as:

$$\frac{\pi \times n_{\theta r}}{30 \times 10^3} \left[10^{-7} \times f_{0r} \left(v_r \times n_{\theta r}\right)^{\frac{2}{3}} \times d_m^3 + f_{1r} \times P_{1r} \times d_m \right] = q_r \times A_r \tag{11}$$

The thermal speed rating $n_{\theta r}$ is determined from Formula (11) by iteration.

Annex A
(informative)

Coefficients f_{0r} and f_{1r}

Table A.1 contains values of coefficients f_{0r} and f_{1r} for use in the calculation of the thermal speed rating $n_{\theta r}$ from Formula (11) for different bearing types without contacting seals.

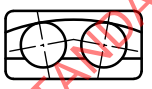
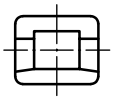
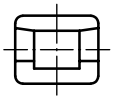
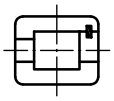
They are the result of extensive experimental investigations as well as the analysis of empirical values from literature.

Although the values for f_{0r} and f_{1r} naturally scatter, a mean value without tolerances is given in Table A.1, which makes it possible to calculate uniform thermal speed ratings.

The coefficients f_{0r} and f_{1r} are dependent on the bearing type.

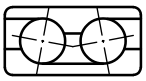
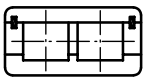
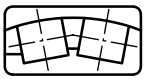
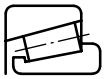
The dimension series referred to in Table A.1 are those defined in ISO 15 and ISO 104.

Table A.1 — Coefficients f_{0r} and f_{1r}

Bearing type	Dimension series	f_{0r}	f_{1r}
Single-row deep groove ball bearings 	18	1,7	0,000 10
	28	1,7	0,000 10
	38	1,7	0,000 10
	19	1,7	0,000 15
	39	1,7	0,000 15
	00	1,7	0,000 15
	10	1,7	0,000 15
	02	2	0,000 20
	03	2,3	0,000 20
	04	2,3	0,000 20
Self-aligning ball bearings 	02	2,5	0,000 08
	22	3	0,000 08
	03	3,5	0,000 08
	23	4	0,000 08
Single-row angular contact ball bearings $22° < \alpha \leq 45°$ 	02	2	0,000 25
	03	3	0,000 35
Four-point contact ball bearings 	02	2	0,000 37
	03	3	0,000 37
Single-row cylindrical roller bearings with cage  	10	2	0,000 20
	02	2	0,000 30
	22	3	0,000 40
	03	2	0,000 35
	23	4	0,000 40
	04	2	0,000 40
Single-row cylindrical roller bearings full complement 	18	5	0,000 55
	29	6	0,000 55
	30	7	0,000 55
	22	8	0,000 55
	23	12	0,000 55

[a] Dimension series for thrust needle roller bearings according to ISO 3031.

Table A.1 *(continued)*

Double-row or paired single-row angular contact ball bearings 	32 33	5 7	0,000 35 0,000 35	Double-row cylindrical roller bearings full complement 	48 49 50	9 11 13	0,000 55 0,000 55 0,000 55
Needle roller bearings 	48 49 69	5 5,5 10	0,000 50 0,000 50 0,000 50	Thrust cylindrical roller bearings 	11 12	3 4	0,001 50 0,001 50
Spherical roller bearings 	39 30 40	4,5 4,5 6,5	0,000 17 0,000 17 0,000 27	Thrust needle roller bearings 	[a]	5	0,001 50
	31 41 22	5,5 7 4	0,000 27 0,000 49 0,000 19				
	32 03 23	6 3,5 4,5	0,000 36 0,000 19 0,000 30	Thrust spherical roller bearings 	92 93 94	3,7 4,5 5	0,000 30 0,000 40 0,000 50
Tapered roller bearings 	02 03 30	3 3 3	0,000 40 0,000 40 0,000 40				
	29 20 22	3 3 4,5	0,000 40 0,000 40 0,000 40	Thrust spherical roller bearings modified design (optimised internal construction) 	92 93 94	2,5 3 3,3	0,000 23 0,000 30 0,000 33
	23 13 31	4,5 4,5 4,5	0,000 40 0,000 40 0,000 40				
	32	4,5	0,000 40				

[a] Dimension series for thrust needle roller bearings according to ISO 3031.