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Rolling bearings — Linear motion rolling bearings —

Part 1: Dynamic load ratings and rating life

Roulements — Roulements à mouvement linéaire —

Partie 1: Charges dynamiques de base et durée nominale

Reference number
ISO 14728-1:2004(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 14728-1 was prepared by Technical Committee ISO/TC 4, *Rolling bearings*, Subcommittee SC 8, *Load ratings and life*.

ISO 14728 consists of the following parts, under the general title *Rolling bearings — Linear motion rolling bearings*:

— *Part 1: Dynamic load ratings and rating life*

— *Part 2: Static load ratings*

Introduction

It is often impractical to establish the suitability of a linear motion rolling bearing selected for a specific application by testing. The following procedures have proved to be an appropriate and convenient substitute for testing:

— life calculation with dynamic load (ISO 14728-1);

— static load safety factor calculation with static load (ISO 14728-2).

The life of a linear motion bearing is given by the distance which one of the raceways moves, in relation to the other raceway, before the first evidence of fatigue develops in the material of one of the raceways or one of the rolling elements.

The formulae for calculating the basic dynamic load ratings are derived from the theory of Lundberg[1] and Palmgren[2].

Rolling bearings — Linear motion rolling bearings —

Part 1:
Dynamic load ratings and rating life

1 Scope

This part of ISO 14728 specifies methods of calculating the basic dynamic load rating and basic rating life for linear motion rolling bearings manufactured from contemporary, commonly used, high quality, hardened bearing steel in accordance with good manufacturing practice and basically of conventional design as regards the shape of the rolling contact surfaces. The life of linear motion rolling bearings is defined and the conditions are established for reliable life calculations.

This part of ISO 14728 is not applicable to designs where the rolling elements operate directly on the slide surface of the machine equipment, unless that surface is equivalent in all respects to the raceway of the linear motion rolling bearing component it replaces.

2 Normative references

The following referenced documents are indispensable for the application 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 281:1990, *Rolling bearings — Dynamic load ratings and rating life*

ISO 5593:1997, *Rolling bearings — Vocabulary*

ISO 15241:2001, *Rolling bearings — Symbols for quantities*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 281, ISO 5593 and the following apply.

3.1
recirculating linear ball bearing, sleeve type, with or without raceway grooves
basically cylindrical sleeve provided with a number of closed loops of recirculating balls designed to achieve linear rolling motion along a hardened cylindrical shaft

See Figure 1.

NOTE The raceways in the sleeve can be designed cylindrical as well as steel inserts with raceway grooves parallel to the axis.

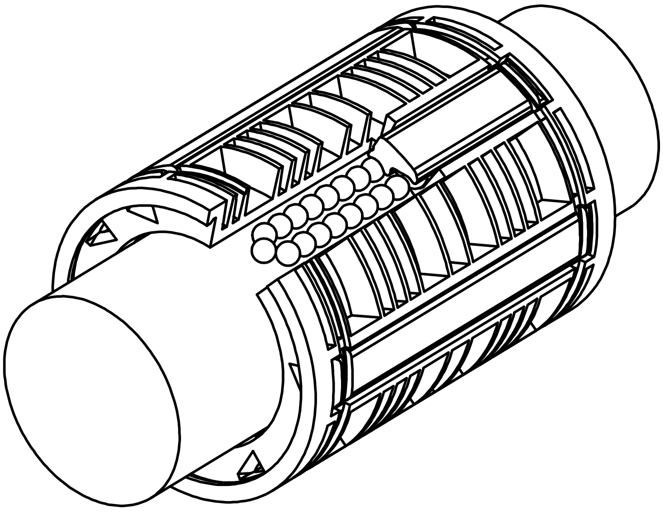


Figure 1 — Recirculating linear ball bearing, sleeve type

3.2
recirculating linear ball [roller] bearing, linear guideway type
linear ball (roller) bearing provided with a number of symmetrically arranged, closed loops of recirculating balls [rollers] designed to achieve linear rolling motion along a hardened guideway furnished with adequate raceways

See Figure 2.

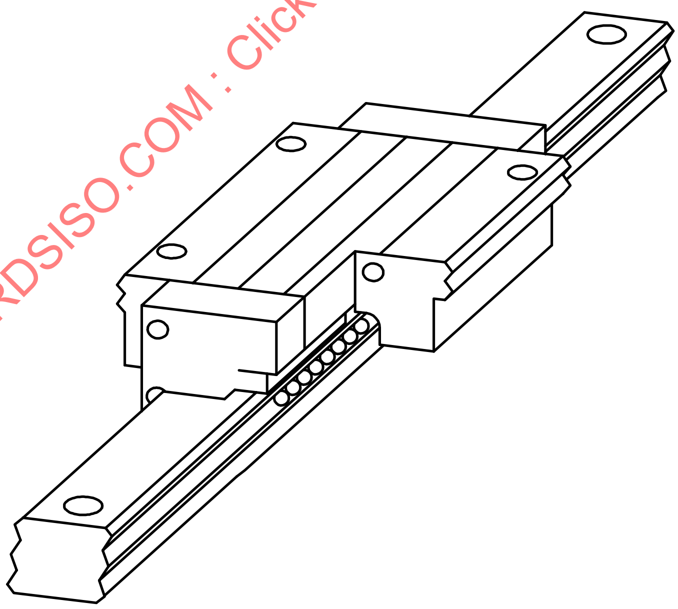


Figure 2 — Recirculating linear ball [roller] bearing, linear guideway type

3.3
non-recirculating linear ball bearing, linear guideway, deep groove type
linear bearing with balls as rolling elements, each ball having two points of contact

See Figure 3.

NOTE The cross-sectional radii of the raceway grooves in the two guideways are equal and may lie between 0,52 D_w and infinity.

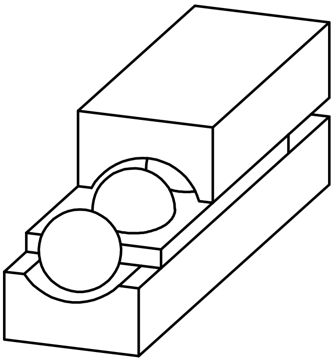


Figure 3 — Non-recirculating linear ball bearing, linear guideway, deep groove type

3.4
non-recirculating linear ball bearing, linear guideway, four-point-contact type
linear bearing with balls as rolling elements, each ball having four points of contact

See Figure 4.

NOTE The cross-sectional radii of the raceway grooves for the four points of contact in the two guideways are equal and may lie between 0,52 D_w and infinity.

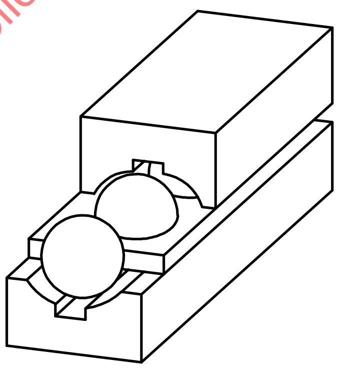


Figure 4 — Non-recirculating linear ball bearing, linear guideway, four-point-contact type

3.5
non-recirculating linear roller bearing, linear guideway, flat type
linear bearing with needle rollers or cylindrical rollers as rolling elements

See Figure 5.

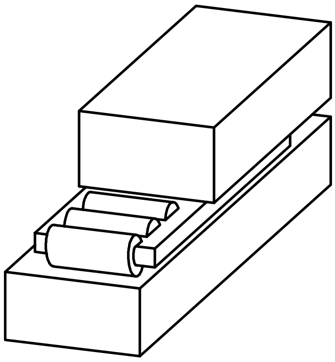


Figure 5 — Non-recirculating linear roller bearing, linear guideway, flat type

3.6
non-recirculating linear roller bearing, linear guideway, V-angle type
linear bearing with guideways designed as parts of a V with a 90° angle

See Figure 6.

NOTE Needle rollers or cylindrical rollers are used as rolling elements.

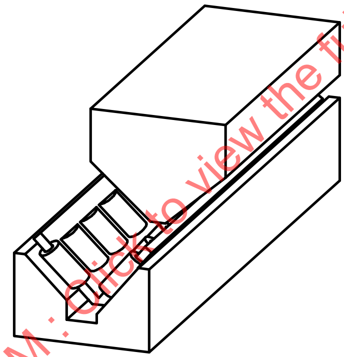


Figure 6 — Non-recirculating linear roller bearing, linear guideway, V-angle type

3.7
non-recirculating linear roller bearing, linear guideway, crossed roller type
linear bearing with cylindrical rollers arranged in a crossed roller construction

See Figure 7.

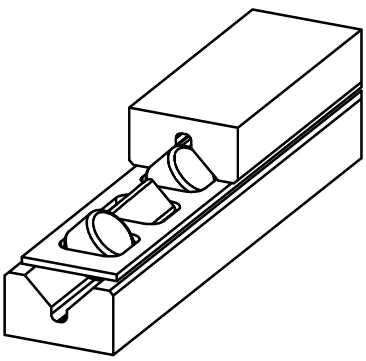


Figure 7 — Non-recirculating linear roller bearing, linear guideway, crossed roller type

3.8
life
⟨for an individual linear motion rolling bearing⟩ distance one of the raceways moves in relation to the other raceway before the first evidence of fatigue develops in the material of one of the raceways or one of the rolling elements

3.9
reliability
⟨for a group of apparently identical linear motion rolling bearings operating under the same conditions⟩ percentage of the group that is expected to attain or exceed a specified life

NOTE The reliability of an individual linear motion rolling bearing is the probability that the bearing will attain or exceed a specified life.

3.10
basic rating life
⟨for an individual linear motion rolling bearing or a group of apparently identical linear motion rolling bearings operating under the same conditions⟩ life associated with 90 % reliability, with contemporary, commonly used material and manufacturing quality and under conventional operating conditions

3.11
basic dynamic load rating of a linear motion rolling bearing
constant stationary load that a linear motion rolling bearing could theoretically endure for a basic rating life of 10^5 m

NOTE If a basic rating life of 5×10^4 m is used to define the basic dynamic load rating, then a conversion factor should be used as shown below:

— for basic dynamic load rating of ball guided systems:

$$C_{100B} = \frac{C_{50B}}{1{,}26}$$

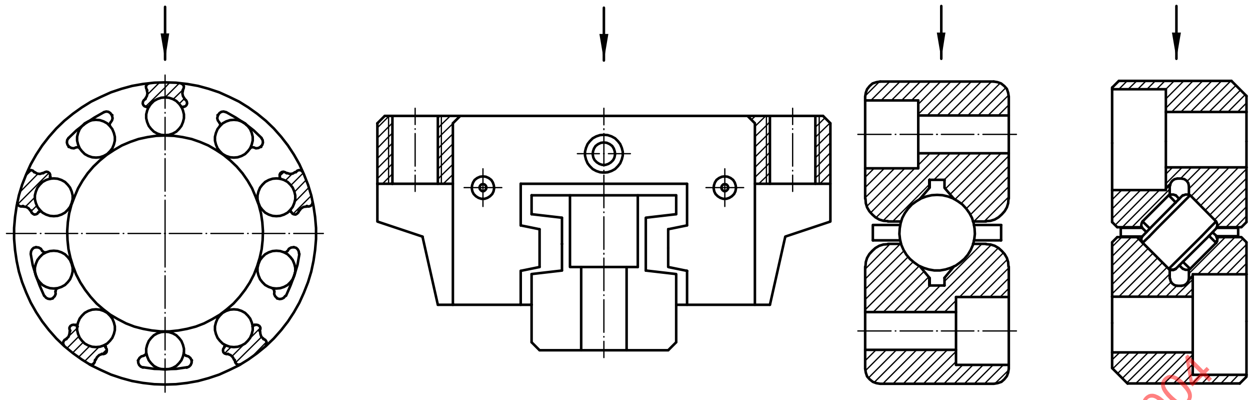
— for basic dynamic load rating of roller guided systems:

$$C_{100R} = \frac{C_{50R}}{1{,}23}$$

3.12
dynamic equivalent load
constant stationary load under the influence of which a linear motion rolling bearing would have the same life as it would attain under the actual load conditions

3.13
direction of load
direction of load applied for load rating calculation

NOTE For calculation of basic dynamic load ratings, the direction of the load is defined for all linear motion bearings as shown by the arrows in Figure 8.



Rolling bearing defined in

3.1 3.2 3.4 3.7

Figure 8 — Direction of load

3.14
pitch diameter
⟨of recirculating linear ball bearing, sleeve type⟩ diameter of the circle containing the centres of the balls in contact with the raceways, in a plane perpendicular to the bearing axis

3.15
nominal contact angle
angle between the direction of load on the linear bearing and the nominal line of action of the resultant of the forces transmitted by a bearing raceway member to a rolling element

See Figure 9.

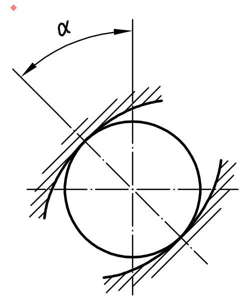


Figure 9 — Nominal contact angle

4 Symbols

For the purposes of this document, the symbols given in ISO 281, ISO 15241 and Table 1 apply.

Table 1 — Symbols, terms and units

Symbol	Term	Unit
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	1
C	Basic dynamic load rating	N
C_0	Basic static load rating	N
C_{50B}	Basic dynamic load rating for ball guided linear motion rolling bearings calculated for a basic rating life of 5×10^4 m	N
C_{50R}	Basic dynamic load rating for roller guided linear motion rolling bearings calculated for a basic rating life of 5×10^4 m	N
C_{100B}	Basic dynamic load rating for ball guided linear motion rolling bearings calculated for a basic rating life of 10^5 m	N
C_{100R}	Basic dynamic load rating for roller guided linear motion rolling bearings calculated for a basic rating life of 10^5 m	N
c_L	Adjustment factor for recirculating linear ball bearings, sleeve type, with or without raceway grooves, applicable in the calculation of load ratings	1
D_{pw}	Pitch diameter of ball rows	mm
D_w	Ball diameter	mm
D_{we}	Roller diameter applicable in the calculation of load ratings	mm
F	Load on bearing	N
f_c	Factor that depends on the geometry of the bearing components, the accuracy to which the various components are made, and on the material	1
f_s	Correction factor for short stroke application, applicable for recirculating linear ball bearings, sleeve type with or without grooves, specified by the manufacturer	1
i	Number of rows of balls or rollers applicable in the calculation of load ratings NOTE In the case of recirculating linear bearings, sleeve type, it is the total number of rows of balls.	1
i_t	Number of load-carrying rows of balls in loaded zone $-90° < \phi_j < +90°$ of recirculating linear ball bearings, sleeve type, with or without raceway grooves, applicable in the calculation of load ratings	1
k_F	Dynamic load factor	1
k_i	Factor for recirculating linear ball bearings, sleeve type, with or without raceway grooves, applicable in the calculation of load ratings	1
L_{we}	Roller length applicable in the calculation of load ratings	mm
L_{10}	Basic rating life associated with 90 % reliability	10^5 m
l_s	Travel length of linear bearings	mm
l_t	Raceway length applicable in the calculation of load ratings. For recirculating linear bearings, that of sleeve or carriage, determined by the manufacturer, and for non-recirculating linear bearings, that of guideway, equal to the centre distance between the load carrying balls or rollers at both ends of one row	mm
P	Dynamic equivalent load	N
p	Exponent	1
r_g	Cross-sectional radius of the raceway groove on guideway	mm
t_w	Centre distance between two neighbouring balls or rollers	mm
Z	Number of balls or rollers in one row	1
Z_t	Number of load-carrying balls or rollers in one row applicable in the calculation of load ratings	1
α	Nominal contact angle	°
ϕ_j	Angle between the direction of load and the ball row j	°
λ	Reduction factor	1

5 Basic dynamic load ratings

5.1 Linear ball bearings

5.1.1 Recirculating linear ball bearings, sleeve type with raceway grooves

The basic dynamic load rating for this bearing, in vertical loading position, is given by the following equations:

$$C_{100B} = b_m \times f_c \times k_i \times l_t^{1/30} \times Z_t^{2/3} \times D_w^{2,1}$$

where

$$f_c = \lambda \times c_L \times 29{,}8 \times \left[2{,}18 \times \left(1 - \frac{D_w}{D_{pw}} \right)^{-4{,}67} + \left(\frac{2 \times r_g}{2 \times r_g - D_w} \right)^{-1{,}37} \right]^{-0{,}3}$$

$$k_i = \frac{\sum_{j=1}^{j=i_t} (\cos \varphi_j)^{2{,}5}}{\left[\sum_{j=1}^{j=i_t} (\cos \varphi_j)^5 \right]^{0{,}3}}$$

b_m = 1,3

λ = 0,9

c_L = 1 to 1,2

In the number of load carrying rows of balls in the loaded area, i_t, those rows which are arranged in an angular area of $-90° < \phi_j < +90°$ to the direction of normal load (see Figure 8) shall be taken into account.

The values of b_m and λ given above are the maximum values, smaller values may be used by the manufacturer.

The value of c_L is determined by the manufacturer in the range given above.

The values for k_i of recirculating linear ball bearing, sleeve type, with equally spaced ball rows, are given in Table 2.

5.1.2 Recirculating linear ball bearings, sleeve type without raceway grooves

The basic dynamic load rating for this bearing, in vertical loading position, is given by the following equations:

$$C_{100B} = b_m \times f_c \times k_i \times l_t^{1/30} \times Z_t^{2/3} \times D_w^{2,1}$$

where

$$f_c = \lambda \times c_L \times 22{,}9 \times \left[0{,}91 \times \left(1 - \frac{D_w}{D_{pw}} \right)^{-4{,}67} + \left(1 + \frac{D_w}{D_{pw}} \right)^{-1{,}67} \right]^{-0{,}3}$$

$$k_i = \frac{\sum_{j=1}^{j=i_t} (\cos \varphi_j)^{2,5}}{\left[\sum_{j=1}^{j=i_t} (\cos \varphi_j)^5\right]^{0,3}}$$

b_m = 1,3

λ = 0,9

c_L = 1 to 1,2

In the number of load carrying rows of balls in the loaded area, i_t, those rows which are arranged in an angular area of $-90° < \phi_j < +90°$ to the direction of normal load (see Figure 8) shall be taken into account.

The values of b_m and λ given above are the maximum values, smaller values may be used by the manufacturer.

The value of c_L is determined by the manufacturer in the range given above.

The values for k_i of recirculating linear ball bearing, sleeve type, with equally spaced ball rows, are given in Table 2.

Table 2 — Values of k_i

i	3	4	5	6	7	8	9	10
k_i	1,000	1,000	1,104	1,329	1,531	1,681	1,807	1,948

5.1.3 Recirculating linear ball bearings, linear guideway type

The basic dynamic load rating for this bearing is given by the following equations:

$$C_{100B} = b_m \times f_c \times l_t^{1/30} \times i^{0,7} \times Z_t^{2/3} \times D_w^{2,1} \times \cos\alpha$$

where

$$f_c = \lambda \times 24,5 \times \left(\frac{2 \times r_g}{2 \times r_g - D_w}\right)^{0,41}$$

b_m = 1,3

λ = 0,9

The values of b_m and λ given above are the maximum values, smaller values may be used by the manufacturer.

The values of f_c calculated with λ = 0,9 are given in Table 3.

Table 3 — Values of f_c

r_g	f_c
0,52 D_w	83,9
0,53 D_w	71,6
0,54 D_w	64,1
0,55 D_w	58,9
0,56 D_w	55,1
0,57 D_w	52,1
0,58 D_w	49,7
0,59 D_w	47,7
0,6 D_w	46,0

The load-carrying ability of a bearing is not necessarily increased by the use of smaller raceway groove radii, but it is reduced by the use of larger raceway groove radii than those indicated in Table 3.

5.1.4 Non-recirculating linear ball bearings, linear guideway, deep groove and four-point-contact types

The basic dynamic load rating for these bearings is given by the following equations:

$$C_{100B} = b_m \times f_c \times l_t^{1/30} \times i^{0,7} \times Z_t^{2/3} \times D_w^{2,1} \times \cos\alpha$$

where

$$f_c = \lambda \times 24,2 \times \left(\frac{2 \times r_g}{2 \times r_g - D_w} \right)^{0,41}$$

$l_t = (Z_t - 1) \times t_w$

$b_m = 1,3$

$\lambda = 0,9$

The values of b_m and λ given above are the maximum values, smaller values may be used by the manufacturer.

The values of i and Z_t are given in Table 4.

Table 4 — Values of i and Z_t

Bearing	i	Z_t
Deep groove type	1	Z
Four-point-contact type	2	Z

The values of f_c calculated with λ = 0,9 are given in Table 5.

Table 5 — Values of f_c

r_g	f_c
0,52 D_w	82,8
0,53 D_w	70,7
0,54 D_w	63,3
0,55 D_w	58,2
0,56 D_w	54,4
0,57 D_w	51,5
0,58 D_w	49,1
0,59 D_w	47,1
0,6 D_w	45,4
∞	21,8

5.2 Linear roller bearings

5.2.1 Recirculating linear roller bearings, linear guideway, carriage type

The basic dynamic load rating for this bearing is given by the following equations:

$$C_{100R} = b_m \times f_c \times l_t^{1/36} \times i^{7/9} \times Z_t^{3/4} \times L_{we}^{7/9} \times D_{we}^{35/27} \times \cos\alpha$$

where

f_c = $\lambda \times 195$

b_m = 1,1

λ = 0,83

The values of b_m and λ given above are the maximum values, smaller values may be used by the manufacturer.

5.2.2 Non-recirculating linear roller bearings, linear guideway, flat, V-angle and crossed roller types

The basic dynamic load rating for these bearings is given by the following equations:

$$C_{100R} = b_m \times f_c \times l_t^{1/36} \times i^{7/9} \times Z_t^{3/4} \times L_{we}^{7/9} \times D_{we}^{35/27} \times \cos\alpha$$

where

f_c = $\lambda \times 194$

l_t = $(Z_t - 1) \times t_w$

b_m = 1,1

λ = 0,83