

---

---

**Rolling bearings — Explanatory notes  
on ISO 281 —**

**Part 1:  
Basic dynamic load rating and basic  
rating life**

**iTeh STANDARD PREVIEW**  
*Roulements — Notes explicatives sur l'ISO 281 —*  
*(standards.iteh.ai)* *Partie 1: Charges dynamiques de base et durée nominale de base*

[ISO/PRF TR 1281-1](https://standards.iteh.ai/catalog/standards/sist/9428f3e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1)

<https://standards.iteh.ai/catalog/standards/sist/9428f3e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1>

**PROOF / ÉPREUVE**

---

---



## iTeh STANDARD PREVIEW (standards.iteh.ai)

[ISO/PRF TR 1281-1](https://standards.iteh.ai/catalog/standards/sist/9428f3e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1)

<https://standards.iteh.ai/catalog/standards/sist/9428f3e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1>



### **COPYRIGHT PROTECTED DOCUMENT**

© ISO 2021

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

	Page
Foreword.....	iv
Introduction.....	v
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
<b>4 Symbols</b> .....	<b>1</b>
<b>5 General</b> .....	<b>4</b>
<b>6 Basic dynamic load rating</b> .....	<b>4</b>
6.1 General.....	4
6.2 Basic dynamic radial load rating, $C_r$ , for radial ball bearings.....	5
6.3 Basic dynamic axial load rating, $C_a$ , for single row thrust ball bearings.....	9
6.3.1 Thrust ball bearings with contact angle $\alpha \neq 90^\circ$ .....	9
6.3.2 Thrust ball bearings with contact angle $\alpha = 90^\circ$ .....	9
6.4 Basic dynamic axial load rating, $C_a$ , for thrust ball bearings with two or more rows of balls.....	10
6.5 Basic dynamic radial load rating, $C_r$ , for radial roller bearings.....	11
6.6 Basic dynamic axial load rating, $C_a$ , for single row thrust roller bearings.....	13
6.6.1 Thrust roller bearings with contact $\alpha \neq 90^\circ$ .....	13
6.6.2 Thrust roller bearings with contact angle $\alpha = 90^\circ$ .....	13
6.7 Basic dynamic axial load rating, $C_a$ , for thrust roller bearings with two or more rows of rollers.....	14
<b>7 Dynamic equivalent load</b> .....	<b>16</b>
7.1 Expressions for dynamic equivalent load.....	16
7.1.1 Theoretical dynamic equivalent radial load, $P_r$ , for single row radial bearings.....	16
7.1.2 Theoretical dynamic equivalent radial load, $P_r$ , for double row radial bearings.....	20
7.1.3 Theoretical dynamic equivalent radial load, $P_r$ , for radial contact groove ball bearings.....	21
7.1.4 Practical expressions for dynamic equivalent radial load, $P_r$ , for radial bearings with constant contact angle.....	22
7.1.5 Practical expressions for dynamic equivalent radial load, $P_r$ , for radial ball bearings.....	25
7.1.6 Practical expressions for dynamic equivalent axial load, $P_a$ , for thrust bearings.....	26
7.2 Factors $X$ , $Y$ and $e$ .....	28
7.2.1 Radial ball bearings.....	28
7.2.2 Values of $X$ , $Y$ and $e$ for each type of radial ball bearing.....	29
7.2.3 Tabulation of factors $X$ , $Y$ and $e$ for radial ball bearings.....	34
7.2.4 Calculated values of $Y$ and $e$ different from standard.....	36
7.2.5 Thrust ball bearings.....	36
7.2.6 Radial roller bearings.....	37
7.2.7 Thrust roller bearings.....	38
<b>8 Basic rating life</b> .....	<b>38</b>
<b>Bibliography</b> .....	<b>41</b>

## 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](http://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](http://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 of 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 [www.iso.org/iso/foreword.html](http://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 Technical Corrigendum 1 (ISO/TR 1281-1:2008/Cor 1:2009) and the first edition (ISO/TR 1281-1:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

- The old Clause 7 “Life adjustment factor for reliability” of ISO/TR 1281-1:2008 has been deleted, this subject is covered in ISO/TR 1281-2 (see ISO/TR 1281-1:2008/Cor 1:2009).
- The derivation of the old [Formulae \(29\)](#) and [\(46\)](#) [Formulae [\(28\)](#) and [\(45\)](#) in this edition] has been corrected.
- Typing errors have been corrected in [Formulae \(30\)](#) and [\(31\)](#) and in the derivation of the factor  $Y_3$ .

A list of all parts in the ISO/TR 1281 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

### ISO/R281:1962

A first discussion on an international level of the question of standardizing calculation methods for load ratings of rolling bearings took place at the 1934 conference of the International Federation of the National Standardizing Associations (ISA). When ISA held its last conference in 1939, no progress had been made. However, in its 1945 report on the state of rolling bearing standardization, the ISA 4 Secretariat included proposals for definition of concepts fundamental to load rating and life calculation standards. The definitions it contained are in essence those given in ISO 281:2007 for the concepts “life” and “basic dynamic load rating” (now divided into “basic dynamic radial load rating” and “basic dynamic axial load rating”).

In 1946, on the initiative of the Anti-Friction Bearing Manufacturers Association (AFBMA), New York, discussions of load rating and life calculation standards started between industries in the USA and Sweden. Chiefly on the basis of the results appearing in Reference [5], an AFBMA standard, *Method of evaluating load ratings of annular ball bearings*[3], was worked out and published in 1949. On the same basis, the member body for Sweden presented, in February 1950, a first proposal to ISO, “Load rating of ball bearings”.

In view of the results of both further research and a modification to the AFBMA standard in 1950, as well as interest in roller bearing rating standards, in 1951, the member body for Sweden submitted a modified proposal for rating of ball bearings as well as a proposal for rating of roller bearings.

Load rating and life calculation methods were then studied. Reference [6] was then of considerable use, serving as a major basis for the sections regarding roller bearing rating.

### ISO 281-1:1977

In 1964, in view of the development of improved bearing steels, the time had come to review ISO/R281 and submitted a proposal [standards.iteh.ai/catalog/standards/sist/94283e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1](https://standards.iteh.ai/catalog/standards/sist/94283e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1)

In 1969, on the other hand, TC 4 followed a suggestion by the member body for Japan and reconstituted its WG 3, giving it the task of revising ISO/R281. The AFBMA load rating working group had at this time started revision work.

The major part of ISO 281-1:1977 constituted a re-publication of ISO/R281, the substance of which had been only very slightly modified. However, based mainly on American investigations during the 1960s, a new clause was added, dealing with adjustment of rating life for reliability other than 90 % and for material and operating conditions.

Furthermore, supplementary background information regarding the derivation of mathematical expressions and factors given in ISO 281-1:1977 was published as ISO/TR 8646:1985.

### ISO 281:1990

ISO 281:1990 was published as “First edition” and entitled “Dynamic load ratings and rating life”. It is referred to as the “technical revision” of ISO 281-1:1977. The new rating factor  $b_m$  for “contemporary, normally used material and manufacturing quality, the value of which varies with bearing type and design” was the introduction as a co-value to the basic dynamic load ratings.

### ISO 281:2007 (second edition)

Since the publication of ISO 281:1990 additional knowledge regarding the influence on bearing life of contamination, lubrication, internal stresses from mounting, stresses from hardening, fatigue load limit of the material, has been gained. In ISO 281:1990/Amd 2:2000, a general method was presented to consider such influences in the calculation of a modified rating life of a bearing. The said Amendment was incorporated into the second edition, which also provides a practical method to consider the influence on bearing life of lubrication conditions, contaminated lubricant and fatigue load of bearing

material. The life modification factors for reliability,  $a_1$ , have been slightly adjusted and extended to 99,95 % reliability.

**iTeh STANDARD PREVIEW**  
**(standards.iteh.ai)**

[ISO/PRF TR 1281-1](https://standards.iteh.ai/catalog/standards/sist/9428f3e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1)

<https://standards.iteh.ai/catalog/standards/sist/9428f3e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1>

# Rolling bearings — Explanatory notes on ISO 281 —

## Part 1: Basic dynamic load rating and basic rating life

### 1 Scope

This document specifies supplementary background information regarding the derivation of mathematical expressions and factors given in ISO 281:2007.

### 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 281:2007, *Rolling bearings — Dynamic load ratings and rating life*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 281:2007 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

$A$	constant of proportionality
$A_1$	constant of proportionality determined experimentally
$B_1$	constant of proportionality determined experimentally
$C_1$	basic dynamic radial load rating of a rotating ring
$C_2$	basic dynamic radial load rating of a stationary ring
$C_a$	basic dynamic axial load rating for thrust ball or roller bearing
$C_{a1}$	basic dynamic axial load rating of the rotating ring of an entire thrust ball or roller bearing
$C_{a2}$	basic dynamic axial load rating of the stationary ring of an entire thrust ball or roller bearing
$C_{ak}$	basic dynamic axial load rating as a row $k$ of an entire thrust ball or roller bearing
$C_{a1k}$	basic dynamic axial load rating as a row $k$ of the rotating ring of thrust ball or roller bearing
$C_{a2k}$	basic dynamic axial load rating as a row $k$ of the stationary ring of thrust ball or roller bearing

$C_e$	basic dynamic load rating for outer ring
$C_i$	basic dynamic load rating for inner ring
$C_r$	basic dynamic radial load rating for radial ball or roller bearing
$D_{pw}$	pitch diameter of ball or roller set
$D_w$	ball diameter
$D_{we}$	mean roller diameter
$E_o$	modified modulus of elasticity
$F_a$	axial load
$F_r$	radial load
$J_1$	factor relating mean equivalent load on a rotating ring to $Q_{max}$
$J_2$	factor relating mean equivalent load on a stationary ring to $Q_{max}$
$J_a$	axial load integral
$J_r$	radial load integral
$L$	bearing life
$L_{10}$	basic rating life
$L_{we}$	effective contact length of roller
$L_{wek}$	$L_{we}$ per row $k$
$N$	number of stress applications to a point on the raceway
$P_a$	dynamic equivalent axial load for thrust bearing
$P_r$	dynamic equivalent radial load for radial bearing
$P_{r1}$	dynamic equivalent radial load for the rotating ring
$P_{r2}$	dynamic equivalent radial load for the stationary ring
$Q$	normal force between a rolling element and the raceways
$Q_C$	rolling element load for the basic dynamic load rating of the bearing
$Q_{C1}$	rolling element load for the basic dynamic load rating of a ring rotating relative to the applied load
$Q_{C2}$	rolling element load for the basic dynamic load rating of a ring stationary relative to the applied load
$Q_{max}$	maximum rolling element load
$S$	probability of survival, reliability
$V$	volume representative of the stress concentration
$V_f$	rotation factor
$X$	radial load factor for radial bearing

**iTeh STANDARD PREVIEW**  
(standards.iteh.ai)

[ISO/PRF TR 1281-1](https://standards.iteh.ai/catalog/standards/sist/94283e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1)

<https://standards.iteh.ai/catalog/standards/sist/94283e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1>



$X_a$	radial load factor for thrust bearing
$Y$	axial load factor for radial bearing
$Y_a$	axial load factor for thrust bearing
$Z$	number of balls or rollers per row
$Z_k$	number of balls or rollers per row $k$
$a$	semimajor axis of the projected contact ellipse
$a_1$	life adjustment factor for reliability
$b$	semiminor axis of the projected contact ellipse
$c$	exponent determined experimentally
$c_c$	compression constant
$e$	measure of life scatter, i.e. Weibull slope determined experimentally
$e$	limiting value of $F_a / F_r$ for the applicability of different values of factors $X$ and $Y$ in the new edition
$f_c$	factor which depends on the geometry of the bearing components, the accuracy to which the various components are made, and the material
$h$	exponent determined experimentally
$i$	number of rows of balls or rollers
$l$	circumference of the raceway
$r$	cross-sectional raceway groove radius
$r_e$	cross-sectional raceway groove radius of outer ring or housing washer
$r_i$	cross-sectional raceway groove radius of inner ring or shaft washer
$t$	auxiliary parameter
$z_0$	depth of the maximum orthogonal subsurface shear stress
$\alpha$	nominal contact angle
$\alpha'$	actual contact angle
$\gamma$	$D_w \cos \alpha / D_{pw}$ for ball bearings with $\alpha \neq 90^\circ$
	$D_w / D_{pw}$ for ball bearings with $\alpha = 90^\circ$
	$D_{we} \cos \alpha / D_{pw}$ for roller bearings with $\alpha \neq 90^\circ$
	$D_{we} / D_{pw}$ for roller bearings with $\alpha = 90^\circ$
$\varepsilon$	parameter indicating the width of the loaded zone in the bearing
$\eta$	reduction factor
$\lambda$	reduction factor
$\mu$	factor introduced by Hertz

- $\nu$  factor introduced by Hertz, or adjustment factor for exponent variation
- $\sigma_{\max}$  maximum contact stress
- $\Sigma\rho$  curvature sum
- $\tau_0$  maximum orthogonal subsurface shear stress
- $\varphi_0$  one half of the loaded arc

## 5 General

The derivation of the basic dynamic load ratings is described in [Formulae \(1\) to \(46\)](#). The dynamic equivalent load and the radial and axial load factors are covered in [Formulae \(47\) to \(82\)](#), while basic rating life is described in [Formulae \(83\) to \(89\)](#).

## 6 Basic dynamic load rating

### 6.1 General

The background to basic dynamic load ratings of rolling bearings according to ISO 281 appears in References [\[5\]](#) and [\[6\]](#).

The expressions for calculation of basic dynamic load ratings of rolling bearings develop from a power formula that can be written as follows:

$$\ln \frac{1}{S} \propto \frac{\tau_0^c N^e V}{z_0^h} \tag{1}$$

iTeH STANDARD PREVIEW  
(standards.iteh.ai)  
ISO/PRF TR 1281-1  
<https://standards.iteh.ai/catalog/standards/sist/9428f3e8-1d32-455d-b943-9b319d06a119/iso-prf-tr-1281-1>

where

- $S$  is the probability of survival;
- $\tau_0$  is the maximum orthogonal subsurface shear stress;
- $N$  is the number of stress applications to a point on the raceway;
- $V$  is the volume representative of the stress concentration;
- $z_0$  is the depth of the maximum orthogonal subsurface shear stress;
- $c, h$  are experimentally determined exponents;
- $e$  is the measure of life scatter, i.e. the Weibull slope determined experimentally.

For “point” contact conditions (ball bearings) it is assumed that the volume,  $V$ , representative of the stress concentration in [Formula \(1\)](#) is proportional to the major axis of the projected contact ellipse,

$2a$ , the circumference of the raceway,  $l$ , and the depth,  $z_o$ , of the maximum orthogonal subsurface shear stress,  $\tau_o$ :

$$V \propto 2a z_o l \quad (2)$$

Substituting [Formula \(2\)](#) into [Formula \(1\)](#):

$$\ln \frac{1}{S} \propto \frac{\tau_o^c N^e a l}{z_o^{h-1}} \quad (3)$$

“Line” contact was considered in References [\[5\]](#) and [\[6\]](#) to be approached under conditions where the major axis of the calculated Hertz contact ellipse is 1,5 times the effective roller contact length:

$$2a = 1,5L_{we} \quad (4)$$

In addition,  $b/a$  should be small enough to permit the introduction of the limit value of  $ab^2$  as  $b/a$  approaches 0:

$$ab^2 = \frac{2}{\pi} \frac{3Q}{E_o \sum \rho} \quad (5)$$

(for variable definitions, see [6.2](#)).

## 6.2 Basic dynamic radial load rating, $C_r$ , for radial ball bearings

From the theory of Hertz, the maximum orthogonal subsurface shear stress,  $\tau_o$ , and the depth,  $z_o$ , can be expressed in terms of a radial load  $F_r$ , i.e. a maximum rolling element load,  $Q_{max}$ , or a maximum contact stress,  $\sigma_{max}$ , and dimensions for the contact area between a rolling element and the raceways. The relationships are:

$$\tau_o = T \sigma_{max}$$

$$z_o = \zeta b$$

$$T = \frac{(2t - 1)^{1/2}}{2t(t + 1)}$$

$$\zeta = \frac{1}{(t + 1)(2t - 1)^{1/2}}$$

$$a = \mu \left( \frac{3Q}{E_o \sum \rho} \right)^{1/3}$$

$$b = \nu \left( \frac{3Q}{E_o \sum \rho} \right)^{1/3}$$

where

$\sigma_{max}$  is the maximum contact stress;

$t$  is the auxiliary parameter;

$a$  is the semimajor axis of the projected contact ellipse;

- $b$  is the semiminor axis of the projected contact ellipse;
- $Q$  is the normal force between a rolling element and the raceways;
- $E_0$  is the modified modulus of elasticity;
- $\Sigma\rho$  is the curvature sum;
- $\mu, \nu$  are factors introduced by Hertz.

Consequently, for a given rolling bearing,  $\tau_0, a, l$  and  $z_0$  can be expressed in terms of bearing geometry, load and revolutions. Formula (3) is changed to a formula by inserting a constant of proportionality. Inserting a specific number of revolutions (e.g.  $10^6$ ) and a specific reliability (e.g. 0,9), the formula is solved for a rolling element load for basic dynamic load rating which is designated to point contact rolling bearings introducing a constant of proportionality,  $A_1$ :

$$Q_C = \frac{1,3}{4^{(2c+h-2)/(c-h+2)} 0,5^{3e/(c-h+2)}} A_1 \left( \frac{2r}{2r-D_w} \right)^{0,41} \frac{(1\mp\gamma)^{(1,59c+1,41h-5,82)/(c-h+2)}}{(1\pm\gamma)^{3e/(c-h+2)}} \times \left( \frac{\gamma}{\cos\alpha} \right)^{3/(c-h+2)} D_w^{(2c+h-5)/(c-h+2)} Z^{-3e/(c-h+2)} \tag{6}$$

where

- $Q_C$  is the rolling element load for the basic dynamic load rating of the bearing;
- $D_w$  is the ball diameter;
- $\gamma$  is  $D_w \cos \alpha / D_{pw}$ ;

in which

- $D_{pw}$  is the pitch diameter of the ball set;
- $\alpha$  is the nominal contact angle;

$Z$  is the number of balls per row.

The basic dynamic radial load rating,  $C_1$ , of a rotating ring is given by:

$$C_1 = Q_{C1} Z \cos \alpha \frac{J_r}{J_1} = 0,407 Q_{C1} Z \cos \alpha \tag{7}$$

The basic dynamic radial load rating,  $C_2$ , of a stationary ring is given by:

$$C_2 = Q_{C2} Z \cos \alpha \frac{J_r}{J_2} = 0,389 Q_{C2} Z \cos \alpha \tag{8}$$

where

- $Q_{C1}$  is the rolling element load for the basic dynamic load rating of a ring rotating relative to the applied load;
- $Q_{C2}$  is the rolling element load for the basic dynamic load rating of a ring stationary relative to the applied load;
- $J_r = J_r(0,5)$  is the radial load integral for zero diametral clearance (see [Table 3](#));
- $J_1 = J_1(0,5)$  is the factor relating mean equivalent load on a rotating ring to  $Q_{max}$  for zero diametral clearance (see [Table 3](#));
- $J_2 = J_2(0,5)$  is the factor relating mean equivalent load on a stationary ring to  $Q_{max}$  for zero diametral clearance (see [Table 3](#)).

The relationship between  $C_r$  for an entire radial ball bearing, and  $C_1$  and  $C_2$ , is expressed in terms of the product law of probability as:

$$C_r = C_1 \left[ 1 + \left( \frac{C_1}{C_2} \right)^{(c-h+2)/3} \right]^{-3/(c-h+2)} \quad (9)$$

Substituting [Formulae \(6\)](#), [\(7\)](#) and [\(8\)](#) into [Formula \(9\)](#), the basic dynamic radial load rating,  $C_r$ , for an entire ball bearing is expressed as:

$$C_r = 0,41 \frac{1,3}{4(2c+h-2)/(c-h+2)} \frac{0,53e/(c-h+2)}{A_1 \left( \frac{2r_i}{2r_i - D_w} \right)^{0,41} \frac{(1-\gamma)^{(1,59c + 1,41h - 5,82)/(c-h+2)}}{(1+\gamma)^{3e/(c-h+2)}} \gamma^{3/(c-h+2)} \times$$

$$\left[ 1 + \left\{ 1,04 \left[ \frac{r_i}{r_e} \left( \frac{2r_e - D_w}{2r_i - D_w} \right) \right]^{0,41} \left( \frac{1-\gamma}{1+\gamma} \right)^{(1,59c + 1,41h + 3e - 5,82)/(c-h+2)} \right\}^{(c-h+2)/3} \right]^{-3/(c-h+2)} \times$$

$$(i \cos \alpha)^{(c-h-1)/(c-h+2)} Z^{(c-h-3e+2)/(c-h+2)} D_w^{9(2c+h-5)/(c-h+2)} \quad (10)$$

where

- $A_1$  is the experimentally determined proportionality constant;
- $r_i$  is the cross-sectional raceway groove radius of the inner ring;
- $r_e$  is the cross-sectional raceway groove radius of the outer ring;
- $i$  is the number of rows of balls.

Here, the contact angle,  $\alpha$ , the number of rolling elements (balls),  $Z$ , and the ball diameter,  $D_w$ , depend on bearing design. On the other hand, the ratios of raceway groove radii,  $r_i$  and  $r_e$ , to a half-diameter of a rolling element (ball),  $D_w/2$  and  $\gamma = D_w \cos \alpha / D_{pw}$ , are not dimensional, therefore it is convenient in practice that the value for the initial terms on the right-hand side of [Formula \(10\)](#) to be designated as a factor,  $f_c$ :

$$C_r = f_c (i \cos \alpha)^{(c-h-1)/(c-h+2)} Z^{(c-h-3e+2)/(c-h+2)} D_w^{9(2c+h-5)/(c-h+2)} \quad (11)$$

With radial ball bearings, the faults in bearings resulting from manufacturing need to be taken into consideration, and a reduction factor,  $\lambda$ , is introduced to reduce the value for a basic dynamic radial load