International Standard

ISO 17956

First edition
2025-01

Rolling bearings — Method for calculating the effective static safety factor for universally loaded rolling bearings

Roulements — Méthode de calcul du facteur de sécurité statique efficace pour les roulements chargés universellement

Reference number
ISO 17956:2025(en)

Contents

Page

Foreword ..... **iv**
Introduction ..... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Symbols **2**
5 Calculation of the effective static safety factor **2**
5.1 General 2
5.2 Effective static safety factor for ball bearings 3
5.3 Effective static safety factor for roller bearings 4
5.4 Guideline values of the effective static safety factor 4
Annex A (informative) **Further information** **5**
Bibliography **10**

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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.

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

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.

Introduction

ISO 76 specifies a simplified method for the calculation of static safety factor of rolling bearings. However, this method cannot account for actual operating conditions like tilt, misalignment, moment load or for operating clearance.

The calculation method specified in this document is based on the detailed analysis of bearing internal load distribution, as described in ISO 16281[1]. It uses maximum ball or lamina loads for the calculation of the effective static safety factor, thus following the general principle of ISO 76. The calculation method yields no satisfactory results for rolling bearings subjected to considerable truncation of the area of contact between the rolling elements and the raceway.

The primary purpose of this document is to provide a unified and manufacturer-independent advanced calculation method that allows for the consideration of actual operating conditions, thus enabling the end user to compare different bearing solutions on the same calculation basis. It is also intended to serve as a manufacturer-independent neutral basis for certification purposes, for example, as required per IEC 61400-4[2] for bearings in wind turbine gearboxes.

It is not intended to supersede other advanced bearing analysis methods that are currently used in the design process as the primary tool for bearing design and selection.

The static load rating according to ISO 76 was originally based on a permanent plastic deformation under static load, i.e. a constant load on a non-rotating bearing. However, it is common practice in rolling bearing design and analysis to calculate the static safety factor also for rotating load cases. Therefore, it is recommended to calculate the effective static safety factor for the load situation where the maximum contact load occurs, independent of rotating or non-rotating condition.

Rolling bearings — Method for calculating the effective static safety factor for universally loaded rolling bearings

1 Scope

This document specifies the calculation of the effective static safety factor under consideration of tilt or misalignment, operating clearance of the bearing, and internal load distribution on rolling elements. The calculation method provided in this document covers influencing parameters in addition to those described in ISO 76.

The directions and limitations given in ISO 76 and ISO 20056-2 apply to this document. The calculation method pertains to the static safety factor of the bearings. Other mechanisms of failure, like false brinelling, fatigue life, wear or microspalling (gray-staining), lie outside the scope of this document.

This document applies to single and multi-row radial and thrust ball and roller bearings, subjected to radial and axial load and with radial clearance and tilt taken into account. References to methods for the analysis of the internal load distribution under general load are given.

The analysis of effective static safety factor for multi-row bearings or bearings of a more complex geometry can be derived from the formulae given in this document. For these bearings, the load distribution for each individual row is considered.

The calculation of effective static safety factor is also applicable to hybrid bearings, using the static load ratings according to ISO 20056-2.

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 76:2006, *Rolling bearings — Static load ratings*

ISO 5593, *Rolling bearings — Vocabulary*

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

ISO 20056-2:2017, *Rolling bearings — Load ratings for hybrid bearings with rolling elements made of ceramic — Part 2: Static load ratings*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 76, ISO 5593, ISO 20056-2, and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
effective static safety factor
<ball bearing> ratio between the maximum ball load used in the definition of the static load rating, and the maximum ball load, based on the bearing internal load distribution, under actual operating conditions

3.2
effective static safety factor
<roller bearing> ratio between the maximum roller load used in the definition of the static load rating, recalculated to lamina load, and the load of the maximum loaded lamina, based on the bearing internal load distribution, under actual operating conditions

4 Symbols

For the purposes of this document, the symbols given in ISO 76, ISO 15241 and the following apply.

C_{0a} basic static axial load rating, in newtons

C_{0r} basic static radial load rating, in newtons

i number of rows of rolling elements

j subscript for individual rolling element

k subscript for individual lamina of a roller

m subscript for individual row of a multi-row bearing

NOTE Subscripts are used in the order j,k,m, separated by commas, e.g. $q_{j,k,m}$ denotes the load on lamina k of roller j of row m.

n_s number of laminae per roller

Q_j rolling element load of rolling element j, in newtons

Q_{max} maximum rolling element load in the bearing, in newtons

Q_0 rolling element load at which the nominal Hertzian contact stress defining the static load rating is reached, in newtons

$q_{j,k}$ load on the lamina k of roller j, in newtons

q_{max} maximum lamina load of any rolling element in the bearing, in newtons

q_0 lamina load at which the nominal stress defining the static load rating is reached, in newtons

$S_{0,eff}$ effective static safety factor

Z number of rolling elements of a bearing row

α nominal contact angle of a bearing, in degrees

5 Calculation of the effective static safety factor

5.1 General

The static load ratings and static safety factor according to ISO 76 and ISO 20056-2 are defined on the basis of Hertzian contact stresses for point contact and pure line contact of a cylinder. Therefore, Hertzian contact models are used in this document to calculate the effective static safety factor.

The static load ratings according to ISO 76 and ISO 20056-2 are based on a rolling element load Q_0, at which a nominal Hertzian pressure is reached, as described in ISO/TR 10657:2021, Clause 4[3]. The static load rating of the complete bearing is then calculated under assumption of a fixed load distribution between the rolling elements. The static safety factor is then calculated by comparing this rolling element load to an estimated maximum rolling element load under combined thrust and radial load, as described in ISO/TR 10657:2021, Clause 5.

For the consideration of actual bearing internal load distribution, this estimation of the maximum rolling element load is replaced by an analytical calculation of the actual bearing internal load distribution as described in ISO 16281:2025, Annex A.

For ball bearings, the maximum rolling element load Q_{max} is compared to the rolling element load Q_0 used for the definition of the static load rating. Thus, the algorithm prescribed in this document only replaces an approximation of the load distribution by the calculation of the actual bearing internal load distribution for the actual operating conditions.

For roller bearings, a lamina model Q_0 is used to be able to account for tilt, misalignment, or moment load. Therefore, the rolling element load, which, according to ISO 76 and ISO 20056-2, is calculated by a pure Hertzian line contact model for an unprofiled cylinder, is recalculated to a lamina load q_0. This lamina load q_0 is then compared to the maximum load of any lamina of the bearing under actual load conditions.

Since the lamina model used in the load distribution analysis according to ISO 16281 takes into account the roller profile, for a roller loaded with a centric load Q_0, the maximum lamina load q_{max} will be slightly higher than the lamina load q_0, even under ideal load conditions. Therefore, the lamina model is slightly conservative compared to the original definition of the static load rating. Further background information is given in Annex A.

NOTE Alternative calculation approaches based on the comparison of maximum actual non-Hertzian contact stress, as calculated by advanced contact models or finite element analysis, to the maximum Hertzian contact stress as defined in ISO 76 are overly conservative for line contact, especially when edge stresses are considered. Comparing such a non-Hertzian contact stress to a purely Hertzian contact stress significantly underestimates the effective static safety factor.

5.2 Effective static safety factor for ball bearings

The effective static safety factor of a ball bearing is calculated as

$$S_{0,eff} = \frac{Q_0}{Q_{max}} \quad (1)$$

where Q_{max} is the maximum rolling element load in the bearing,

$$Q_{max} = \max\{Q_j\} \quad (2)$$

and Q_0 is the ball load at which the nominal Hertzian contact stress defining the static load rating is reached. A method for the calculation of the ball loads in a universally loaded ball bearing is given in ISO 16281:2025, 6.2.

For radial and angular contact ball bearings

$$Q_0 = \frac{5}{i\ Z\ \cos\alpha} C_{0r} \quad (3)$$

and for thrust ball bearings

$$Q_0 = \frac{1}{Z\ \sin\alpha}\ C_{0a} \quad (4)$$

5.3 Effective static safety factor for roller bearings

The effective static safety factor of a roller bearing is calculated as

$$S_{0,\mathrm{eff}} = \frac{q_0}{q_{\max}} \tag{5}$$

where $q_{\max}$ is the maximum lamina load of any rolling element in the bearing,

$$q_{\max} = \max\left\{q_{j,k,m}\right\} \tag{6}$$

and q_0 is the lamina load at which the nominal Hertzian contact stress defining the static load rating is reached. Methods for the calculation of the lamina loads in a universally loaded roller bearing are given in ISO 16281:2025, 6.3.

For radial roller bearings

$$q_0 = \frac{1}{n_\mathrm{S}} \frac{5}{i\ Z\ \cos\alpha} C_{0\mathrm{r}} \tag{7}$$

and for thrust roller bearings

$$q_0 = \frac{1}{n_\mathrm{S}} \frac{1}{Z\ \sin\alpha} C_{0\mathrm{a}} \tag{8}$$

The number of laminae per roller, n_S, shall not be less than 30. If a variable lamina width is used, the maximum lamina width shall not be larger than $^1/_{30}$ of the effective length of the roller.

NOTE Formulae (7) and (8) assume uniform length of the laminae. For non-uniform lamina length, the term $\frac{1}{n_\mathrm{S}}$ in these formulae can be replaced by the ratio of individual lamina length to effective length of the roller. The effective static safety factor is then calculated per lamina row, where the total effective static safety factor is the minimum of the results per lamina row.

5.4 Guideline values of the effective static safety factor

Guideline values of the static safety factors are presented in ISO 76:2006, 9.2 for ball bearings and ISO 76:2006, 9.3 for roller bearings.

For hybrid bearings, guideline values for the static safety factor are given in ISO 20056-2:2017, Clause 7.

These guide values also apply to the effective static safety factor defined in this document.

Annex A
(informative)

Further information

A.1 Criteria for the effective static safety factor

A.1.1 Definition of static load ratings

The static load ratings according to ISO/R 76:1958[4]1) were originally based on a total permissible plastic deformation of rolling element and raceway of 0,000 1 of the rolling element diameter. Since such small plastic deformations are hard to measure and even harder to calculate, the definition was then changed with ISO 76:1987[5]2) to static load ratings corresponding to permissible calculated Hertzian contact stress values. The defined stress values were calculated based on the Hertzian contact stress analysis for ideal point contact and pure line contact according to ISO/TR 10657[3]. Both calculation models are based on simplified assumption to allow for mathematical formulae that were practically applicable before the advent of computers[6].

The main assumptions are:

— homogeneous and isotropic material;

— contact area in a flat plane with dimensions that are small compared to the curvature radii;

— contact and subsurface stresses are below the yield limit of the material.

Technically, all three assumptions are not fulfilled for rolling bearings. There is a grain structure in the steel, the actual plane of contact has a significant curvature for ball or spherical roller bearings with tight osculation, and corresponding to the definition of the static load ratings, the material's yield limit is exceeded when the bearings is subjected to a load corresponding to the static load rating. The resulting inaccuracies are well understood, and Hertzian theory has been successfully applied in bearing analysis for more than 100 years.

However, stress values defined as Hertzian contact stresses, like the contact stress values defined for the static load rating per ISO 76, are not directly comparable to contact stress values obtained from more advanced calculation methods like Finite Element Method or non-Hertzian contact analysis methods. Therefore, the method defined in this document, is still based on Hertzian contact stress analysis, to maintain compatibility with the load ratings per ISO 76.

A.1.2 Point contact

In the Hertzian model for point contact, an elastic half-space model is used, where one contacting body is modelled as a continuous, homogeneous and perfectly elastic body of infinitely large size with a flat surface, while the total curvature of both bodies is transferred to the second body by use of equivalent curvature radii.

Therefore, the area of contact is defined as a plane, where all contact forces are acting normal to this plane, i.e. in the direction of the applied load, see Figure A.1.

1) Withdrawn standard.

2) Withdrawn standard.

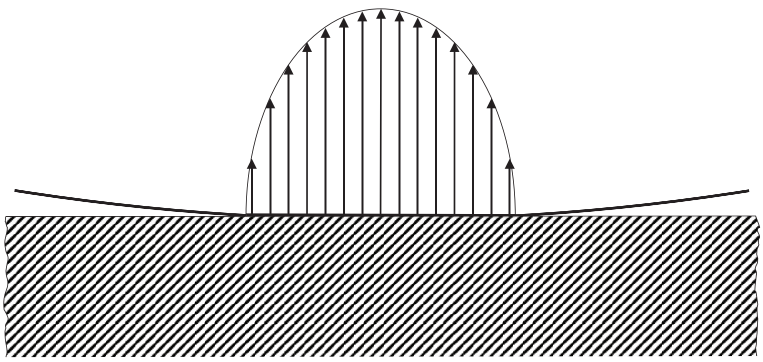

Figure A.1 — Hertzian contact model of ball in raceway groove

In an actual rolling bearing, for example a deep grove ball bearing as depicted in a cross-sectional view in Figure A.2, there is a significant curvature of the contact area. Since the contacting forces are acting normal to the local area of contact, the portion of the contact forces acting perpendicular to the applied contact load cancel out. Therefore, the actual contact forces are larger than calculated by the Hertzian model, and thus the actual contact stress can significantly exceed the Hertzian contact stress. However, there is no generally accepted method for the consideration of spatial curvature, so calculated stress value can be depending on the calculation approach and the level of discretization.

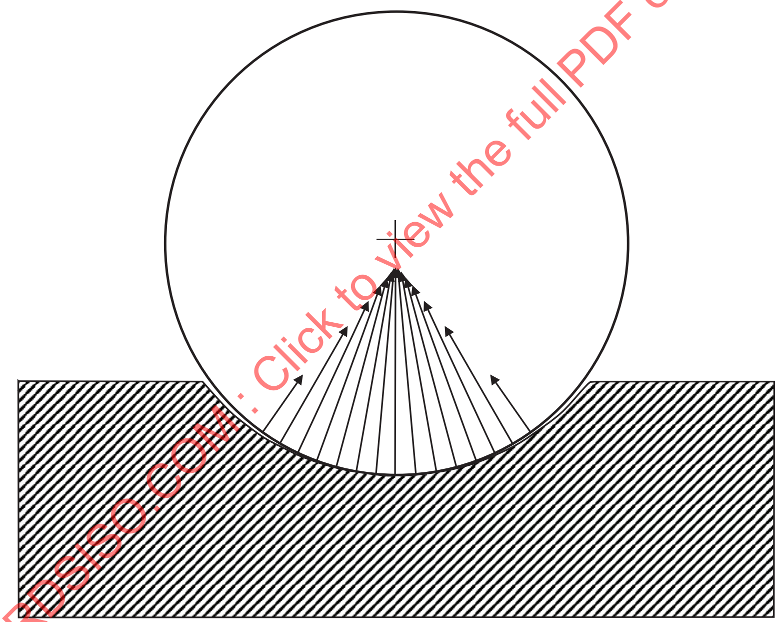

Figure A.2 — Actual contact geometry and load distribution of ball in raceway groove

Since the primary purpose of this document is the unification of calculation methods, the method specified in this document is based on a maximum contact load calculated by Hertzian model, at which the maximum stress defined per ISO 76 is reached, thus giving consistent and comparable results for the effective static safety factor.

A.1.3 Line contact

The Hertzian model for ideal line contact is derived for two cylindrical bodies of infinite length or mathematically exact equal length. For this case, the contact stress distribution is uniform along the length of the contact, see Figure A.3.

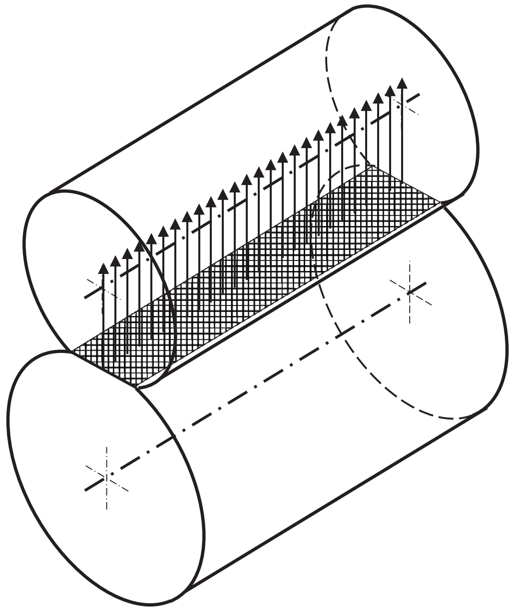

Figure A.3 — Hertzian line contact

In real applications, where the contacting bodies have different finite lengths, tensile stresses in the longer body will lead to non-uniform contact stress along the contact line, as shown in Figure A.4.

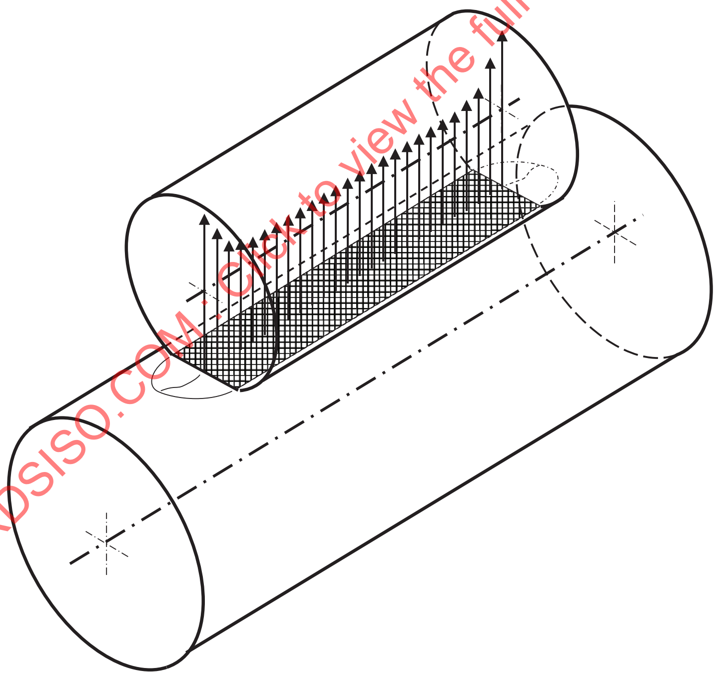

Figure A.4 — Edge stress in actual line contact of cylindrical bodies

These edge stresses cannot be calculated by the Hertzian contact model, but by Finite Element Method or by dedicated non-Hertzian contact models, given for example in References [7], [8] and [9] or similar advanced computer programs. Again, contact stress values obtained by such detailed methods will be higher than results calculated by the Hertzian model, which would result in significantly smaller permissible load to obtain the same contact stress as calculated by the Hertzian model. Therefore, such models are not recommended for the determination of the effective static safety factor.

A.1.3.1 Consideration of edge stresses

The static load rating is a criterion based on avoidance of excessive noise and vibration of a rolling bearing, where the governing criterion is bulk plastic deformation in the rolling contact.

This criterion cannot be simply transferred to account for non-Hertzian stresses caused by edge load. Stresses from edge load have a much lower penetration depth than Hertzian stresses in the centre of the contact, therefore, any plastic deformation caused by edge load will be much smaller than the plastic deformation occurring under a Hertzian stress of the same numerical value. Further, most advanced contact stress models will overestimate edge stresses, since such models typically do not account for the elasticity of the free surface at the edge.

Therefore, contrary to the rating life analysis, a consideration of edge stresses is not recommended for the calculation of effective static safety factor.

A.1.3.2 Lamina model for line contact

In contemporary rolling bearings, edge load is mitigated by use of profiled rollers. Since the Hertzian contact model cannot account for roller profile and angular deflection of the contact, lamina models are generally used to account for the load distribution along the line of contact.

In a lamina model, as shown in Figure A.5, the rolling element is virtually divided into a sufficiently large number of cylindrical laminae, where the diameter of each lamina is adjusted for the actual roller profile. In static equilibrium analysis, the radial stiffness of each lamina is then used to model the radial and angular stiffness of a profiled roller. As a result, lamina loads are calculated for each lamina of the roller.

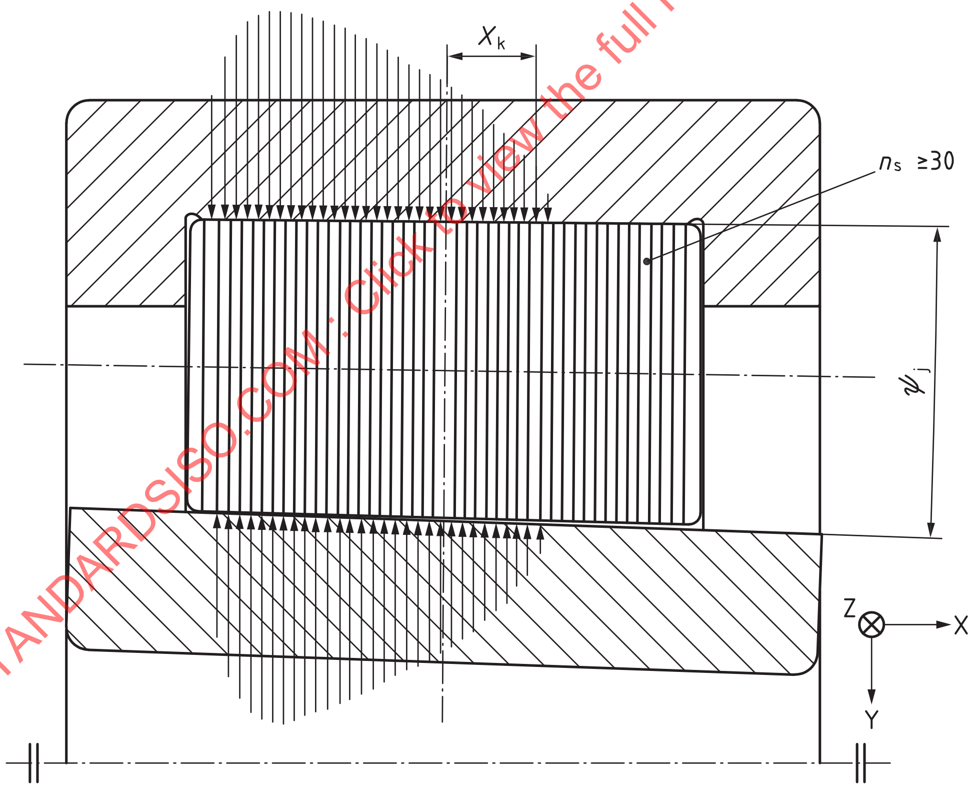

Figure A.5 — Lamina model

The effective static safety factor is then calculated from the ratio of the lamina load, at which the nominal Hertzian contact stress defining the static load rating is reached, to the maximum lamina load in the actual load-case considered, see 5.3.

This calculation approach has been successfully used over decades in rolling bearing design and analysis, and can be considered a good compromise between Hertzian contact analysis which cannot account for