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BSI Standards Publication

Calculation of load capacity of spur and helical gears

Part 4: Calculation of tooth flank fracture load capacity

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National foreword

This Published Document is the UK implementation of ISO/TS 6336-4:2019.

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This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Part 4: Calculation of tooth flank fracture load capacity

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Partie 4: Calcul de la capacité de charge de la rupture en flanc de dent

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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.

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 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 60, *Gears*, Subcommittee SC 2, *Gear capacity calculation*.

A list of all parts in the ISO 6336 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.

Introduction

The ISO 6336 series consists of International Standards, Technical Specifications (TS) and Technical Reports (TR) under the general title *Calculation of load capacity of spur and helical gears* (see Table 1).

— International Standards contain calculation methods that are based on widely accepted practices and have been validated.

— Technical Specifications (TS) contain calculation methods that are still subject to further development.

— Technical Reports (TR) contain data that is informative, such as example calculations.

The procedures specified in ISO 6336-1 to ISO 6336-19 cover fatigue analyses for gear rating. The procedures described in ISO 6336-20 to ISO 6336-29 are predominantly related to the tribological behaviour of the lubricated flank surface contact. ISO 6336-30 to ISO 6336-39 include example calculations. The ISO 6336 series allows the addition of new parts under appropriate numbers to reflect knowledge gained in the future.

Requesting standardized calculations according to the ISO 6336 series without referring to specific parts requires the use of only those parts that are currently designated as International Standards (see Table 1 for listing). When requesting further calculations, the relevant part or parts of the ISO 6336 series need to be specified. Use of a Technical Specification as acceptance criteria for a specific designs need to be agreed in advance between the manufacturer and the purchaser.

Table 1 — Parts of the ISO 6336 series (status as of DATE OF PUBLICATION)

Calculation of load capacity of spur and helical gears	International Standard	Technical Specification	Technical Report
Part 1: Basic principles, introduction and general influence factors	X		
Part 2: Calculation of surface durability (pitting)	X		
Part 3: Calculation of tooth bending strength	X		
Part 4: Calculation of tooth flank fracture load capacity		X	
Part 5: Strength and quality of materials	X		
Part 6: Calculation of service life under variable load	X		
Part 20: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Flash temperature method *(replaces: ISO/TR 13989-1)*		X	
Part 21: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Integral temperature method *(replaces: ISO/TR 13989-2)*		X	
Part 22: Calculation of micropitting load capacity *(replaces: ISO/TR 15144-1)*		X	
Part 30: Calculation examples for the application of ISO 6336 parts 1, 2, 3, 5			X
Part 31: Calculation examples of micropitting load capacity *(replaces: ISO/TR 15144-2)*			X

This document provides principles for the calculation of the tooth flank fracture load capacity of cylindrical involute spur and helical gears with external teeth. The method is based on theoretical and

experimental investigations (see References [9], [10], [12] and [15]) on case carburized test gears and gears from different industrial applications.

This document as a part of the ISO 6336 series includes a newly developed method for assessing the risk of tooth flank fracture, which is still subject to further development. It is published in order to gain a broader experience with the obtained results in various scopes of application. The knowledge gained will serve for further development and refinement of this document.

Tooth flank fracture is characterized by a primary fatigue crack in the region of the active contact area, initiated below the surface due to shear stresses caused by the flank contact. Failures due to tooth flank fracture are reported from different industrial gear applications and have also been observed on specially designed test gears for gear running tests. Tooth flank fracture is most often observed on case carburized gears but failures are also known for nitrided and induction hardened gears. Most of the observed tooth flank fractures occurred on the driven partner.

The basis for the calculation of the tooth flank fracture load capacity are sophisticated calculation methods based on the shear stress intensity hypothesis (SIH, see References [13] and [16]) which were transferred to a calculation method in closed form solution. With only a small set of parameters concerning gear geometry, gear material and gear load condition, a calculation of the local material exposure can be performed in order to calculate the tooth flank fracture load capacity.

It should also be understood that some aspects of this type of failure can be a complex interaction of stress fluctuations and material inhomogeneities. As an example, the presence of retained austenite in the carburized case can result in the transformation during service and its associated volumetric change can cause a minute distortion of the teeth and loss of original contact quality thereby changing the localised stress distribution. Another phenomenon is the development of localised “white etching areas” (local work hardening) which ultimately develop into crack initiation and propagation. Clearly, there is considerable research required to isolate these types of effects and the analysis of case histories is paramount to the understanding of the subject.

Calculation of load capacity of spur and helical gears —

Part 4:
Calculation of tooth flank fracture load capacity

1 Scope

This document describes a procedure for the calculation of the tooth flank fracture load capacity of cylindrical spur and helical gears with external teeth.

It is not intended to be used as a rating method in the design and certification process of a gearbox.

The formulae specified are applicable for driving as well as for driven cylindrical gears while the tooth profiles are in accordance with the basic rack specified in ISO 53. They can also be used for teeth conjugate to other racks where the actual transverse contact ratio is less than $\varepsilon_\alpha = 2{,}5$. The procedure was validated for case carburized[15] gears and the formulae of this document are only applicable to case carburized gears with specifications inside the following limits:

— Hertzian stress: 500 N/mm^2 ≤ p_H ≤ 3 000 N/mm^2;

— Normal radius of relative curvature: 5 mm ≤ ρ_{red} ≤ 150 mm;

— Case hardening depth at 550 HV in finished condition: 0,3 mm ≤ *CHD* ≤ 4,5 mm.

This document is not applicable for the assessment of types of gear tooth damage other than tooth flank fracture.

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 1122-1, *Vocabulary of gear terms — Part 1: Definitions related to geometry*

ISO 1328-1, *Cylindrical gears — ISO system of flank tolerance classification — Part 1: Definitions and allowable values of deviations relevant to flanks of gear teeth*

ISO 6336-1, *Calculation of load capacity of spur and helical gears — Part 1: Basic principles, introduction and general influence factors*

ISO 6336-2, *Calculation of load capacity of spur and helical gears — Part 2: Calculation of surface durability (pitting)*

ISO 21771, *Gears — Cylindrical involute gears and gear pairs — Concepts and geometry*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1122-1, ISO 6336-1 and ISO 6336-2 apply.