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Wind energy generation systems –
Part 4: Design requirements for wind turbine gearboxes

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FOREWORD

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IEC 61400-4 has been prepared by IEC technical committee 88: Wind energy generation systems, in co-operation with ISO technical committee 60: Gears. It is an International Standard.

It is published as a double logo standard.

This second edition cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) extension of the scope to wind turbines above 2 MW reference power;
b) considerations for converging differing approaches to reliability in gear, bearing and wind turbine standards;

c) new clause on wind turbine loads specific to drivetrains;

d) revised clause on verification and validation;

e) new clause on design requirements for plain bearings;

f) revised and expanded design considerations for rolling bearings;

g) revised clause on considerations and requirements in the design and analysis of gearbox structural elements;

h) updated considerations and requirements on lubricants and lubrication systems;

i) removal of requirements for documenting the compliance of a design with the requirements of the document in favour of reference to IECRE OD-501-2.

The text of this International Standard is based on the following documents:

Draft	Report on voting
88/971/CDV	88/1003A/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table. In ISO, the standard has been approved by 11 P-members out of 12 having cast a vote.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts of the IEC 61400 series, under the general title: *Wind energy generation systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

IEC 61400-4 outlines minimum requirements for specification, design, and verification of gearboxes in wind turbines. It does not serve as a complete design specification or instruction manual. It is intended for use by experienced designers of wind turbine drivetrains, gearboxes, and gears or bearings who are capable of selecting reasonable values for the design factors, based on knowledge of similar designs and the effects of such items as lubrication, deflection, manufacturing tolerances, metallurgy, residual stress, and system dynamics.

Any of the requirements of this document may be altered:

- if more accurate data are available from full scale load tests, precise measurements, comprehensive mathematical analysis, or any combination of these;
- or on the basis of proven operating experience;
- and if the evidence is accessible for independent assessment (e.g. by an accredited renewable energy certification body);
- and if the accuracy and reliability of the alternative method is demonstrated with respect to the safety and reliability of the complete wind turbine drive system.

WIND ENERGY GENERATION SYSTEMS –

Part 4: Design requirements for wind turbine gearboxes

1 Scope

This part of IEC 61400 is applicable to enclosed speed increasing gearboxes for horizontal axis wind turbine drivetrains with a power rating in excess of 500 kW. This document applies to newly designed gearboxes for wind turbines installed onshore or offshore. The technical requirements given in this document are not intended for repaired or refurbished gearboxes, or for the extension of the service life beyond the design life.

This document provides requirements and guidance on the analysis of the wind turbine loads in relation to the design of the gear and gearbox elements. The gearing elements covered by this document include such gears as spur, helical or double helical and their combinations in parallel and epicyclic arrangements in the main power path. This document does not apply to power take off (PTO) gears.

This document includes requirements, design recommendations, and rating of gearboxes with rolling bearings, plain bearings, or combinations of both bearing types.

Also included are requirements and guidance on the engineering of shafts, shaft hub interfaces, lubrication, wind turbine controller interface, and the gear case structure to achieve a design that is capable of withstanding the environment and operating conditions of a wind turbine. Requirements for dynamic analysis of the gearbox within the wind turbine system are specified for the purpose of identifying load levels exceeding the predictions of the global aeroelastic simulation. The analysis of noise transmission and emission (e.g. tonal emission at gear mesh frequencies) is not within the scope of this edition of the document.

Further, this document provides requirements and guidance on gearbox design verification, prototype testing and production testing, as well as consideration of design for service and maintenance.

A method for a systematic assessment of the design reliability of a gearbox design under reference operating conditions is specified in IEC TS 61400-4-1[1].

This document is supported by two Technical Reports: IEC TR 61400-4-2[2] provides additional information on lubrication of wind turbine drivetrains and IEC TR 61400-4-3[3] contains explanatory notes and supportive information to the requirements specified in this document.

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1 Under preparation. Stage at the time of publication: IEC/DTS 61400-4-1:2024.

2 Under preparation. Stage at the time of publication: IEC/DTR 61400-4-2:2024.

3 Under preparation. Stage at the time of publication: IEC/DTR 61400-4-3:2024.

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.

IEC 61400-1:2019, *Wind energy generation systems – Part 1: Design requirements*

IEC 61400-3-1, *Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines*

IEC TS 61400-3-2, *Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines*

IEC 61400-8, *Wind energy generation systems – Part 8: Design of wind turbine structural components*

IEC TS 61400-30, *Wind energy generation systems − Part 30: Safety of wind turbine generators − General principles for design*

ISO 281, *Rolling bearings – Dynamic load ratings and rating life*

ISO 683 (all parts), *Heat-treatable steels, alloy steels and free-cutting steels*

ISO 683-17, *Heat-treatable steels, alloy steels and free-cutting steels − Part 17: Ball and roller bearing steels*

ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel – Part 1: Bolts, screws and studs with specified property classes – Coarse thread and fine pitch thread*

ISO 898-2, *Fasteners − Mechanical properties of fasteners made of carbon steel and alloy steel − Part 2: Nuts with specified property classes*

ISO 898-3, *Mechanical properties of fasteners made of carbon steel and alloy steel – Part 3: Flat washers with specified property classes*

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 3104, *Petroleum products – Transparent and opaque liquids – Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 4042, *Fasteners – Electroplated coating systems*

ISO 4406, *Hydraulic fluid power – Fluids – Method for coding the level of contamination by solid particles*

ISO 6336 (all parts), *Calculation of load capacity of spur and helical gears*

ISO 6336-1:2019, *Calculation of load capacity of spur and helical gears – Part 1: Basic principles, introduction and general influence factors*

ISO 6336-2:2019, *Calculation of load capacity of spur and helical gears – Part 2: Calculation of surface durability (pitting)*

ISO 6336-3:2019, *Calculation of load capacity of spur and helical gears – Part 3: Calculation of tooth bending strength*

ISO TS 6336-4, *Calculation of load capacity of spur and helical gears – Part 4: Calculation of tooth flank fracture load capacity*

ISO 6336-5:2016, *Calculation of load capacity of spur and helical gears – Part 5: Strength and quality of materials*

ISO 6336-6:2019, *Calculation of load capacity of spur and helical gears – Part 6: Calculation of service life under variable load*

ISO TS 6336-20, *Calculation of load capacity of spur and helical gears – Part 20: Calculation of scuffing load capacity – Flash temperature method*

ISO TS 6336-21, *Calculation of load capacity of spur and helical gears – Part 21: Calculation of scuffing load capacity – Integral temperature method*

ISO TS 6336-22, *Calculation of load capacity of spur and helical gears – Part 22: Calculation of micropitting load capacity*

ISO 6618, *Petroleum products and lubricants – Determination of acid or base number – Colour-indicator titration method*

ISO 6619, *Petroleum products and lubricants – Neutralization number – Potentiometric titration method*

ISO 7146-1, *Plain bearings – Appearance and characterization of damage to metallic hydrodynamic bearings – Part 1: General*

ISO 8579-1, *Acceptance code for gear units – Part 1: Test code for airborne sound*

ISO TR 10064-3, *Code of inspection practice – Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes*

ISO 10683, *Fasteners – Non-electrolytically applied zinc flake coating systems*

ISO 10825-1, *Gears – Wear and damage to gear teeth – Part 1: Nomenclature and characteristics*

ISO 12925-1, *Lubricants, industrial oils and related products (class L). Family C (gears) – Part 1: Specifications for lubricants for enclosed gear systems*

ISO 14104, *Gears – Surface temper etch inspection after grinding, chemical method*

ISO 14635-1:2023, *Gears – FZG test procedures – Part 1: FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils*

ISO 15243:2017, *Rolling bearings – Damage and failures – Terms, characteristics and causes*

ISO 16281:2025, *Rolling bearings – Methods for calculating the modified reference rating life for universally loaded bearings*

ISO 17956:2025, *Rolling bearings – Method for calculating the effective static safety factor for universally loaded rolling bearings*

ISO 21920-1, *Geometrical product specifications (GPS) – Surface texture: Profile – Part 1: Indication of surface texture*

ISO 21920-2, *Geometrical product specifications (GPS) – Surface texture: Profile – Part 2: Terms, definitions and surface texture parameters*

ISO 21920-3, *Geometrical product specifications (GPS) – Surface texture: Profile – Part 3: Specification operators*

ANSI/AGMA 6001, *Design and selection of components for enclosed gear drives*

ANSI/AGMA 6123, *Design manual for enclosed epicyclic gear drives*

ASTM D445, *Standard test method for kinematic viscosity of transparent and opaque liquids (and calculation of dynamic viscosity)*

ASTM D664, *Standard test method for acid number of petroleum products by potentiometric titration*

ASTM D974, *Standard test method for acid and base number by color-indicator titration*

ASTM D5185, *Standard test method for multielement determination of used and unused lubricating oils and base oils by inductively coupled plasma atomic emission spectrometry (ICP-AES)*

ASTM D6304, *Standard test method for determination of water in petroleum products, lubricating oils, and additives by coulometric Karl Fischer titration*

DIN 471, *Circlips (retaining rings) for shafts: Normal type and heavy type*

DIN 472, *Circlips (retaining rings) for bores: Normal type and heavy type*

DIN 743 (all parts), *Calculation of load capacity of shafts and axles*

DIN 3990-16, *Calculation of load capacity of cylindrical gears – Part 16: Determination of the micro-pitting load-carrying capacity of lubricants using FZG test method GT-C/8.3/90*

DIN 6885-1, *Drive type fastenings without taper action; Parallel keys, keyways, deep pattern*

DIN 6892, *Mitnehmerverbindungen ohne Anzug – Passfedern – Berechnung und Gestaltung* (available in German only)

DIN 7190, *Interference fits – Calculation and design rules*

DIN 51399-1, *Testing of lubricants – Determination of elements content in additives, wear and other contaminations – Part 1: Direct determination by optical emission spectral analysis with inductively coupled plasma (ICP OES)*

DIN 51777, *Petroleum products – Determination of water content using titration according to Karl Fischer*

DIN 51819-3, *Testing of lubricants – Mechanical-dynamic testing in the roller bearing test apparatus FE8 – Part 3: Test method for lubricating oils – Applied test bearing: axial cylindrical roller bearing*

FVA 563 I, *FVA Guideline: Recommendations for the standardization of load carrying capacity test on hardened and tempered cylindrical gears,* Research Association for Drive Technology (FVA). Frankfurt, 2012

VDI 2230-1:2015, *Systematic calculation of highly stressed bolted joints – Joints with one cylindrical bolt*

VDI 2230-2:2014, *Systematic calculation of highly stressed bolted joints – Multi bolted joints*

VDI/VDE 2862-2, *Minimum requirements for application of fastening systems and tools – Applications in plant construction, mechanical engineering, equipment manufacturing and for flange connections in components under pressure boundary*