IEC TR 61400-4-2

Edition 1.0 2026-02

Corrected version
2026-04

TECHNICAL REPORT

Wind energy generation systems -
Part 4-2: Lubrication of drivetrain components in wind turbines

IEC TR 61400-4-2: 2026-02(en)

ICS 27.180

ISBN 978-2-8327-1068-5

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Wind energy generation systems -
Part 4-2: Lubrication of drivetrain components in wind turbines

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC 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, IEC 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 https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 61400-4-2 has been prepared by IEC technical committee 88: Wind energy generation systems, in co-operation with ISO technical committee 60: Gears. It is a Technical Report.

It is published as a dual logo technical report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
88/1132/DTR	88/1162/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report 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, published 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.

This corrected version of IEC TR 61400-4-2:2026 incorporates the following correction:

– addition in the foreword that this is a double logo technical report prepared in cooperation with ISO/TC 60

INTRODUCTION

The purpose of this IEC Technical Report (TR) is to provide a common reference for lubrication related matters for wind turbine drive trains. ISO/TR 18792 provides information for lubrication of industrial gearboxes. Some information is similar or identical to this document.

The contents are non-normative but useful to wind turbine system and component designers, wind turbine manufacturers, and owners/operators to ensure that lubricant related matters are addressed in the gearbox design and operation phases.

This current edition of the document covers oil lubricated gearboxes and is developed based on experience with predominantly gearboxes with rolling bearings. It can be applied to gearboxes with plain bearings, but possibly does not yet address all aspects of this technology. The document structure is prepared to receive further content related to other components in the wind turbine drivetrain and include additional types of lubricants.

1 Scope

This document, which is a Technical Report, provides non-binding information regarding the lubricant, lubrication system layout, and performance for wind turbine gearboxes. This document covers oil lubricated gearboxes. Additionally, guidance for selected lubricant parameters as well as for monitoring and maintaining lubricant characteristics is offered.

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, *Wind energy generation systems - Part 1: Design requirements*

IEC 61400-3 (all parts), *Wind energy generation systems - Part 3: Design requirements*

IEC 61400-4, *Wind energy generation systems - Part 4: Design requirements for wind turbine gearboxes*

3 Terms, definitions, abbreviated terms, units and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61400-1, IEC 61400-3 series, IEC 61400-4 and the following apply.

NOTE In case of conflict, the definitions in this document take precedence.

3.1.1
lubricant supplier
entity supplying lubricants for the wind turbine gearbox

Note 1 to entry: The lubricant supplier is responsible for the performance of the lubricant and the blending specifications, but will not necessarily produce any of the components, or blend the final product.

3.1.2
nacelle
turbine structure above the tower that holds the drivetrain, generator, other subcomponents, and parts of the controls and actuation systems

3.1.3
oil
fluid used to lubricate, flush away debris, and regulate heat transfer in the gearbox

Note 1 to entry: The word oil is ambiguous but is used in this document in addition to other common terms such as: lubricant, lubricating oil, fluid, gear oil.

3.1.4
line
rigid or flexible means to convey fluids, such as pipes, tubes or hoses, including related fixtures, fittings, couplings, valves or connectors

3.2 Abbreviated terms, units and conventions

This document uses equations and relationships from several engineering specialties. As a result, there are, in some cases, conflicting definitions for the same symbol. All the symbols used in the document are nevertheless listed, but, if there is ambiguity, the specific definition is presented in the clause where they are used in equations, graphs, or text.

F_c	flow circulation (or dwell time)	min
L_{50}	basic reference rating life at 50% reliability	h
Q_{min}	minimum oil flow	l/min
P_G	generated mechanical power losses	kW
P_{cn}	power dissipated by natural convection through the gearbox surface	kW
C_{oil}	specific heat capacity of the oil	kJ/(kg K)
V_{min}	minimum oil volume	L
ρ	oil density	kg/m^3
ΔT	temperature difference between oil sump and oil inlet to the gearbox	K
m_{w50}	mass loss of roller caused by wear or fatigue during loading phase in FE8 test	mg

AGMA	American Gear Manufacturers Association
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
CEC	Commission of the European Communities
DIN	Deutsches Institut für Normung
EP	extreme pressure, refers to a type of additive
GFT	"Graufleckentragfähigkeit", micropitting resistance
FTIR	Fourier transform infrared spectroscopy
FZG	"Forschungsstelle für Zahnräder und Getriebebau" TU Munich
IBC	international bulk container tote for liquids
IEC	International Electrotechnical Commission
IR	Infrared
ISO	International Organization for Standardization
PAG	poly-alkylene-glycol or polyglycol, synthetic lubricants
PAO	poly-alpha-olefin, fully paraffinic synthetic lubricant based on synthesized hydrocarbons
PQ	particle quantifier (index)
PTO	power take off
VG	(ISO) viscosity grade

4 General information

Wind turbines, including their drive trains and gearboxes, operate in extreme environments with highly variable load conditions, for example:

– temperatures from arctic to hot climates;
– humidity from dry deserts to humid marine conditions;
– sudden load variations, long periods of high loads and long periods under no-load conditions;
– short start-up and shut-down situations;
– unmanned operation with extended time between service (typically between 6 months and 12 months).

Lubricant and lubrication system elements can be selected and balanced for these sometimes conflicting needs. Information is provided in Clause 5 for lubricant selection, Clause 6 for system design, and Clause 7 for maintenance. The following clauses provide information in addition to IEC 61400-4, which supports designers, manufacturers, end users and service personnel to develop, manufacture, operate and maintain lubricants and lubrication systems in wind turbines.

5 Lubricants

5.1 Type of lubricant

Compared to most other gearbox applications, gearboxes in wind turbines are exposed to high percentage of utilization, though with high variation between periods of partial and full load. During full load operation, gears operate at low to moderate pitch line velocity with high to very high contact loads, whereas bearings are exposed to moderate contact loads. Lubricants fortified with performance enhancing additives and of the highest practical viscosity can be used to improve operation under these conditions. The base fluids of these lubricants can be chosen from highly refined mineral oils, full synthetic fluids, or semi-synthetic blends (mixtures of highly refined mineral oils and synthetic fluids). The choice of a finished lubricant depends on many factors including viscosity, viscosity index, pour point, additives, and overall lubrication costs. Site specific operating conditions, wind turbine performance, cold start and operating temperature within the nacelle as well as serviceability influence the selection of the most cost-effective gearbox lubricant.

5.2 Lubricant characteristics

5.2.1 General

Most large modern wind turbines are equipped with multistage gearboxes that convert the low rotor speed to high generator speed for high efficiency. Ideally, each stage of the gearbox would benefit from a different oil viscosity, but this is not practical. Additionally, the gears and bearings in each stage would benefit from different performance chemicals such as higher antiscuff (also known as extreme pressure (EP)) levels and higher antiwear at the input stages. Oxidation stability is important because of the potential risk of deposit formation such as varnish and sludge that can clog filters, small oil passages and oil spray nozzles, as well as create deposit on critical surfaces. Using multiple additives with different characteristics can have synergistic or antagonistic effects. Therefore, it is common to make some compromise in the choice of additives and final lubricant characteristics.

The key functions of the lubricant are to minimize friction and wear between surfaces in relative motion, to remove heat generated by the mechanical action of the system and to protect internal parts of the gearbox against corrosion. Sufficient viscosity to separate the mating surfaces as well as appropriate chemical additive systems can help to accomplish these tasks and minimize thermal and oxidative degradation and promote antiwear performance.

The choice of the appropriate lubricant depends in part on matching its properties to the application. Therefore, a detailed elastohydrodynamic analysis of the gearbox components with reference to ISO/TS 6336-20, ISO/TS 6336-21, ISO/TS 6336-22 and ISO 281 has proven useful.

The following design- or operating characteristics can, amongst others, influence lubricant:

- the type of gearing used in the gearbox;
- selected operating conditions, such as:
  - ambient temperature range;
  - operating temperature range;
  - operating speed range;
- any critical special circumstances, such as:
  - low temperature start-up;
  - ambient temperatures above 50 °C;
  - high transient loads.

5.2.2 Viscosity

Viscosity is the most important physical property of a lubricant, and it has a direct impact on gearbox performance and its service life. It is the property of a lubricating oil to resist against flow and contributes to the development of a protective lubricating film.

5.2.3 Viscosity grade

IEC 61400-4 specifies that the correct viscosity grade of the lubricating oil for a gearbox is selected based on operating, not start-up, conditions. The viscosity grade in the context of this document is the kinematic viscosity grade, ISO VG, according to ISO 3448.

Additional operating parameters of importance are the viscosity index of the oil, the viscosity ratio for rolling bearings and the pitch line velocity of the gears.

If the viscosity of the lubricating oil is too low, the application can suffer from wear. Too high viscosity can cause excessive losses which can lead to temperature increase, resulting in a decreased lifetime of the lubricant. Furthermore, too high viscosity can lead to oil starvation when the oil is cold, e.g. during start-up conditions. Where there is a large difference between the input and output shaft speeds (as in typical multistage wind turbine gearboxes), it is beneficial to base the viscosity grade on the low-speed input gear to ensure development of an adequate lubricant film.

General information on viscosity grade can be found in ISO/TR 18792. The most common viscosity grade used in wind turbine gearboxes is ISO VG320, but other grades between ISO VG220 and ISO VG460 are also in use.

5.2.4 Low temperature characteristics

Sufficient lubricant flow to all gear and bearing contacts at the coldest start-up temperature can help to avoid starvation which could lead to premature damage. There are no published low temperature requirements for ISO viscosity grades for wind or industrial applications. Oils with viscosity grade ISO VG320 (ISO 3448) can cope with the typical ambient temperature ranges in wind turbine applications, if the chosen oils provide a sufficiently low pour point.

NOTE The pour point of oils used in wind turbine gearboxes is typically significantly below the maximum value specified in ISO 12925-1 for CKMSP lubricants.

Heaters (see 6.6) can be used to adjust sump temperature at start-up. VDMA 23901 provides additional information regarding cold weather applications.

5.2.5 Performance characteristics

The minimum requirements for gear oils are defined in IEC 61400-4. In addition, as part of the lubricant selection process, the oil typically satisfies additional selected performance characteristics to improve long-term reliability of the gearbox. This is primarily a function of the chemical additive system used in the lubricant. Additives are essential for fulfilling predicted gearbox design life. Some additives are surface active substances that protect the surface from specific damage types by building chemical and/or physical reaction layers. However, surface size and reactivity are limited and can be considered when selecting additional performance characteristics. For example, measures to increase wear protection can lead to a lower level of corrosion protection and vice versa. Likewise, measures to improve paint compatibility can decrease the seal compatibility.

Evaluation of the following characteristics has proven useful to predict lubricant performance in wind turbine gearboxes:

– gear scuffing;
– gear micropitting;
– bearing wear and bearing fatigue in mixed friction regime;
– oxidation of oil;
– corrosion protection (ferrous and non-ferrous);
– foaming and air release;
– filterability;
– shear stability;
– compatibility with materials (ferrous and non-ferrous metals, elastomers, seals, gaskets, sealants, paints and coatings, adhesives or plastics);
– compatibility with auxiliary components (e.g. filter media, desiccant used in breather vent devices, electronic sensors, or connectors);
– compatibility with utilities such as run-in oils or corrosion preservatives.

Acceptance of lubricant performance is commonly based on results from standardized test methods. For some critical performance characteristics, no standardized test methods exist at date of publication of this document. Test methods with documented data for repeatability and reproducibility are preferable.

Table 1 and Table 2 summarize an exemplary and non-exhaustive set of commonly used standardized and non-standardized test methods and typical performance levels with relevance for wind turbine gearboxes.

NOTE For elastomer and paint compatibility, the table provides example values since various materials can be used.

Wind turbines are one of the bearing applications where early premature failures associated with white etching cracks are observed. IEC 61400-4 discusses potential causes and possible means to reduce the risk of occurrence. Lubricant interaction is a potential contributor to the failure mode. However, at the time of publication of this document, there are no test methods for lubricants which predict the risk of this failure mode, and where test results correlate consistently with field experience.

Regardless of the method chosen to determine specific lubricant performance, it can be useful to compare the results with those obtained with a reference oil, preferably one with a positive field service history.

It has proven useful to demonstrate lubricant performance by field experience of at least 1 to 2 years.

Table 1 – Standardized test methods for evaluating wind turbine lubricants

Property	Procedure name	Test method	Test conditions	Typical performance characteristics
Gear – adhesive wear (scuffing)	FZG scuffing test	ISO 14635-1	A/8,3/90 A/8,3/60 (additional)	Fail load stage ≥ 14 [a]
			Alternatively: A/16,6/90 [a]	Fail load stage ≥ 12
			Additional: A/8,3/60 bearing Mdf [a]	Fail load stage ≥ 12
Bearing - antiwear protection under extreme mixed friction	FE8 [d]	DIN 51819-3	D-7,5/100-80 7,5 r/min; 100 kN 80 h: 80 °C	Roller wear: m_{w50} ≤ 30 mg [c] No microspalled areas according to ISO 15243
Bearing - fatigue under moderate mixed friction	FE8 [e]	DIN 51819-3	D-75/90-70 75 r/min 90 kN 800 h 70 °C [a]	Roller wear: m_{w50} ≤ 30 mg [c] No surface damages
Gear micropitting	FZG micropitting test	DIN 3990-16	GT-C/8,3 /90	Failure load stage ≥ 10 and GFT-high
			GT-C/8,3/60	Failure load stage ≥ 10 and GFT-high
Shear stability	Tapered roller bearing shear test	ISO 26422	20 h, 60 °C, 5 000 N	Stay in ISO VG class
Static elastomer compatibility [b, c]		ISO 1817	Example: duration for PAO-oils: 1 008 h Example: temperature for nitrile butadiene rubber (NBR) elastomers: 95 °C Example: temperature for fluorocarbon-based elastomers: 120 °C Example: temperature for hydrogenated nitrile butadiene rubber (HNBR) elastomers: 120 °C	Volume change −5 % to +9 % Hardness change ± 10 % Elongation change < 50 % Tensile strength change < 60 %

Property	Procedure name	Test method	Test conditions	Typical performance characteristics
Compatibility of paint system [b] (consisting of primers and top coat)	Hardness testing For film thickness up to 250 µm: cross-cut testing For film thickness larger than: 250 µm: pull-off testing	ISO 1522 ISO 2409 ISO 2812-1 ISO 2812-3 ISO 16276-1 ISO 16276-2	Example for test duration: – 168 h for primers – 504 h for top coat Example for test temperatures: – 95 °C for mineral oils; – 130 °C for synthetic oils	Visual inspection: No blistering Cross-cut ≤ 1 Pull-off force > 5 MPa
Compatibility of adhesives and sealants [b]	Static immersion test	ISO 10123 ISO 4587	672 h at 80 °C	To be specified dependent on product type (different for adhesives and sealants)
Foaming	Flender foam test	ISO 12152	25 °C	≤ 15 % after 1 min, ≤ 10 % after 5 min
			40 °C	≤ 13 % after 1 min, ≤ 9 % after 5 min
			60 °C	≤ 10 % after 1 min, ≤ 7 % after 5 min
Copper Corrosion [b]		ISO 2160	Example: 100 °C, 24 h	Max. 2
Filter element compatibility [b, f]	Collapse burst rating	ISO 2943	According to ISO 2943	According to ISO 2943

[a] Modified test conditions.

[b] To address the needs of the specific applications and/or wind turbine manufacturer requirements, the methods, performance characteristics and test conditions can be modified considering the lubricant and the material type. The choice of test temperature is dependent upon the stability of the material and/or the stability of the oil.

[c] To address specific end user applications, the method can vary depending on the elastomer in use.

[d] Sometimes referred to as Schaeffler wind energy 4 stage test stage 1 found in Schaeffler TPI 176.

[e] Sometimes referred to as Schaeffler wind energy 4 stage test stage 2 found in Schaeffler TPI 176.

[f] This test is typically executed once for a family of filter elements using the same filter media and other materials.

Table 2 – Non-standardized test methods for lubricant performance

Property	Procedure name	Test method	Test conditions	Typical performance characteristics
Corrosion (non-ferrous)	SKF Emcor	ISO 11007 [a]	Distilled water	Rating max. 1
			Salt water (0,5 % NaCl)	Rating max. 2
Bearing - additive reactions under EHD conditions	Schaeffler wind energy 4 stage test, stage 3	Schaeffler wind energy stage 3 on L11 test rig [b]	Test bearing: 6 206 Test speed: 9 000 r/min Test load: 8,5 kN Run time: 700 h No temperature control	$L_{50} \geq 550$ h
Bearing - oil behaviour at increased temperature and with addition of water	Schaeffler wind energy 4 stage test, stage 4	Schaeffler wind energy stage 4 on FE8 test rig [b]	Test bearing: 81 212 MPB Test speed: 750 r/min Test load: 60 kN Run time: >600 h Preheating system/ water / Temperature control: 100 °C	Filter blocking < 2 Roller wear < 30 mg Fatigue damage: no Residue at bearing: moderate/heavy Residue at preheat system: moderate/heavy
Chemical and thermal stability	SKF roller test	SKF	8 weeks at 100 °C	Corrosion attack max. 2 Viscosity change max 10 % No sludge No incrustation
Filterability	Multi-pass with oil analysis and foam test	CC Jensen HYDAC multi-pass HN 30-08	Filter the oil in a test rig through the filter 100 to 10 000 times	Foam same as fresh oil Additive change – define % Define secondary additive % change
Filterability	Single-pass	HYDAC single-pass HN 30-04 (ISO 13357-2 [a])	Application filter media	Filterability index: – ≥ 80 % for stage 1 – ≥ 60 % for stage 2.

[a] Modified test conditions.

[b] Information on Schaeffler wind energy 4 stage test can be found in Schaeffler TPI 176.