



BSI Standards Publication

Wind energy generation systems

Part 8: Design of wind turbine structural components

National foreword

This British Standard is the UK implementation of EN IEC 61400-8:2024. It is identical to IEC 61400-8:2024.

The UK participation in its preparation was entrusted to Technical Committee PEL/88, Wind turbines.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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structural components
(IEC 61400-8:2024)

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Conception des composants structurels des éoliennes
(IEC 61400-8:2024)

Windenergieanlagen - Teil 8: Design von
Windenergieanlagen-Strukturkomponenten
(IEC 61400-8:2024)

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Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

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- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2025-05-07
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2027-08-07

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Endorsement notice

The text of the International Standard IEC 61400-8:2024 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standard indicated:

ISO 12944-5:2019 NOTE Approved as EN ISO 12944-5:2019 (not modified)

ISO 1461:2022 NOTE Approved as EN ISO 1461:2022 (not modified)

ISO 14713-1:2017 NOTE Approved as EN ISO 14713-1:2017 (not modified)

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cencenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61400-1	2019	Wind energy generation systems - Part 1: Design requirements	EN IEC 61400-1	2019
IEC 61400-3-1	2019	Wind energy generation systems - Part 3-1: Design requirements for fixed offshore wind turbines	EN IEC 61400-3-1	2019
-	-		+ A11	2020
IEC/TS 61400-3-2	2019	Wind energy generation systems - Part 3-2: Design requirements for floating offshore wind turbines	⁻¹	-
IEC 61400-5	2020	Wind energy generation systems - Part 5: Wind turbine blades	EN IEC 61400-5	2020
IEC 61400-6	2020	Wind energy generation systems - Part 6: Tower and foundation design requirements	EN IEC 61400-6	2020
IEC 61400-13	2015	Wind turbines - Part 13: Measurement of mechanical loads	EN 61400-13	2016
ISO/IEC 17025	2017	General requirements for the competence of testing and calibration laboratories	EN ISO/IEC 17025	2017
ISO 148-1	2016	Metallic materials - Charpy pendulum impact test - Part 1: Test method	EN ISO 148-1	2016
ISO 945-1	2019	Microstructure of cast irons - Part 1: Graphite classification by visual analysis	EN ISO 945-1	2019
ISO 1083	2018	Spheroidal graphite cast irons - Classification	-	-
ISO 1099	2017	Metallic materials - Fatigue testing - Axial force-controlled method	-	-
ISO 1143	2021	Metallic materials - Rotating bar bending fatigue testing	-	-

¹ To be published. Stage at time of publication: FprEN IEC 61400-3-2:2024.

EN IEC 61400-8:2024 (E)

ISO 2394	2015	General principles on reliability for structures	-	-
ISO 3800	1993	Threaded fasteners; axial load fatigue testing; test methods and evaluation of results	-	-
ISO 6892-1	2019	Metallic materials - Tensile testing - Part 1: Method of test at room temperature	EN ISO 6892-1	2019
ISO 7500-1	2018	Metallic materials - Calibration and verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Calibration and verification of the force-measuring system	EN ISO 7500-1	2018
ISO 12107	2012	Metallic materials - Fatigue testing - Statistical planning and analysis of data	-	-
ISO 12108	2018	Metallic materials - Fatigue testing - Fatigue crack growth method	-	-
ISO 12135	2021	Metallic materials - Unified method of test for the determination of quasistatic fracture toughness	-	-
ISO/TR 14345	2012	Fatigue - Fatigue testing of welded components - Guidance	-	-
ISO 16269-6	2014	Statistical interpretation of data - Part 6: Determination of statistical tolerance intervals	-	-
ASTM-E466-21	2021	Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials	-	-
BS 7910	2013	Guide to methods for assessing the acceptability of flaws in metallic structures	-	-
-	-	Personal fall protection equipment - Anchor devices - Recommendations for anchor devices for use by more than one person simultaneously	AnchorCEN/TS 16415	2013
-	-	Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures	EN 1090-2	2018
-	-	Execution of steel structures and aluminium structures - Part 3: Technical requirements for aluminium structures	EN 1090-3	2019
-	-	Founding - Magnetic particle testing	EN 1369	2012
-	-	Founding - Magnetic particle inspection	EN 1369	1996
-	-	Founding - Liquid penetrant testing - Part 1: Sand, gravity die and low pressure die castings	EN 1371-1	2011
-	-	Founding - Liquid penetrant inspection - Part 1: Sand, gravity die and low pressure die castings	EN 1371-1	1997
-	-	Eurocode 3: Design of steel structures - Part 1-8: Design of joints	EN 1993-1-8	2007

-	-	Eurocode 3: Design of steel structures - Part 1-9: Fatigue	EN 1993-1-9	2007
-	-	Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through-thickness properties	EN 1993-1-10	2007
-	-	Eurocode 9: Design of aluminium structures - Part 1-1: General structural rule	EN 1991-1-1	2008
-	-	Eurocode 9: Design of aluminium structures - Part 1-3: Structures susceptible to fatigue	EN 1999-1-3	2007
-	-	Ultrasonic examination - Part 3: Spheroidal graphite cast iron castings	EN 12680-3	2011
-	-	Wind turbines - Protective measures - Requirements for design, operation and maintenance	EN 50308	2004
DIN 50100	2016	Load controlled fatigue testing - Execution and evaluation of cyclic tests at constant load amplitudes on metallic specimens and components	-	-
FKM Guideline	2018	Fracture Mechanics Proof of Strength for Engineering Components (FKM – RBM-04-18)	-	-
IIW-Doc. 2259-152259-15	2014	Recommendations for fatigue design of welded joints and components, International Institute of Welding	-	-
IIW-Doc. XIII-2240r2-08/XV-1289r2-08	2010	Guideline for the Fatigue Assessment by Notch Stress Analysis for Welded Structures	-	-
VDI 2230-1	2015	Systematic calculation of highly stressed bolted joints - Joints with one cylindrical bolt	-	-
VDI 2230-2	2014	Systematic calculation of high duty bolted joints - Joints with several cylindrical bolts	-	-
VDMA 23902	2014	Guideline for fracture mechanical strength assessment of planet carriers made of nodular cast iron EN-GJS-700-2 for wind turbine gear boxes, Verband Deutscher Maschinen- und Anlagenbau e.V.	-	-

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms, definitions, symbols and abbreviated terms.....	10
3.1 Terms and definitions.....	10
3.2 Symbols and abbreviated terms	12
4 Reliability considerations	14
4.1 Approaches to reliability based design	14
4.2 Models and basic variables for structural verification	16
4.2.1 Reliability assessment	16
4.2.2 Material properties.....	16
4.3 Partial safety factors and reliability targets.....	16
5 Application of loads and analysis models.....	17
5.1 Loads models	17
5.2 Analysis model.....	17
5.2.1 General	17
5.2.2 Load path modelling	17
5.2.3 Application of load components	17
5.2.4 Boundary conditions	18
5.3 Modelling of nonlinear mechanical behaviour	18
5.3.1 General	18
5.3.2 Nonlinear stress effects	18
5.3.3 Application of ultimate loads	18
5.3.4 Application of fatigue loads.....	18
5.4 Partial safety factors	19
5.5 Partial safety factor for resistance.....	21
5.6 Nacelle and hub component considerations	22
5.6.1 General	22
5.6.2 Hub structure and bolts.....	22
5.6.3 Nacelle front structure (alternatively: mechanical drive-train structure)	23
5.6.4 Gearbox structure.....	23
5.6.5 Yaw structure	23
5.6.6 Nacelle rear structure	24
5.6.7 Nacelle cover and spinner	24
6 Deflection analysis	24
7 Strength verification.....	25
7.1 General.....	25
7.2 Determination of stress and strain.....	25
7.3 Material properties	25
7.3.1 Material data	25
7.3.2 Influence of size	26
7.4 Static strength assessment	26
7.4.1 Assessment process.....	26
7.4.2 Cast, forged and steel components.....	26
7.4.3 Welded structures.....	26

7.4.4	Bolted joints.....	28
7.4.5	Fibre reinforced material.....	29
7.5	Fatigue strength assessment	29
7.5.1	Fatigue strength methods	29
7.5.2	Determination of local stresses	29
7.5.3	Stress hypothesis for fatigue	29
7.5.4	S/N curves.....	30
7.5.5	Influence on fatigue strength	30
7.5.6	Partial safety factors for fatigue	31
7.5.7	Damage accumulation	32
7.5.8	Bolted joints.....	33
7.5.9	Fibre reinforced material.....	33
7.6	Fracture mechanics assessment.....	33
7.6.1	General	33
7.6.2	Define objective.....	34
7.6.3	Material parameter	34
7.6.4	Defect model	35
7.6.5	Structural model	36
7.6.6	Loading	36
7.6.7	Strength assessment	37
7.7	Fracture mechanics-based design.....	40
8	Material data for design from testing.....	41
8.1	Qualification of material	41
8.2	Derivation of static strength and impact energy properties (base material).....	41
8.3	Derivation of fatigue strength properties (base material)	41
8.4	Welded joints	42
8.5	Cast, forged and steel.....	42
8.5.1	Derivation of static strength properties.....	42
8.5.2	Fracture toughness.....	42
8.5.3	Derivation of fatigue strength properties	43
8.6	Bolts	44
8.7	Nacelle cover	44
9	Model verification and validation.....	44
Annex A (informative)	Model verification and validation methods	46
A.1	General.....	46
A.2	Verification.....	46
A.3	Validation (laboratory testing)	46
A.4	Validation (field testing)	46
Annex B (informative)	Welded joint stresses	47
Annex C (informative)	S-N curve determination by test, statistical evaluation and influencing factors.....	48
C.1	General.....	48
C.2	S-N curve.....	48
C.3	Specimens	48
C.4	Test procedure.....	48
C.4.1	General	48
C.4.2	Finite lifetime	49
C.4.3	Long life fatigue regime	49

C.5	Influencing factors of S-N curve	49
Annex D (informative)	Limit state equations	50
D.1	General.....	50
D.2	Yielding failure.....	50
D.3	Fatigue limit state equation	51
D.4	Fatigue assessment based on fracture mechanics	55
Annex E (informative)	Load effect uncertainty computation	58
Annex F (informative)	Considerations for structural elements.....	60
F.1	General.....	60
F.2	Global and local failures	60
F.3	Mean stress influence	61
Bibliography		63
Figure 1	– Illustration of a nacelle structure, where for example a direct drive generator is mounted behind the hub	22
Figure 2	– Idealized elastic plastic stress-strain curve	27
Figure 3	– Representative S /N curve	30
Figure 4	– Fracture mechanics calculation – process flow chart	34
Figure 5	– Idealized crack types	35
Figure 6	– Failure assessment diagram (FAD)	37
Figure 7	– Crack growth under cyclic loading by Paris/Erdogan	39
Figure 8	– Crack propagation and critical crack length in failure assessment diagram.....	40
Figure B.1	– Fatigue analysis procedure for the weld toe	47
Figure D.1	– Haigh diagram with R_e as the yield stress and R_m as the tensile limit	53
Figure E.1	– Model example	58
Figure F.1	– Locations of failure for local (A) and global (B) failure	60
Figure F.2	– Local and global failure for two different notch radii	61
Figure F.3	– Haigh-diagram for evaluation of mean stress influence	61
Table 1	– Component classes as in IEC 61400-1:2019	17
Table 2	– List of potential sources for modelling deviations.....	20
Table 3	– Modelling partial safety factor $\gamma_{\text{modelling}}$: yielding where coefficient of variation of yield strength is less than 15 %.....	20
Table 4	– Modelling partial safety factor, $\gamma_{\text{modelling}}$: fatigue of welded details and cast iron	21
Table 5	– Minimum resistance partial safety factors, γ_M , for welded steel for different survival probabilities of the characteristic S-N curve	21
Table 6	– Minimum resistance partial safety factors γ_M , for cast iron, forged and steel components (if not utilizing relevant design standards such as EN 1993-1-9) for different survival probabilities of the characteristic S-N curve.....	21
Table 7	– Partial safety factors γ_M for S/N-curves of cast iron materials.....	32
Table D.1	– Representative stochastic model for fatigue analysis of cast iron	55
Table E.1	– Test cases combination.....	58
Table E.2	– Result comparison validation vs simplified models and ratio δ_{mf} calculation	59

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND ENERGY GENERATION SYSTEMS –

Part 8: Design of wind turbine structural components

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.
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IEC 61400-8 has been prepared by IEC technical committee 88: Wind energy generation systems. It is an International Standard.

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

Draft	Report on voting
88/1010/FDIS	88/1023/RVD

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 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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This part of the IEC 61400 series outlines the minimum requirements for the design of wind turbine nacelle-based structures and is not intended for use as a complete design specification or instruction manual.

Several different groups can be responsible for undertaking the various elements of the design, manufacture, assembly, installation and maintenance of a wind turbine nacelle and for ensuring that the requirements of this document are met. The division of responsibilities between these parties is a contractual matter and is outside the scope of this document.

The requirements stated in this document may be altered if it can be sufficiently demonstrated that the structural integrity of the system is not compromised.

The specific scope of the document is provided in Clause 1. For cases out of the scope of this document, reference should be made to relevant IEC/ISO standards.

WIND ENERGY GENERATION SYSTEMS –

Part 8: Design of wind turbine structural components

1 Scope

This part of IEC 61400 outlines the minimum requirements for the design of wind turbine nacelle-based structures and is not intended for use as a complete design specification or instruction manual. This document focuses on the structural integrity of the structural components constituted within and in the vicinity of the nacelle, including the hub, mainframe, main shaft, associated structures of direct-drives, gearbox structures, yaw structural connection, nacelle enclosure. It also addresses connections of the structural components to control and protection mechanisms, as well as structural connections of electrical units and other mechanical systems. This document focuses primarily on ferrous material-based nacelle structures but can apply to other materials also as appropriate. The design of bolted and welded joints in the nacelle structures is included, as well as cast and forged components. Material testing requirements to use in the design process for nacelle structures are specified. While the structural connections of the gearbox and the main shaft are in the scope, the design of the gears and bearings are not included.

The safety level of the wind turbine designed according to this document shall be at or exceed the level inherent in IEC 61400-1:2019. Probabilistic methods to calibrate partial safety factors and for use in the design process are provided.

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 61400-3-1:2019, *Wind energy generation systems – Part 3: Design requirements for fixed offshore wind turbines*

IEC TS 61400-3-2:2019, *Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines*

IEC 61400-5:2020, *Wind energy generation systems – Part 5: Wind turbine blades*

IEC 61400-6:2020, *Wind energy generation systems – Part 6: Tower and foundation design requirements*

IEC 61400-13:2015, *Wind turbines – Part 13: Measurement of mechanical loads*

ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

ISO 148-1:2016, *Metallic materials – Charpy pendulum impact test – Part 1: Test method*

ISO 945-1:2019, *Microstructure of cast irons – Part 1: Graphite classification by visual analysis*

ISO 1083:2018, *Spheroidal graphite cast irons – Classification*

ISO 1099:2017, *Metallic materials – Fatigue testing – Axial force-controlled method*

ISO 1143:2021, *Metallic materials – Rotating bar bending fatigue testing*

ISO 2394:2015, *General principles on reliability for structures*

ISO 3800:1993, *Threaded fasteners – Axial load fatigue testing – Test methods and evaluation of results*

ISO 6892-1:2019, *Metallic materials – Tensile testing – Part 1: Method of test at room temperature*

ISO 7500-1:2018, *Metallic materials – Calibration and verification of static uniaxial testing machines – Part 1: Tension/compression testing machines – Calibration and verification of the force-measuring system*

ISO 12107:2012, *Metallic materials – Fatigue testing – Statistical planning and analysis of data*

ISO 12108:2018, *Metallic materials – Fatigue testing – Fatigue crack growth method*

ISO 12135:2021, *Metallic materials – Unified method of test for the determination of quasistatic fracture toughness*

ISO/TR 14345:2012, *Fatigue – Fatigue testing of welded components – Guidance*

ISO 16269-6:2014, *Statistical interpretation of data – Part 6: Determination of statistical tolerance intervals*

ASTM-E466-21:2021, *Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials*

BS 7910:2013, *Guide to methods for assessing the acceptability of flaws in metallic structures*

CEN/TS 16415:2013, *Personal fall protection equipment – Anchor devices – Recommendations for anchor devices for use by more than one person simultaneously*

EN 1090-2:2018, *Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures*

EN 1090-3:2019, *Execution of steel structures and aluminium structures – Part 3: Technical requirements for aluminium structures*

EN 1369:2012, *Founding – Magnetic particle testing*

EN 1369:1996, *Founding – Magnetic particle inspection*

EN 1371-1:2011, *Founding – Liquid penetrant testing – Part 1: Sand, gravity die and low pressure die castings*

EN 1371-1:1997, *Founding – Liquid penetrant inspection – Part 1: Sand, gravity die and low pressure die castings*

EN 1993-1-8:2007, *Eurocode 3: Design of steel structures – Part 1-8: Design of joints*

EN 1993-1-9:2007, *Eurocode 3: Design of steel structures – Part 1-9: Fatigue*

EN 1993-1-10:2007, *Eurocode 3: Design of steel structures – Part 1-10: Material toughness and through-thickness properties*

EN 1999-1-1:2008, *Eurocode 9: Design of aluminium structures – Part 1-1: General structural rule*

EN 1999-1-3:2007, *Eurocode 9: Design of aluminium structures – Part 1-3: Structures susceptible to fatigue*

EN 12680-3:2011, *Ultrasonic examination – Part 3: Spheroidal graphite cast iron castings*

EN 50308:2004, *Wind turbines – Protective measures – Requirements for design, operation and maintenance*

DIN 50100:2016, *Load controlled fatigue testing – Execution and evaluation of cyclic tests at constant load amplitudes on metallic specimens and components*

FKM Guideline, *Fracture Mechanics Proof of Strength for Engineering Components, 2018 (FKM – RBM-04-18)*

IIW-Doc. 2259-152259-15, *Hobbacher A., Recommendations for fatigue design of welded joints and components, International Institute of Welding, 2014*

IIW-Doc. XIII-2240r2-08/XV-1289r2-08, *Fricke W., Guideline for the Fatigue Assessment by Notch Stress Analysis for Welded Structures, 2010*

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

VDI 2230-2:2014, *Systematic calculation of high duty bolted joints – Joints with several cylindrical bolts*

VDMA 23902:2014, *Guideline for fracture mechanical strength assessment of planet carriers made of nodular cast iron EN-GJS-700-2 for wind turbine gear boxes, Verband Deutscher Maschinen- und Anlagenbau e.V.*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Terms and definitions

3.1.1

basquin equation

power law representation of S-N curves

3.1.2**component capacity**

maximum static stress the component can withstand

3.1.3**damage equivalent load**

equivalent constant range load

load which when repeated a certain number of cycles, causes the same amount of damage as the original combination of several loads and cycles

3.1.4**defect model**

model which is used to substitute the geometrical dimensions of an idealized defect type

3.1.5**design life**

minimum intended life of the structure, as used in the design process that the structure shall survive under fatigue

3.1.6**design load**

mechanical loads whether dynamic or static that the structure shall withstand in its design life

3.1.7**failure assessment diagram****FAD**

diagram which is used to check if there is any risk of brittle failure or plastic collapse while performing a fracture mechanic strength assessment

3.1.8**fail-safe**

design property of a structure or system which prevents its failure

3.1.9**global stresses**

stresses in terms of nominal stresses which are applicable for simple continuous structures (e.g. beams, shells, plates), where the stress can be derived out of sectional forces by analytical methods

Note 1 to entry: Notch factors may need to be considered.

3.1.10**impact energy**

energy absorbed/required to break a V-notched test sample on pendulum impact testing machine

3.1.11**limit state**

state of a structure beyond which it no longer satisfies the design requirements

3.1.12**local stresses**

local stress analysis points at specific regions of a global structure (e.g. at radii, notches) with consideration of the notch shape

3.1.13**mode I**

failure mode I

crack opening mode (in tensile direction) in accordance with FKM Guideline of fracture mechanics or BS 7910

3.1.14**Paris-Erdogan equation**

equation used to compute the cyclic crack growth behaviour

3.1.15**primary structures**

structures which are in the main force flow of the nacelle structure (e.g. the planet carrier of the gearbox)

3.1.16**S-N curve**

relation between the number of stress cycles a material can undergo before failure

3.1.17**safe-life**

design life period of a system after which it should be removed from service

3.1.18**secondary structures**

structures which are not in the main force flow of the nacelle structure (e.g. the housing of the gearbox)

3.1.19**structural model**

model oriented to the shape and dimensions of the defect surrounding structure

3.2 Symbols and abbreviated terms

COV	coefficient of variation
EPFM	elastic plastic fracture mechanics
FAD	failure assessment diagram
FE	finite element
FEA	finite element analysis
LEFM	linear elastic fracture mechanics
LRF_f	load reserve factor against fatigue load
LRF_u	load reserve factor against ultimate load
LRF_{full}	load reserve factor with the full detailed model
$LRF_{simplified}$	load reserve factor with the simplified model
LSE	limit state equation
PSF	partial safety factor
$M_{\delta mf}$	mean value of δmf
RNA	rotor nacelle assembly (herein used without inclusion of blades)
S/N	stress cycle curve for fatigue of materials

a	depth of surface cracks, half depth of embedded cracks/ continuous embedded cracks	mm
a_0	initial crack length	mm
a_{crit}	critical crack length/limiting crack depth	mm
a_{end}	calculated crack length after calculated lifetime	mm
A	elongation at fracture	%
c	half crack length of surface and embedded cracks	mm
C	constant value in crack growth law, e.g. Paris-Erdogan equation	
da/dN	crack growth rate per load cycle	mm/load cycle
D	accumulated damage	-
E	modulus of elasticity (Young's modulus)	MPa
h	location of the crack in the depth direction	mm
L_r	FAD parameter, ratio of applied load to plastic limit load	-
J	J-Integral	kJ/m ² , N/mm
K	stress intensity factor	Mpa·m ^{0,5}
K_C	fracture toughness	Mpa·m ^{0,5}
K_I	stress intensity factor for crack opening mode I (tensile mode)	Mpa·m ^{0,5}
K_{IC}	fracture toughness for crack opening mode I (tensile mode)	Mpa·m ^{0,5}
K_r	FAD parameter, ratio of applied SIF to fracture toughness K_{mat}	Mpa·m ^{0,5}
K_{mat}	characteristic value of fracture toughness	Mpa·m ^{0,5}
K_v	impact energy	Joule, Nm
m	slope of S/N curve	-
M	mean stress sensitivity	-
n	exponent in crack growth law according to Paris-Erdogan equation	-
n_i	counted number of fatigue cycles in load bin i	-
N_D	number of cycles at knee in characteristic stress-life curve for test specimens, from constant amplitude tests	-
N_i	endurable number of cycles at the i^{th} load level, derived from the S/N curve	-
R	stress ratio	-
$R_{p0,2}$	yield strength	MPa
$V_{\delta_{\text{mf}}}$	coefficient of variation of δ_{mf}	
t	thickness of defect model	mm
Z	reduction of area at fracture	mm ²
γ_f	partial safety factor for loads	-
γ_n	consequence of failure factor	-
γ_M	partial safety factor accounting for uncertainties in the material parameters and resistance models	-
$\gamma_{\text{modelling}}$	partial safety factor accounting for simplifications in the load effect model	-

γ_{mt}	product of partial safety factors of $\gamma_{modelling}$ and γ_M	
δ_{mf}	ratio of load reserve factor with full model to load reserve factor with simple model	
ΔK	cyclic stress intensity factor	MPa·m ^{0,5}
β^t	annual reliability index	
ΔK_{th}	threshold value under cyclic loading	MPa·m ^{0,5}
ε_{lim}	total strain limit	%
ρ	plasticity interaction factor	-
σ_a	amplitude of occurring stress cycle	MPa
σ_A	design fatigue strength of component at N_D cycles	MPa
$\sigma_{A,R}$	value of σ_A relevant to loading cycles with minimum/maximum ratio R	MPa
σ_I	relevant stress for crack opening mode I (tensile mode)	MPa
σ_D	endurance limit at knee point of the constant amplitude S/N curve	MPa
σ_{lim}	component capacity (e.g. yield strength, tensile strength) in terms of limiting stress level	MPa
σ_m	mean stress	MPa
σ_L	component stress (e.g. von Mises equivalent stress, first principal stress)	MPa
σ_{ref}	net section stress	MPa
σ_Y	yield strength of the material	MPa

4 Reliability considerations

4.1 Approaches to reliability based design

Structures comprising the nacelle and hub components shall fulfil a set of requirements related to functionality, sustainability and integrity under normal and abnormal events. In addition, the RNA structure should fulfil a certain level of reliability balancing cost (amount of structure) and the risk of failure (likelihood of a critical failure). This is conducted through structural reliability assessments of models established for different limit state functions.

The RNA structure shall be evaluated for the limit states given in IEC 61400-1:2019 (7.6.1.1) and the structural analysis and reliability assessment shall be based on ISO 2394 and IEC 61400-1:2019, 7.1. For completeness, the limit states as described in IEC 61400-1:2019 are given below:

- analysis for ultimate strength,
- analysis for fatigue failure,
- stability analysis (e.g. buckling),
- critical deflection analysis.

Further elaboration of these limit states can be found in ISO 2394.

Three approaches for structural design assessment may be implemented as stated in ISO 2394:

- the risk informed approach,

- the reliability-based approach (probabilistic design),
- the semi-probabilistic approach (deterministic design).

Although all three approaches may be applied, wind turbine design including RNA design either follows the reliability-based -or semi-probabilistic approach. For semi-probabilistic approach, structural design standards shall be used i.e. IEC 61400-1:2019 or Eurocodes.

Reliability based assessment shall use uncertainty models which shall describe the structure and its behaviour, through which the design requirements of the structure are quantified, considering external relevant conditions. Those uncertainty models can be represented by stochastic variables or processes and a limit state approach to model the relevant failure scenarios.

Models may be simplified considering decisive factors and neglecting those factors with low impact, based on proper studies. Uncertainties quantification should follow the guidance given in ISO 2394 and IEC 61400-1:2019, Annex K.

The requirements for each LSE shall be consistent with the design equations following deterministic codes of practice as IEC 61400-1 or equations resulting from specific studies where response function of such components to different inputs are derived e.g. Petersen-Seidel (IEC 61400-6:2020) for bolt connections.

Limit state equations are built based on models describing the limit state for structural verification. A LSE with relevant basic parameters (X) is expressed as:

$$g(X) \leq 0 \quad (1)$$

where $g(X) < 0$ represents failure, in other words, an adverse state. Different forms of LSE can be found:

- those separated into one resistance function, $r(\alpha)$, and one load effect function, $s(\sigma)$, e.g. yielding limit, leading to the following expression form:

$$r(\alpha) - s(\sigma) \leq 0 \quad (2)$$

- those where a certain resistance-load effect function should comply to a given limit (ε), e.g. fatigue and Petersen-Seidel, leading to the following expression:

$$\varepsilon \pm f[r(\alpha), s(\sigma)] \leq 0 \quad (3)$$

These types of LSEs are specific to structural/component failure modes, where uncertainties related to resistance, load effect and models shall be defined.

Different LSEs for yielding and fatigue failure criteria are shown in Annex D.

RNA component reliability analysis shall follow the framework specified in ISO 2394:2015, 8.5. The following steps for component reliability analysis are recommended:

- 1) Select appropriate limit state function;
- 2) Specify appropriate time reference;
- 3) Identify basic variables and develop appropriate probabilistic models;
- 4) Compute reliability index and failure probability;
- 5) Perform sensitivity studies.

4.2 Models and basic variables for structural verification

4.2.1 Reliability assessment

Reliability assessment of RNA components shall consider calculation models describing its physical behaviour, which can be categorized as:

- actions and environmental influences,
- geometrical parameters,
- material and resistance properties, and
- active and passive control measures.

A description of each one of those physical behaviours and their models should follow those in ISO 2394.

4.2.2 Material properties

Material parameters shall be modelled by stochastic variables if a reliability-based approach is used and by characteristic/nominal values and partial safety factors if a semi-probabilistic approach is used for design. When a limit state verification is sensitive to the variability of a material property, the variability of the material property should be taken into account in a reliability assessment. Unless otherwise stated, where a low value of material or product property is unfavourable, the characteristic value should be defined as in IEC 61400-1:2019, Clause K.11.

If non-standardized material properties need to be used, then the material property values shall be determined from standardised tests performed under specified conditions, specifications of which are described in Clause 8.

4.3 Partial safety factors and reliability targets

In a semi-probabilistic approach, partial safety factors should follow those specified in recognized standards, which possess at least the reliability levels required in IEC 61400-1 or may be calibrated to a specific reliability level through a reliability-based approach i.e. as in IEC 61400-1:2019, Annex K or ISO 2394.

Target levels for reliability index β shall be based on annual failure probabilities. Different target reliability levels should be considered based on its component class classified as in Table 1. The maximum recommended annual probability of failure target for component class 2 is 5×10^{-4} ($\beta = 3,3$) as given in IEC 61400-1:2019. The annual target reliabilities for component class 3 and component class 1 may be obtained from ISO 2394.