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Part 23: Full-scale structural testing of rotor blades

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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UK Vote

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

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88/1018/RR

IEC TC 88 : WIND ENERGY GENERATION SYSTEMS

SECRETARIAT:

Denmark

SECRETARY:

Mrs Christine Weibøl Bertelsen

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC☐ ENVIRONMENT☐ QUALITY ASSURANCE☐ SAFETY

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Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "In Some Countries" clauses. (See [AC/22/2007](#) or new [GUIDANCE DOC](#)).

TITLE:

Wind energy generation systems – Part 23: Full-scale structural testing of rotor blades

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND ENERGY GENERATION SYSTEMS –

Part 23: Full-scale structural testing of rotor blades

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International Standard IEC 61400-23 has been prepared by IEC technical committee 88: Wind energy generation systems.

This second edition cancels and replaces IEC 61400-23 Edition 1.0, published in 2014. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC TS 61400-23 Ed 1.0:

- a) ...;Text will be updated before CDV stage
- b) ...;Text will be updated before CDV stage
- c)

The text of this document is based on the following documents:

Draft	Report on voting
-	-

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.

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,
- replaced by a revised edition, or
- amended.

1

INTRODUCTION

2

The blades of a wind turbine rotor are generally regarded as one of the most critical components of the wind turbine system. In this document, the demands for full-scale structural testing related to validation of the structural design and integrity of a rotor blade are defined as well as the interpretation and evaluation of test results.

5

6

Specific testing methods or set-ups for testing are not demanded or included as full-scale blade testing methods historically have developed independently in different countries and laboratories.

7

8

9

Furthermore, demands for tests determining blade properties are included in this document in order to validate some vital design assumptions used as inputs for the design load calculations.

10

11

Any of the requirements of this document may be altered if it can be suitably demonstrated that the safety of the system is not compromised.

12

13

This document is based on IEC 61400-23 Edition 1.0 published in 2014. Compared to the Ed. 1.0, this document is more detailed and describes more technical requirements and measurements.

14

15

WIND TURBINES ENERGY GENERATION SYSTEMS –

Part 23: Full-scale structural testing of rotor blades

1 Scope

This document defines the requirements for full-scale structural testing of wind turbine blades and for the interpretation and evaluation of achieved test results.

The document focuses on aspects of testing related to an evaluation of the integrity of the blade.

The following tests and measurements are specified in this document:

- static load tests
- fatigue load tests
- blade properties, including mass properties, eigenfrequency and structural damping
- lightning protection load test

It is assumed that the data required to define the parameters of the tests are available and based on the standard for design requirements for wind turbines such as IEC 61400-1, IEC 61400-5 or equivalent.

Specifications to use non-scaled full, partial or segment of blade for testing is described.

Requirements for structural testing of electrical components, including lightning protection systems, for mechanical performance, is described.

Requirements and options to use test performed on similar designs to validate a new or revised design is described. This includes evaluation of similarity and guidance note for how to deal with failure modes to be considered.

For existing and already tested design this includes requirements and guidance on load increase.

The scope of this document does not consider:

- leading edge erosion resistance
- coating testing
- ageing or environmental effects
- validation of material strength properties
- accuracy of the design loads.
- electric performance of lightning protection systems

This revision of the document is intended for testing rotor blades, for horizontal axis wind turbines, made of polymers reinforced with structural fibres and/or wooden sheets. However, most principles mentioned in this document will be transferable to any other wind turbine configuration and materials used in the rotor blade.

The test requirements are specified with the purpose to support the following objectives:

- Validate the design models by verification of the mass properties, the elastic properties, the strain distribution in the blade structure and the deformation of the blade or blade segment
- Verify that the blade structure can carry the design loads without structural failure
- Show at an acceptable level of probability that the rotor blade manufacturing process, relevant for the rotor blade structural strength, is suitable to assure structural integrity of the population of the rotor blade type tested by applying increased design loads
- Identify failure modes not covered by numerical analysis or other test

Additionally, tests determining blade properties have to be performed in order to validate some vital design assumptions used as inputs for the design load calculations.

The full-scale tests defined in this document are performed on a limited number of samples as only one blade of a given design are required for compliance. Statistical distribution of production blade load carrying capability can not be obtained.

Although the tests do give information valid for the blade type, they cannot replace either a rigorous design process or the quality system for series blade production.

Furthermore, the tests described in this document are not intended to be used for the testing of mechanism function nor to establish basic material strength or fatigue design data for blades and/or components.

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 60050-415:1999, *International Electrotechnical Vocabulary – Part 415: Wind turbine generator systems*

IEC 61400-1:2019, *Wind Energy Generation systems – Part 1: Design requirements*

IEC 61400-5:2020 *Wind turbines - Part 5: Rotor blades*

IEC 61400-13:2015 *Measurement of Mechanical Loads*

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

ISO 2394:1998, *General principles on reliability for structures*

ISO/IEC Guide 98-3:2008, *Guide to the Expression of Uncertainty in Measurement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-415 and the following apply.

3.1

actuator

device that can be controlled to apply a constant or varying force and displacement

3.2

applied test load

applied cross-sectional forces and moments calculated from the 'measured forces' during the test

3.3

applied test forces

measured external forces during the test

3.4

blade root

that part of the rotor blade that is connected to the hub of the rotor

3.5

blade subsystem

integrated set of items that accomplishes a defined objective or function within the blade (e.g., lightning protection subsystem, aerodynamic braking subsystem, monitoring subsystem, aerodynamic control subsystem, etc.)

3.6

buckling

instability characterized by a non-linear increase in out of plane deflection with a change in local compressive load

3.7

chord

length of a reference straight line that joins the leading and trailing edges of a blade aerofoil cross-section at a given spanwise location

3.8

constant amplitude loading

during a fatigue test, the application of load cycles with a constant amplitude and mean value

3.9

damage

in physical context: an unintended irreversible property changes of the test specimen

in analytical context: the summarized degradation of mechanical properties with respect to theoretical lifetime

3.10

design loads

loads the blade is designed to withstand, including appropriate partial safety factors

3.11

edgewise

direction that is parallel to the local chord. Refer to 4.4

3.12**Engineering Change (EC)**

a documented change to the design and or manufacturing.

3.13**fatigue formulation**

methodology by which the fatigue life is estimated

3.14**fatigue test**

test in which a cyclic load of constant or varying amplitude is applied to the test specimen

3.15**fixture**

component or device to introduce loads or to support the test specimen

3.16**flapwise**

direction that is perpendicular to the local chord, and spanwise blade axis. Refer to 4.4

Note 1 to entry: Guidance note: Instead of “flatwise” in the industry this direction is often named “flapwise”

3.17**flatwise**

direction that is perpendicular to the local chord, and spanwise blade axis. Refer to 4.4

Note 1 to entry: Guidance note: Instead of “flatwise” in the industry this direction is often named “flapwise”

3.18**full-scale test**

test carried out on the actual non-scaled rotor blade structure or part thereof.

3.19**inboard**

towards the blade root

3.20**lead-lag**

direction that is parallel to the plane of the swept surface and perpendicular to the longitudinal axis of the undeformed rotor blade. Refer to 4.4.

3.21**Limit states**

A limit state is a state of the structure and the loads acting upon it, beyond which the structure no longer satisfies the design requirements. For testing the limit state is defined where the structure will develop critical damage.

3.22**load envelope**

collection of maximum design loads in all directions and spanwise positions

3.23**natural frequency**

eigen frequency

frequency at which a structure will vibrate when perturbed and allowed to vibrate freely

3.24**partial safety factors**

factors that are applied to loads and material strengths to account for uncertainties in the representative (characteristic) values

3.25**planned test load**

cross-sectional forces and moments that are planned to be applied during a test

3.26**planned test forces**

external forces planned to be applied during the test to achieve the 'planned test load'

3.27**prebend**

blade curvature in the flapwise plane in the unloaded condition

3.28**R-value**

ratio between minimum and maximum value during a load cycle

3.29**Safety margin**

The additional margin between structural response from design loads and design resistance including all partial safety factors applied for load and resistance

3.30**S-N formulation**

method used to describe the stress and/or strain (S) vs. cycle (N) characteristics of a material, component or structure

3.31**Similarity**

The use of data from a tested blade where it can be demonstrated through a validated numerical model that the area is comparable in terms of materials, design and manufacturing.

3.32**spanwise**

direction parallel to the longitudinal axis of a rotor blade

3.33**static test**

test with an application of a single load cycle without introducing dynamic effects

3.34**stiffness**

ratio of change of force to the corresponding change in displacement of an elastic body

3.35**strain**

ratio of the elongation (or shear displacement) of a material subjected to stress to the original length of the material

3.36**sweep**

blade curvature in the lead-lag plane in the unloaded condition

3.37**tare loads**

gravitational or other loads that are inherent to the test set-up

3.38**target load**

cross-sectional forces and moments that are developed from the design load and are the ideal test load (including normative load factors)

3.39**test program**

Document describing how to test a specific design in compliance with this document, including cross sectional bending moments, loads and directions

3.40**test specification**

Document describing how to execute the Test Program

3.41**tested area**

region of the test object that experiences the intended loading

3.42**twist**

spanwise variation in angle of the chord lines of blade cross-sections

3.43**variable amplitude loading**

application of load cycles of non-constant mean and/or cyclic range

3.44**whiffle tree**

device for distributing a single load source over multiple points on a test specimen

4 Notation**4.1 Symbols**

C conversion factors for material strength

D theoretical damage

F load

F_a flatwise shear force (chordwise co-ordinates)

F_b edgewise shear force (chordwise co-ordinates)

F_c spanwise (tensile) force (chordwise co-ordinates)

F_x flapwise shear force (rotor co-ordinate system)

F_y lead-lag shear force (rotor co-ordinate system)

F_z spanwise (tensile) force (rotor co-ordinate system)

M_a edgewise bending moment (chordwise co-ordinates)

M_b flatwise bending moment (chordwise co-ordinates)

M_c blade torsion moment (chordwise co-ordinates)

266	M_x	lead-lag bending moment (rotor co-ordinate system)
267	M_y	flapwise bending moment (rotor co-ordinate system)
268	M_z	blade torsion moment (rotor co-ordinate system)
269	N	cycle number
270	S	strain or stress

271 **4.2 Greek symbols**

272	γ	partial safety factor or test load factor
273	σ	stress or strain

274 **4.3 Subscripts**

275	design	design loading conditions
276	df	design load: fatigue
277	du	design load: static
278	ef	uncertainty in fatigue formulation of test load
279	f	load
280	lf	environmental effects: fatigue
281	lu	environmental effects: static
282	m	material
283	n	consequence of failure
284	nf	consequence of failure: fatigue
285	nu	consequence of failure: static
286	sf	blade to blade variation: fatigue test load
287	su	blade to blade variation: static test load
288	target	target loading conditions
289	test	test loading conditions

290 **4.4 Coordinate systems**

291 Two different coordinate systems may be used for reference during structural testing. The first,
 292 shown in Figure 4.4-1, references the local blade chord directions. The second, shown in Figure
 293 4.4-2, references the global rotor plane directions. The position of the origin of the coordinate
 294 frames relative to the rotor blade section shall be defined in each case.

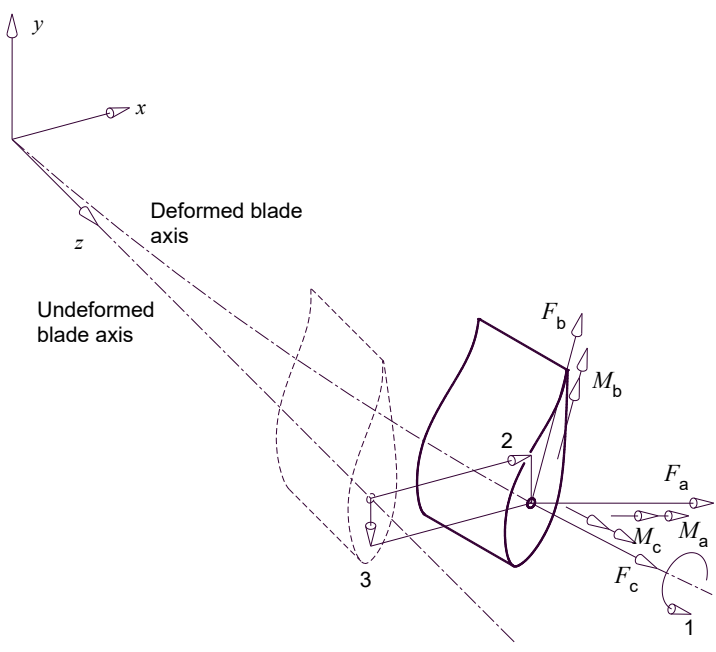
295 -----

296 Guidance note:

297 The definitions flatwise/edgewise and flapwise/lead-lag differ from the definition flapwise/edgewise that is also widely
 298 used in the industry.

299 End guidance note.

300 -----

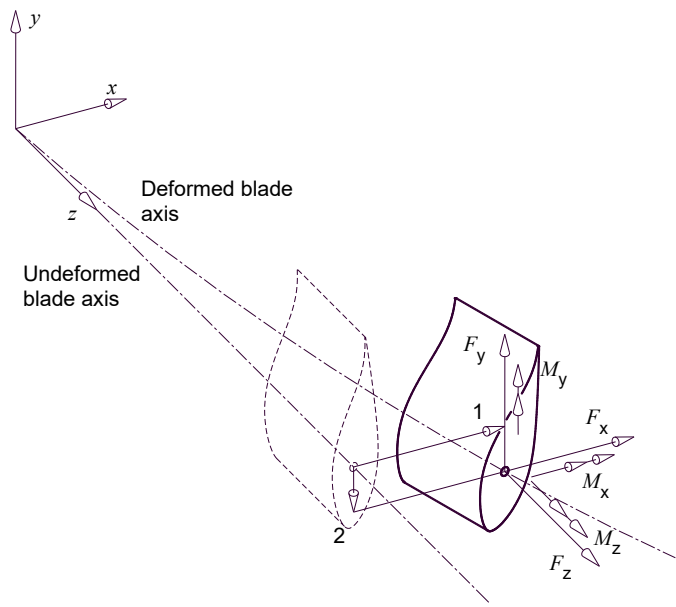


Loads are along and perpendicular to the local blade chord directions. The position of the origin relative to the rotor blade section shall be defined.

- M_a Edgewise bending moment
- M_b Flatwise bending moment
- M_c Torsion moment
- F_a Flatwise shear force
- F_b Edgewise shear force
- F_c Axial force
- 1 Torsion angle
- 2 Flapwise translation
- 3 Lead-lag translation

IEC 1040/14

Figure 4.4-1 – Chordwise (flatwise, edgewise) coordinate system



Loads are along the rotor plane reference directions. The position of the origin relative to the rotor blade section shall be defined.

- M_x Lead-lag bending moment
- M_y Flapwise bending moment
- M_z Torsion moment
- F_x Flapwise shear force
- F_y Lead-lag shear force
- F_z Spanwise force
- 1 Flapwise translation
- 2 Lead-lag translation

IEC 1041/14

Figure 4.4-2 – Rotor (flapwise, lead-lag) coordinate system