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Edition 1.0 2014-04

INTERNATIONAL STANDARD

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Wind turbines –
Part 23: Full-scale structural testing of rotor blades

Éoliennes –
Partie 23: Essais en vraie grandeur des structures des pales de rotor

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WIND TURBINES –

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 turbines.

This bilingual version (2019-01) corresponds to the monolingual English version, published in 2014-04.

This first edition cancels and replaces IEC TS 61400-23, published in 2001. It constitutes a technical revision.

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

a) description of load based testing only;
b) condensation to describe the general principles and demands.

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

CDV	Report on voting
88/420/CDV	88/448/RVC

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

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61400 series, published under the general title *Wind turbines*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,
- replaced by a revised edition, or
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INTRODUCTION

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

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.

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

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

The standard is based on IEC TS 61400-23 published in 2001. Compared to the TS, this standard only describes load based testing and is condensed to describe the general principles and demands.

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WIND TURBINES –

Part 23: Full-scale structural testing of rotor blades

1 Scope

This part of IEC 61400 defines the requirements for full-scale structural testing of wind turbine blades and for the interpretation and evaluation of achieved test results. The standard focuses on aspects of testing related to an evaluation of the integrity of the blade, for use by manufacturers and third party investigators.

The following tests are considered in this standard:

- static load tests;
- fatigue tests;
- static load tests after fatigue tests;
- tests determining other blade properties.

The purpose of the tests is to confirm to an acceptable level of probability that the whole population of a blade type fulfils the design assumptions.

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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 or equivalent. Design loads and blade material data are considered starting points for establishing and evaluating the test loads. The evaluation of the design loads with respect to the actual loads on the wind turbines is outside the scope of this standard.

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At the time this standard was written, full-scale tests were carried out on blades of horizontal axis wind turbines. The blades were mostly made of fibre reinforced plastics and wood/epoxy. However, most principles would be applicable to any wind turbine configuration, size and material.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 61400-1:2005, *Wind turbines – Part 1: Design requirements*

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions related to wind turbines or wind energy 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
blade root
that part of the rotor blade that is connected to the hub of the rotor

3.3
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.)

3.4
buckling
instability characterized by a non-linear increase in out of plane deflection with a change in local compressive load

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3.5
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

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3.6
constant amplitude loading
during a fatigue test, the application of load cycles with a constant amplitude and mean value

3.7
creep
time-dependant increase in strain under a sustained load

3.8
design loads
loads the blade is designed to withstand, including appropriate partial safety factors

3.9
edgewise
direction that is parallel to the local chord

SEE: 4.4.

3.10
elastic axis
the line, lengthwise of the blade, along which transverse loads are applied in order to produce bending only, with no torsion at any section

Note 1 to entry: Strictly speaking, no such line exists except for a few conditions of loading. Usually the elastic axis is assumed to be the line that passes through the elastic center of every section. This definition is not applicable for blades with bend-twist coupling.

3.11
fatigue formulation
methodology by which the fatigue life is estimated

3.12
fatigue test
test in which a cyclic load of constant or varying amplitude is applied to the test specimen

3.13
fixture
component or device to introduce loads or to support the test specimen

3.14
flapwise
direction that is perpendicular to the surface swept by the undeformed rotor blade axis

SEE: 4.4.

3.15
flatwise
direction that is perpendicular to the local chord, and spanwise blade axis

SEE: 4.4.

3.16
full-scale test
test carried out on the actual blade or part thereof

3.17
inboard
towards the blade root

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3.18
lead-lag
direction that is parallel to the plane of the swept surface and perpendicular to the longitudinal axis of the undeformed rotor blade

SEE 4.4.

3.19
load envelope
collection of maximum design loads in all directions and spanwise positions

3.20
natural frequency
eigen frequency
frequency at which a structure will vibrate when perturbed and allowed to vibrate freely

3.21
partial safety factors
factors that are applied to loads and material strengths to account for uncertainties in the representative (characteristic) values

3.22
prebend
blade curvature in the flapwise plane in the unloaded condition

3.23
R-value
ratio between minimum and maximum value during a load cycle

3.24
S-N formulation
method used to describe the stress and/or strain (S) vs. cycle (N) characteristics of a material, component or structure

3.25
spanwise
direction parallel to the longitudinal axis of a rotor blade

3.26
static test
test with an application of a single load cycle without introducing dynamic effects

3.27
stiffness
ratio of change of force to the corresponding change in displacement of an elastic body

3.28
strain
ratio of the elongation (or shear displacement) of a material subjected to stress to the original length of the material

3.29
sweep
blade curvature in the lead-lag plane in the unloaded condition

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3.30
tare loads
gravitational or other loads that are inherent to the test set-up

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3.31
target load
load that is developed from the design load and is the ideal test load

3.32
test load
forces applied during a test

3.33
tested area
region of the test object that experiences the intended loading

3.34
twist
spanwise variation in angle of the chord lines of blade cross-sections

3.35
variable amplitude loading
application of load cycles of non-constant mean and/or cyclic range

3.36
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)
M_x	lead-lag bending moment (rotor co-ordinate system)
M_y	flapwise bending moment (rotor co-ordinate system)
M_z	blade torsion moment (rotor co-ordinate system)
N	cycle
S	strain or stress

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4.2 Greek symbols

γ	partial factor or test load factor
σ	applied stress or strain

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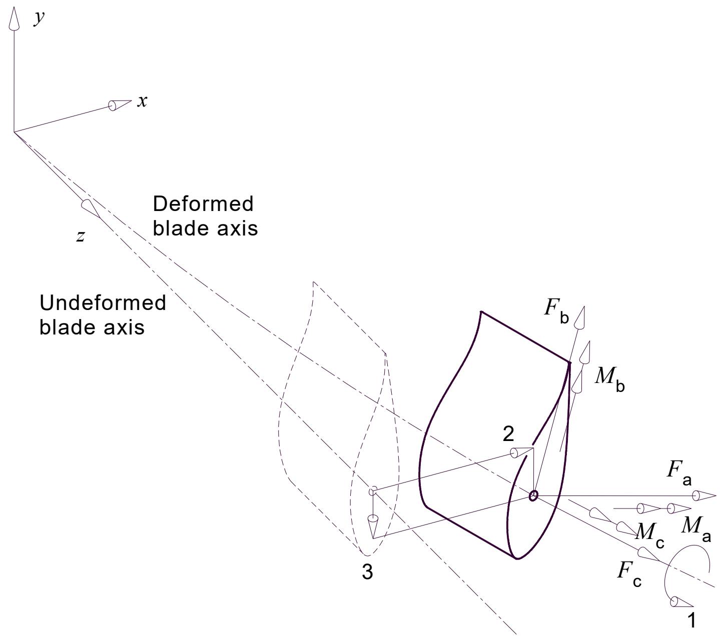
4.3 Subscripts

design	design loading conditions
df	design load: fatigue
du	design load: static
ef	uncertainty in fatigue formulation of test load
f	load
lf	environmental effects: fatigue
lu	environmental effects: static
m	material
n	consequence of failure
nf	consequence of failure: fatigue
nu	consequence of failure: static
sf	blade to blade variation: fatigue test load
su	blade to blade variation: static test load
target	target loading conditions
test	test loading conditions

4.4 Coordinate systems

Two different coordinate systems may be used for reference during structural testing. The first, shown in Figure 1, references the local blade chord directions. The second, shown in Figure 2, references the global rotor plane directions.



Loads are along and perpendicular to the local blade chord directions

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

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Figure 1 – Chordwise (flatwise, edgewise) coordinate system

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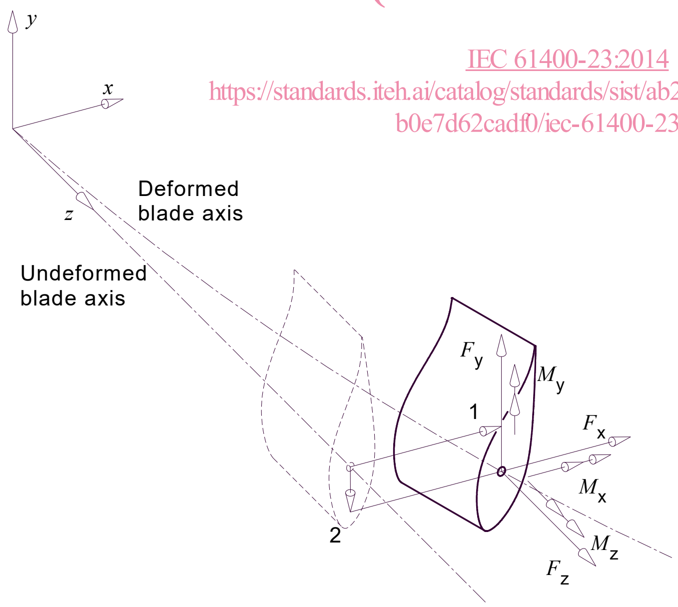

Loads are along the rotor plane reference directions

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

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

5 General principles

5.1 Purpose of tests

The fundamental purpose of a wind turbine blade test is to demonstrate to a reasonable level of certainty that a blade type, when manufactured according to a certain set of specifications, has the prescribed reliability with reference to specific limit states, or, more precisely, to verify that the specified limit states are not reached and the blades therefore possess the load carrying capability and service life provided for in the design.