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Wind turbines —

Part 4:
Design and specification of gearboxes

Aérogénérateurs —

Partie 4: Conception et spécifications des boîtes de vitesses

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 81400-4 was prepared by AWEA and AGMA (as ANSI/AGMA/AWEA 6006-A03) and was adopted, under a special “fast-track procedure”, by Technical Committee ISO/TC 60, *Gears*, in parallel with its approval by the ISO member bodies.

ISO 81400 is part of the IEC 61400 series.

Introduction

The operation and loading of a wind turbine speed increasing gearbox is unlike most other gear applications. The intent of this standard is to describe the differences. Much of the information is based on field experience. This standard is a tool whereby wind turbine and gearbox manufacturers can communicate and understand each other's needs in developing a gearbox specification for wind turbine applications. The annexes present informative discussion of various issues specific to wind turbine applications and gear design.

A combined committee of the American Wind Energy Association (AWEA) and American Gear Manufacturers Association (AGMA) members representing international wind turbine manufacturers, operators, researchers, consultants; and gear, bearing, plus lubricant manufacturers were responsible for the drafting and development of this standard.

The committee first met in 1993 to develop AGMA/AWEA 921–A97, *Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.* The AGMA Information Sheet was approved by the AGMA/AWEA Wind Turbine Gear Committee on October 25, 1996 and by the AGMA Technical Division Executive Committee on October 28, 1996. This standard superseded AGMA/AWEA 921–A97.

The first draft of ANSI/AGMA/AWEA 6006-A03 was made in March, 2000. It was approved by the AGMA membership in October, 2003. It was approved as an American National Standard (ANSI) on January 9, 2004.

Wind turbines - Part 4: Design and specification of gearboxes

1 Scope

This standard applies to gearboxes for wind turbines with power capacities ranging from 40 kW to 2 MW. It applies to all parallel axis, one stage epicyclic, and combined one stage epicyclic and parallel shaft enclosed gearboxes. The provisions made in this standard are based on field experience with wind turbines having the above power capacities and configurations.

Guidelines of this standard may be applied to higher capacity wind turbines provided the specifications are appropriately modified to accommodate the characteristics of higher capacity wind turbines.

Life requirements apply to wind turbines with a minimum design lifetime of 20 years.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below.

AGMA 901-A92, *A Rational Procedure for Preliminary Design of Minimum Volume Gears*

AGMA 913-A98, *Method for Specifying the Geometry of Spur and Helical Gears*

AGMA 925-A03, *Effect of Lubrication on Gear Surface Distress*

AMS 2301, *Aircraft quality steel cleanliness, magnetic particle inspection procedure*

ANSI Y12.3-1968, *Letter symbols for quantities used in mechanics of solids*

ANSI/AGMA 1012-F90, *Gear Nomenclature, Definitions of Terms with Symbols*

ANSI/AGMA 2101-D04, *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*

ANSI/AGMA 6000-B96, *Specification for Measurement of Linear Vibration on Gear Units*

ANSI/AGMA 6001-D97, *Design and Selection of Components for Enclosed Gear Drives*

ANSI/AGMA 6025-D98, *Sound for Enclosed Helical, Herringbone, and Spiral Bevel Gear Drives*

ANSI/AGMA 6110-F97, *Standard for Spur, Helical, Herringbone and Bevel Enclosed Drives*

ANSI/AGMA 6123-A88, *Design Manual for Enclosed Epicyclic Metric Module Gear Drives*

ANSI/AGMA 9005-E02, *Industrial Gear Lubrication*

ASTM A534, *Standard specification for carburizing steels for anti-friction bearings*

Det Norske Veritas Classification AS, Classification Notes No. 41.2, *Calculation of Gear Rating for Marine Transmissions,* July 1993

DIN ISO 281 Bbl. 4:2003, *Dynamische Tragzahl und nominelle Lebensdauer - Verfahren zur Berechnung der modifizierten Referenzlebensdauer für allgemein belastete Wälzlager (Dynamic load ratings and life - Method for calculation of the modified reference rating life for generally loaded rolling bearings)*[1)]

DIN 743:2000, *Tragfähigkeitsberechnung von Wellen und Achsen (Calculation of load capacity of shafts and axles)*

DIN 6885-2:1967, *Drive Type Fastenings without Taper Action; Parallel Keys, Keyways*

DIN 7190:2001, *Interference fits - Calculation and design rules*

1) English translation available as ISO TC 4/SC 8 N254a

ISO 76:1987, *Rolling bearings - Static load ratings*

ISO 281:1990, *Rolling bearings - Dynamic load rating and rating life*

ISO R773:1969, *Rectangular or square parallel keys and their corresponding keyways (dimensions in millimeters)*

ISO 1328-1, *Cylindrical Gears - ISO System Of Accuracy - Part 1: Definitions and Allowable Values of Deviations Relevant to Corresponding Flanks of Gear Teeth*

ISO 4406:1999 (SAE J1165), *Hydraulic fluid power - Fluids - Method for coding the level of contamination by solid particles*

ISO 6336- 1: 1996, *Calculation of load capacity of spur and helical gears- Part 1: Basic principles, introduction and general influence factors*

ISO 6336- 2: 1996, *Calculation of load capacity of spur and helical gears- Part 2: Calculation of surface durability (pitting)*

ISO 6336- 3: 1996, *Calculation of load capacity of spur and helical gears- Part 3: Calculation of tooth bending strength*

ISO 6336-5: 1996, *Calculation of load capacity of spur and helical gears- Part 5: Strength and quality of materials*

ISO/DIS 6336-6[2)], *Calculation of load capacity of spur and helical gears - Part 6: Calculation of service life under variable load*

ISO 8579-1:2002, *Acceptance code for gears - Part 1: Determination of airborne sound power levels emitted by gear units*

ISO 8579-2:1993, *Acceptance code for gears - Part 2: Determination of mechanical vibration of gear units during acceptance testing*

ISO/TR 13593:1999, *Enclosed gear drives for industrial applications*

ISO/TR 13989-1:2000, *Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears - Part 1: Flash temperature method*

ISO 14104:1995, *Gears - Surface temper etch inspection after grinding*

ISO/TR 14179-1:2001, *Gears - Thermal capacity - Part 1: Rating gear drives with thermal equilibrium at 95 °C sump temperature*

[2)] Presently at the development stage.

3 Definitions and symbols

3.0 Terms and definitions

For the purposes of this document, the terms and definitions given in 3.2 through 3.4 and the following apply, wherever applicable, conforming to ANSI/AGMA 1012-F90, and ANSI Y12.3-1968.

3.1 Symbols

The symbols, terms and units used in this standard are shown in table 1.

NOTE: The symbols and terms contained in this document may vary from those used in other AGMA standards. Users of this standard should assure themselves that they are using these symbols and terms in the manner indicated herein.

3.2 Wind turbine terms

active yaw: A system to rotate the nacelle relative to the changing direction of the wind. See passive yaw.

airfoil: Two dimensional cross section of a blade.

annual average wind speed: The time averaged, mean, horizontal wind speed for one calendar year at a particular site and a specified height.

annual average turbulence intensity: A measure of the short-time and spatial variation of the inflow wind speed about its long time average.

availability: The ratio of the number of hours that a turbine could operate to the total number of hours in that period, usually expressed as a percentage. Downtime due to faults or maintenance (scheduled or otherwise) generally make up the unavailable time.

bedplate: In a modular system, the structure that supports the drive train components and nacelle cover. Also called a main frame.

blade: The component of the rotor that converts wind energy into rotation of the rotor shaft.

brake: A device capable of stopping rotation of the rotor or reducing its speed.

certification: Procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements, also known as conformity assessment.

certification standard: Standard that has specific rules for procedures and management to carry out certification of conformity.

control system: A system that monitors the wind turbine and its environment and adjusts the wind turbine to keep it within operating limits.

Table 1 - Symbols

Symbol	Term	Units	Where first used
C	Basic dynamic load rating	N	Eq 1
C_0	Basic static load rating	N	5.1.3.1
f_{ma}	Mesh misalignment	– –	5.1.1.3
K_A	Ratio between the equivalent and the nominal torque	– –	5.1.1.5
$K_{H\beta}$	Load distribution factor	– –	5.1.1.2
K_{lc}	Ratio of maximum contact pressure to contact pressure for line contact without misalignment	– –	Eq 4
K_m	Ratio of maximum contact pressure with misalignment to maximum contact pressure without misalignment	– –	Eq 4
K_v	Dynamic factor	– –	5.1.1.1
k	Load sharing factor for the maximum loaded roller	– –	Eq 2
L_{adv}	Combined advanced rating life	hours	5.1.3.2.3
$L_{adv,\,i}$	Advanced rating life on the ith load level	hours	Eq 5
L_{h10}	Basic rating life	hours	Eq 1
L_{we}	Effective roller length	mm	Eq 3
L_{10r}	Combined nominal reference rating life	hours	5.1.3.2.3
n	Rotational speed	rpm	Eq 1
P	Dynamic equivalent bearing load	N	Eq 1
P_o	Equivalent static bearing load	N	5.1.3.1
P_t	Rated power of wind turbine	kW	Eq 6
p	Exponent in bearing life equation	– –	Eq 1
p_{line}	Contact pressure for line contact	MPa	Eq 3
p_{max}	Maximum contact stress	MPa	Table 3
Q	Single roller maximum load for a clearance free bearing	N	Eq 2
Q_{ty}	Recommended oil quantity	liters	Eq 6
q_i	Time share on the ith load level	– –	Eq 5
Ra	Roughness average	µm	5.2.8.2
Rz	Mean peak-to-valley height	µm	5.2.8.2
S_F	Safety factor for bending strength	– –	5.1.1.4
S_H	Safety factor for pitting resistance	– –	5.1.1.4
Y_N	Stress cycle factor for bending strength	– –	5.1.1.4
Y_{NT}	Life factor for bending	– –	5.1.1.5
Z	Total number of rolling elements	– –	Eq 2
Z_N	Stress cycle factor for pitting resistance	– –	5.1.1.4
Z_{NT}	Life factor for pitting resistance	– –	5.1.1.5
α_0	Nominal contact angle of the bearing	degrees	Eq 2
$\Sigma\rho_{line}$	Curvature sum for line contact	– –	Eq 3
κ	Viscosity ratio	– –	5.1.3.3

cut-in wind speed: The minimum wind speed at hub height at which the control system calls for the turbine to produce power.

cut-out wind speed: The maximum wind speed at hub height at which the control system calls for the turbine to produce power.

damped yaw: A device used to slow yaw motions.

design life: The period of real time that the system is expected to continue functioning. Includes operating, idling and stopped time.

downwind turbine: A HAWT where the wind passes the tower before the rotor.

dynamic equivalent bearing load: A hypothetical load, constant in magnitude and direction, acting radially on radial bearings or axially on thrust bearings, which if applied, would have the same influence on bearing life as the actual loads to which the bearing is subjected.

emergency shutdown: A rapid shutdown of the wind turbine triggered by the control system, a protection system or manual intervention.

extreme load: The extreme load is that load from any source, either operating or non-operating, that is the largest single load that the gearbox will see during its design life beyond which the gearbox no longer satisfies the design requirements. This load can be either forces, moments, torques, or a combination of the three. This load, supplied by the wind turbine manufacturer, includes all partial load safety factors.

extreme torque: The extreme torque is that torque from any source that is the largest single torque that the gearbox will see during its design life beyond which the gearbox no longer satisfies the design requirements.

extreme wind speed: The highest short-term average wind speed that is likely to be experienced by the wind turbine during its service lifetime. It is typically based on statistical estimates of the long term behavior of the wind speed.

feathering: In a variable pitch HAWT, the action of pitching the blades to a minimum power production position.

fixed pitch rotor: A rotor with blades that do not change pitch during operation. The pitch angle of the rotor blades may be changed manually for site specific or seasonal wind spectrum changes.

free yaw: See passive yaw.

HAWT: Horizontal axis wind turbine. The rotational axis of the rotor is approximately parallel to the horizon.

horizontal axis: The axis of rotor rotation is approximately parallel to the horizon.

hub height: For a HAWT, the height to the center of the rotor.

hub: The structure that attaches the blades to the rotor shaft.

idling: Operating condition where the rotor is rotating and the generator is not producing power.

input or mechanical power: The mechanical power measured at the gearbox low speed shaft or the wind turbine rotor shaft.

input shaft: See rotor shaft.

integrated system: A system architecture in which the gearbox housing supports the rotor directly, and in some cases, the generator(s) and other components. See modular system.

lock: The use of a mechanical device to prevent movement of the rotor or yaw drive.

main frame: See bedplate.

main shaft: See rotor shaft.

maximum operating load: The maximum operating load is the highest load in the load spectrum.

maximum power: The highest level of net electrical power delivered by a wind turbine in normal operation.

Miner's sum dynamic equivalent bearing load: The dynamic equivalent bearing load obtained by combining loads and speeds in a wind spectrum using Miner's rule.

modular system: A system architecture in which the rotor shaft assembly, gearbox, generator(s) and, possibly, a yaw drive, are separate components mounted to a common main frame. See integrated system.

motoring: Operating condition where the generator is consuming power.

nacelle: The structure that contains the drive train and other components located at the top of a HAWT.

nacelle cover: The housing that covers the nacelle.

nominal speed: The gearbox low speed shaft speed at which mechanical power is defined.

non-rotating: Operating condition where the rotor is not rotating.

normal shutdown: Transitional operating condition where the rotor decelerates from operating speed to standstill or idling and the generator ceases to generate power.

operational wind speed range: The range of wind speeds between the cut-in and the cut-out speed.

output shaft: See high speed shaft.

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