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Paints and varnishes — Coating systems for wind-turbine rotor blades —

Part 6: Determination and evaluation of ice adhesion using centrifuge

Peintures et vernis — Matériaux de revêtement pour pales de turbines éoliennes —

Partie 6: Détermination et évaluation de l'adhésion de la glace à l'aide d'une centrifugeuse

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

A list of all parts in the ISO 19392 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Ice accretion on rotor blade surfaces of wind turbines can decrease the efficiency and limit the performance of wind turbines in cold, humid environments. Ice formation can also lead to damage of the rotor blade and can be hazardous, if ice falls off the blade. Icephobic coatings ("icephobics") can be applied to rotor blade surfaces to reduce or prevent the adhesion of ice by removing ice prior to reaching a critical ice mass for the rotor blades. They can also increase the efficiency of thermal ice protection systems.

Paints and varnishes — Coating systems for wind-turbine rotor blades —

Part 6: Determination and evaluation of ice adhesion using centrifuge

1 Scope

This document describes a method to measure ice adhesion from artificial ice on test substrates by using a centrifuge. Basic ice types are defined and test parameters for the ice removal are described to achieve reproducibility of test results for ice adhesion measurements for rotor blade coatings. This document does not intend to provide fixed test parameter to account for the diversity of relevant icing scenarios in this field of application.

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.

ISO 1513, *Paints and varnishes — Examination and preparation of test samples*

ISO 4618, *Paints and varnishes —Vocabulary*

ISO 15528, *Paints, varnishes and raw materials for paints and varnishes — Sampling*

ISO 21920-2, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters*

SAE ARP 5905, *Calibration and Acceptance of Icing Wind Tunnels*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
static ice
ice created at a surface from liquid water with no dynamic effects

3.2
impact ice
ice that forms on surfaces from impacting supercooled water droplets (velocity >40 m/s)

3.3
icephobic coating
icephobic
coating or material that reduces or prevents ice formations and/or ice adhesion

4 Principle

Artificial ice is formed under controlled conditions on flat test surfaces to create a convenient ice mass for the ice adhesion strength measurement. The following ice types shall be used:

a) static ice (produced by pouring deionized water into a mould to subsequently freeze the ice onto the test surface under controlled conditions);

b) impact ice (created onto the test surface in an ice wind tunnel by supercooled water droplets at relevant velocity).

After ice formation, prepared test samples are transferred to a centrifuge, preferably situated in the same cold chamber to avoid any change in climatic conditions (e.g. temperature, humidity). The centrifuge with a specified acceleration rate uses centripetal forces to shear the ice from the test surface. The test is finished as soon as detachment of ice is detected (ice hits the centrifuge wall). The visual inspection of the de-iced test sample is mandatory to identify the apparent failure mode, which can be:

— adhesive, meaning there are no ice residues at the test surface (quantitative result); or

— cohesive, meaning there are ice residues at the test surface (qualitative result).

5 Apparatus

Ordinary laboratory apparatus, together with the following:

5.1 Climatic chamber for freezing conditions

Temperature controlled room, allowing storage, handling, and testing of equipment and test specimen at test temperature with a maximum allowable tolerance of ± 1 °C.

5.2 Ice wind tunnel (for “impact” ice formation only)

Open or closed loop facility, calibrated in accordance with SAE ARP 5905 and modified in order to create impact ice on a suitable test specimen for subsequent ice adhesion testing in the centrifuge.

5.3 Centrifuge

Custom-built device to perform the test under relevant temperature conditions and appropriate test parameters as follows:

— adjustable counterweight for relevant ice masses (ideally known prior testing) to prevent imbalance of the rotor;

— piezoelectric cell, vibration sensor, sound recordings or alike to detect the ice impact at the centrifuge wall.

6 Sampling

Take a representative sample of the product to be tested, as described in ISO 15528.

Examine and prepare each sample for testing, as described in ISO 1513.

7 Test panels

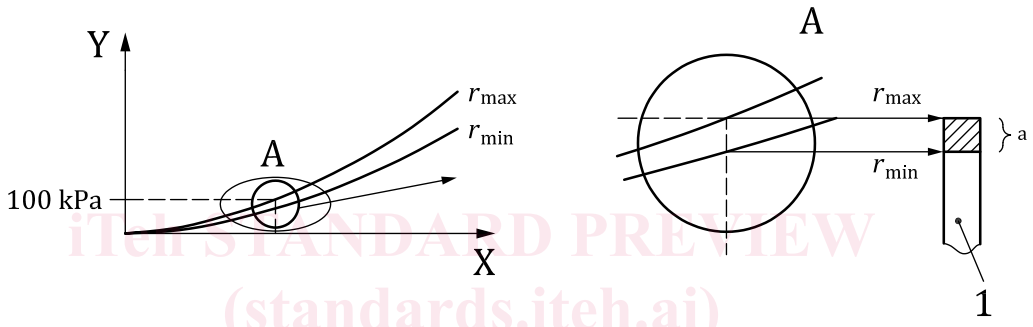
7.1 Substrate

Glass fibre composites or aluminium alloys are preferred.

Prepare and coat glass fibre test specimen similar to the production process with the coating system to be tested.

To account for effects of substrate properties on ice adhesion test results, specify the used substrate material and ensure comparability within the test series.

Sample size shall be adequate for the used centrifuge and allow an iced area, which guarantees reasonable result evaluation. Typically, areas range from minimum 5 cm^2 to maximum 12 cm^2. It shall also consider the minimization of non-uniform stress distribution during centrifuge test (see Figure 1: the difference between the calculated adhesive strength 100 kPa at the maximum radius of the ice covered area should be ≤ 30 % if compared to the minimum radius of the ice covered area).



Key

X centrifuge speed

Y ice adhesion strength

r_{max} max. radius

r_{min} min. radius

1 test sample

A iced area

[a] Iced area with ≤ 30 % difference for adhesive strength between min. and max. radius (at 100 kPa for the max radius).

Figure 1 — Maximum allowable difference of the adhesion strength within the iced area of the test sample

7.2 Preparation

Prepare and coat test specimen in accordance with the coating supplier's instructions.

7.3 Conditioning

Condition the coated test specimen in accordance with the coating supplier's instructions.

7.4 Coating thickness

If applicable, the thickness of the coating shall be specified.

7.5 Roughness of coating

The roughness of the coating/test surface shall be determined. In case of directional texture, consider direction of ice removal at the test surface.

8 Procedure

8.1 Number of determinations

Test at least three replicates of each material at each of the specified conditions.

For assessment of repeatability of de-icing on the same test surface, at least threefold icing/de-icing cycles are required. To address ice-phobic durability multiple icing/de-icing cycles are required.

8.2 Examination before exposure

Before sample preparation, carry out the following measurements:

— visual examination of the area to be exposed (no defects nor irregularities);

— surface roughness, in accordance with ISO 21920-2; incl. Ra, Rz;

— other surface topography parameters may also be measured.

8.3 Sample preparation (ice formation)

Prior to ice accretion, each surface shall be cleaned by using appropriate solvent (e.g. Isopropanol) and a soft tissue. For cleaning procedure follow the coating manufacturer instructions.

The conditioning and preparation of the test surfaces shall be dependent on the intended ice type, as follows:

a) Static ice — use specified volume of deionized water to fill the mould / test specimen assembly at test temperature (see 8.4). Assure tight contact of the mould to avoid water spill. Place the assembly at specified test temperature and wait for thorough freezing. Record the resulting ice mass and freezing time.

Freezing time can affect test results and should be kept constant for the test series.

b) Impact ice — cool down test specimen and relevant equipment to the specified test temperature. Start ice wind tunnel facility, including water injection using deionized water. Insert the pre-conditioned test surface in the running ice wind tunnel and collect impacting supercooled water droplets for a pre-defined time. Remove test specimen from the ice wind tunnel.

After ice formation, remove all additional equipment (e.g. mould, icing mask) from the test specimen, necessary for ice formation processes. No stress insertion shall occur to avoid preliminary ice breakage.

To minimize stress, moulds etc. may not be removed prior to testing. In this case, mould should not affect the ice adhesion measurement and shall be considered in the ice mass determination.

With regard to impact ice, prior to ice formation, determine the mass of each test specimen with an accuracy of ± 0,1 g and record it in the test protocol. After ice formation, repeat this process and calculate the ice mass accordingly.

Handle the prepared samples with care and allow a conditioning time of minimum 15 min, but not longer than five hours prior to testing. Conditions for ice formation shall be reported. Examples are given in Table A.1.