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

Part 3: Determination and evaluation of resistance to rain erosion using water jet

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

Partie 3: Détermination et évaluation de la résistance à l'érosion causée par la pluie au moyen d'un jet d'eau

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Foreword

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For an explanation on 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 the following URL: 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.

Introduction

In the wind energy industry, coatings are applied to rotor blades surface to protect the glass fibre reinforced polymer composite substrate. Rain drops and hailstones can damage these coatings in such a way that individual layers come off or the whole coating delaminates from the substrate.

ISO/TS 19392-1 describes the minimum requirements and weathering of the coating system. Rain erosion can be simulated by means of high speed water jets or water droplets impinging on the specimen surface. ISO/TS 19392-2 describes a method which simulates rain erosion by accelerating one or more coated panels, attached to the end of rotating arms, through a simulated rain field at a constant rotational velocity. This document describes a method where a water jet or a series of water jets at defined pressure hits the surface of the specimen.

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

Part 3: Determination and evaluation of resistance to rain erosion using water jet

1 Scope

This document specifies test methods for the determination of resistance of coating systems or tape for wind-turbine rotor blades to rain erosion by using the water jet test.

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 291, *Plastics — Standard atmospheres for conditioning and testing*

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

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 4618, *Paints and varnishes — Terms and definitions*

ISO 4628-1:2016, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 1: General introduction and designation system*

ISO 4628-2, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering*

ISO 4628-4, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 4: Assessment of degree of cracking*

ISO 4628-5, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 5: Assessment of degree of flaking*

ISO 4628-6, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 6: Assessment of degree of chalking by tape method*

ISO 13076, *Paints and varnishes — Lighting and procedure for visual assessments of coatings*

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

ISO 19403-2, *Paints and varnishes — Wettability — Part 2: Determination of the surface free energy of solid surfaces by measuring the contact angle*

ASTM G73-10, *Standard Test Method for Liquid Impingement Erosion Using Rotating Apparatus*

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 terminological databases for use in standardization at the following addresses:

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

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

3.1
water jet
continuous or discontinuous stream of water in air with defined geometry, velocity and, if discontinuous, frequency

4 Principle

The coated surface of a flat test panel is stressed by an impinging water jet. The erosion damage to the coating for a given duration is produced by one of the following methods:

a) interrupted water jet on fixed panel [pulsating jet erosion test (PJET)];

b) continuous water jet on slowly moving panel (vertical rotation axis);

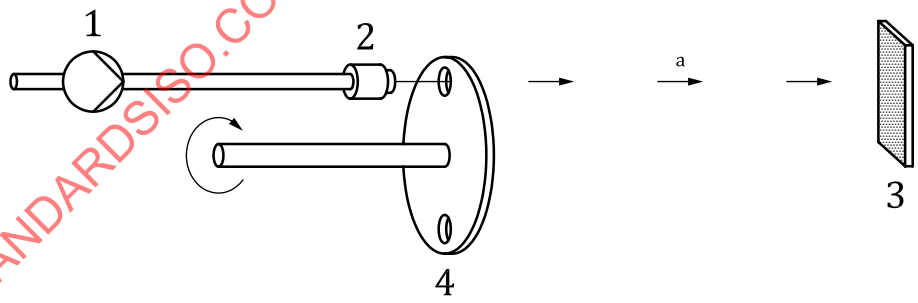
c) continuous water jet on slowly moving panel (horizontal rotation axis).

The test is finished as soon as defects uncover the composite substrate. The end point is detected by visual or microscopic inspection. The evaluation enables a pass or fail decision as well as a comparison with different coating systems in the same conditions. Also possible is the investigation of the course of the damage starting from initiation until complete failure.

5 Apparatus

Ordinary laboratory apparatus, together with the following.

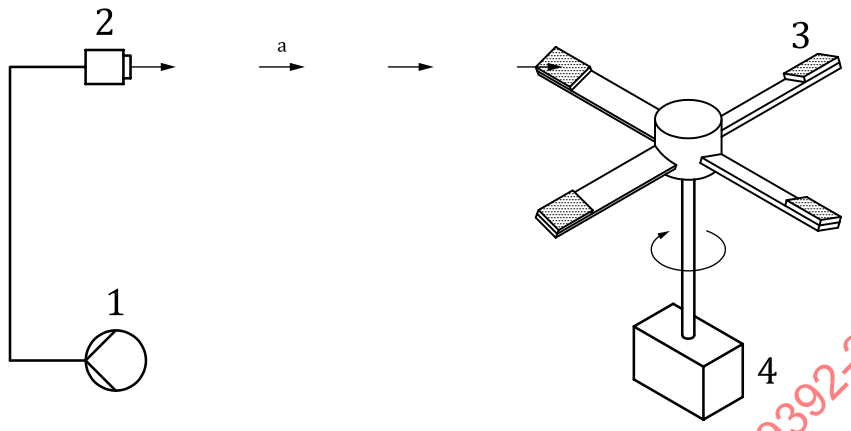
5.1 Device for testing with interrupted water jet on fixed panel (PJET), as shown in Figure 1.



Key
1 high-pressure pump
2 jet nozzle
3 panel holder with panel
4 rotating disc
a Fluid jet.

Figure 1 — Principle of device for testing with interrupted water jet on fixed panel

5.2 Device for testing with continuous water jet on moving panel (vertical rotation axis), as shown in Figure 2.

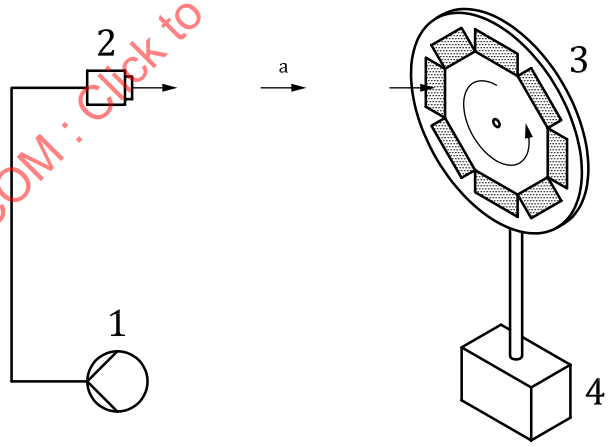


Key

1 high-pressure pump
2 jet nozzle
3 panel holder with panels
4 drive motor
a Fluid jet.

Figure 2 — Schematic illustration of a test device with vertical axis of rotation

5.3 Device for testing with continuous water jet on moving panel (horizontal rotation axis), as shown in Figure 3.



Key

1 high-pressure pump
2 jet nozzle
3 panel holder with panels
4 drive motor
a Fluid jet.

Figure 3 — Schematic illustration of a test device with horizontal axis of rotation

6 Sampling

Take a representative sample of the product to be tested (or of each product in case of a multi-coat system), as described in ISO 15528.

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

7 Test panels

7.1 Substrate

Flat test panels made from glass fibre composite material commonly used for rotor blades with a minimum size as given in Table 2.

Table 1 — Typical sample size and geometry (examples)

	Interrupted water jet on fixed panel (PJET)	Continuous water jet on moving panel (vertical rotation axis)	Continuous water jet on moving panel (horizontal rotation axis)
Sample size mm	75 × 150 × 2	85 × 50 × 5	30 × 60 × 5
Sample shape	Flat sheet	Flat sheet	Flat sheet

Table 2 shows the preferred samples size and geometry. Other samples' sizes and geometries can be used by agreement between the interested parties.

7.2 Preparation

Prepare and coat flat panels in a similar way to the production process with the coating system under test.

The coated test panels should have the same configuration as the real blade leading edge, including fillers or whatever material is used for surface preparation before applying the leading edge protection.

The preparation shall be defined or performed by the customer in accordance with the coating supplier's instructions.

If a taped test specimen is tested, the preparation shall be agreed between the interested parties.

NOTE Differences in the application process can affect the test results.

7.3 Conditioning

Condition the coated or taped test specimen for the specified time and under the specified conditions for at least 7 days under standard ambient conditions according ISO 291, class 2 [(23 ± 2) °C/(50 ± 10) % relative humidity] prior to testing.

7.4 Thickness of coating

The thickness of the coating shall be specified and agreed between the interested parties.

8 Procedure

8.1 Number of determinations

Test at least three samples at each specified conditions.

8.2 Examination before exposure

Before exposure, carry out the following measurements:

— visual examination of the area to be exposed;

— thickness of coating.

For further details, see Annex A.

8.3 Calibration

In order to keep conditions and instrument parameters constant, regular calibration of the test device is necessary. The calibration is mandatory with new test devices and at any change of test parameters.

Carry out the calibration according to ASTM G73-10.

Materials for calibration are, for example, aluminium (Al), stainless steel, polyurethane (PU) and polymethyl methacrylate (PMMA) with a defined purity and a reproducible and traceable source according to ASTM G73-10. Test the calibration material at defined time and measure the mass loss.

8.4 Exposure to simulation of rain erosion

Choose the test medium and test parameters (see Table 2) in accordance with the selected facility's options and examine all test specimens for existing defects before testing.

Possible test media are deionized water according to ISO 3696, Grade 2, tap water, chloride-containing water or artificial sea water according to ISO 15711:2003, Table 1, as agreed between the interested parties and according to operating conditions.

The test medium used and its conductivity value shall be defined and reported as agreed between the interested parties.

The test medium temperature shall be defined and recorded. The location of the temperature measurement shall be reported. Typical test medium temperature is (20 ± 10) °C. Tests at other temperatures may be carried out if agreed between the interested parties.

The air temperature shall be observed.

NOTE The degradation behaviour under or above the glass transition temperature, T_g, can influence the test result.

Table 2 — Test parameters (examples)

Test parameter	Interrupted water jet on fixed panel (PJET)	Continuous water jet on moving panel (vertical rotation axis)	Continuous water jet on moving panel (horizontal rotation axis)
Temperature of test medium[a] °C	20 ± 5	20 ± 5	20 ± 5
Nozzle diameter mm	0,8	0,8	1,0
Flow rate l/min	5,5 ± 0,2	4,6	7,75
Pressure MPa	150	100	160
Jet diameter (on specimen) mm	2	2	4,5
Distance between nozzle and rotating disc mm	8 ± 1	n/a[c]	n/a[c]
Distance between nozzle and test specimen mm	73 ± 1	300 ± 1	170 ± 2
Angle of incidence to the jet degrees (°)	90 ± 2	35 ± 2	90 ± 2
Jet velocity[b] m/s	160	140	165
Sample rotation speed	—	0,11 m/s	7,8 min^{-1}
Test period	6 000 impacts	8 h	1 h

[a] The temperature of the test medium is measured close to the nozzle.

[b] The jet velocity is determined at the nozzle delivery.

[c] Not applicable.

The interim test periods shall follow the test protocol of the individual rig. Test until the composite substrate is visible.

The mass loss shall be related to the change in coating thickness at the deepest observable erosion point or defined point on the length of the specimen.

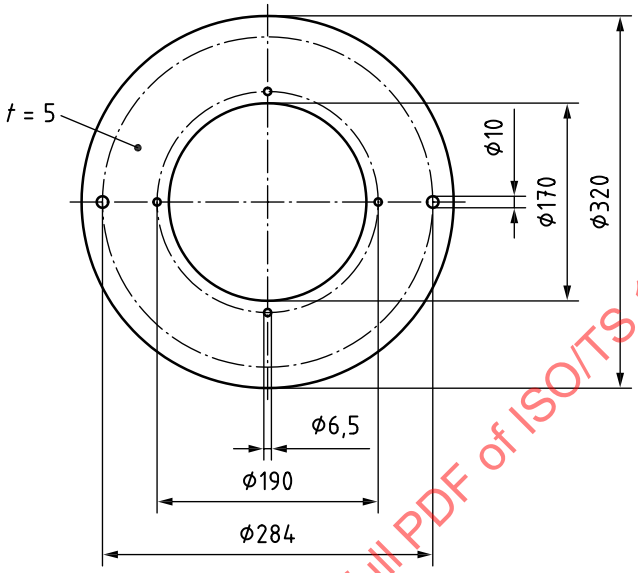
8.5 Interrupted water jet on fixed panel (PJET)

The device for testing with interrupted water jet on a fixed panel uses a high pressure pump feeding the test solution through a nozzle, which generates a focused water jet. Afterwards, the continuous water jet is separated into shorter jets by a rotating disc with two orifices (diameter 10 mm) on opposite sides of the disc (see Figure 4). The disc rotates with a frequency of 20 Hz, resulting in an impact frequency of the water jets on the surface of the sample of 40 Hz.

The velocity of the water jets may be controlled by adjusting the water pressure. The velocity depends on the water pressure. The existing PJET has jet velocities between 70 m/s to 250 m/s. The nozzle diameter of 0,8 mm leads to a front diameter of the water jets of approximately 2 mm.

The distance between nozzle and mounted test specimen is 73 mm but may be adjusted between 23 mm and 100 mm if needed.

Dimensions in millimetres



Key

t thickness

Figure 4 — Rotating disc

8.6 Continuous water jet on moving panel (vertical rotation axis)

The device for testing with continuous water jet on moving panels with vertical rotation axis uses a high pressure pump. It feeds the test solution through a nozzle, which generates a defined water jet. By the rotation of the samples, the water jet moves over the samples in a time range which depends on the diameter of the rotation arm, the size and the velocity of the samples. A total duration of about 2,4 s for the traverse time of the water jet over the test specimen is preferred. The water jet leaves the nozzle with a speed of 140 ms^{-1}. The nozzle has a diameter of 0,8 mm and an opening angle of 0°. The nozzle has a flow rate of 4,6 l/min at a pressure of 100 MPa. The velocity of the water jets may be controlled by adjusting the water pressure.

The distance between nozzle and mounted test specimen is 300 mm but may be adjusted between 100 mm and 500 mm if needed.

8.7 Continuous water jet on moving panel (horizontal rotation axis)

The device for testing with continuous water jet on moving panels with horizontal axis uses a high pressure pump. It feeds the test solution through a nozzle, which generates a defined water jet. By the rotation of the samples, the water jet moves over the samples in a time range which depends on the diameter of the panel holder, the size and the velocity of the sample. A total duration of about 1 s for the traverse time of the water jet over the test specimen is preferred. The velocity of the water jets may be controlled by adjusting the water pressure. The range of the possible jet velocities depends on the set-up (water pressure, pump). The water jet leaves the nozzle with a speed of 170 ms^{-1}. The nozzle has a diameter of 1,0 mm, an opening angle of 0° and is made of ceramic. The nozzle has a flow rate of 7,75 l/min at a pressure of 160 MPa.

The distance between nozzle and the surface of the test panel is 170 mm. The distance may be adjusted between 10 mm and 250 mm if needed.

8.8 Examination after exposure

After exposure, assess the following properties:

— thickness of coating;

— defects on the exposed area determined through a visual examination as specified in Annex A;

— roughness;

— wetting;

— erosion depth.

For further details, see Annex A.

9 Evaluation

The individual ratings achieved in the examinations before and after exposure shall be reported.

The evaluations of defects shall be done as a judgement of the status of the top coat. The rating starts with initial gloss to reduced gloss, on to damaged top coat and in the end the loss of the top coat. When the top coat and the primer are lost, the surface is unprotected.

If other materials like tape are used, it is recommended to use a rating system similar to that described above.

If a functional rating scale other than that described in Table 3 is needed, use Table 3 as a guideline to create a new rating scale which shall be included in every report. For continuous water jet on moving panel (vertical rotation axis), as there is an erosion gradient on the test specimen, the position of the evaluated area(s) shall be noted.

Table 3 — Functional rating scale (guideline)

Rating	Description (use valid functional description)
0	No degrading. Full gloss. (Super-)Hydrophobic.
1	Very small degradation. Almost full gloss. Still hydrophobic, but wetting can be observed.
2	Degradation. Gloss is reduced. Wetting, hydrophobic effect lost. Still full protection from top coat.
3	Top coat is losing material. Rougher surface. Good protection.
4	Protection of top coat is limited. No detectable defects to other layers.
5	Top coat is partly lost. Primer visible or damaged. Poor or no protection.

10 Precision

There are currently no general data on precision.

The current knowledge of test rig aerodynamics and effects of different test variables shows that results cannot be compared directly between different laboratories, as the test rig design has a significant influence on the location and depth of the defect that occurs.

11 Test report

The test report shall contain at least the following information:

a) a reference to this document, i.e. ISO/TS 19392-3:2018;

b) all details necessary for complete identification of the product tested (manufacturer, trade name, batch number, sample ID, etc.);

c) details of the test specimens including:

   1) details of the substrate (including material and thickness) and its surface preparation, if performed by the test facility,

   2) the method used to apply the product to the substrate, including the drying or curing time and conditions for each layer, if performed by the test facility,

   3) if applicable, the conditions under which the panels were aged,

   4) details of how the test panels were conditioned before the test and, if applicable, details of any tests carried out previously with the same test panel,

   5) the dry-film thickness of the coating, in micrometres;

d) test method (a, b or c) according to Clause 4;

e) conditions (see Table 2);

f) the result of the test according to 8.2, 8.8 and Clause 9;

g) any deviation from the specified test method;

h) details of any specific points on which agreement between the interested parties was necessary;

i) any unusual features observed during the test;

j) the date of testing.

Annex A
(normative)

Details of test methods

A.1 Thickness of coating

Determine the thickness, in micrometres, of the dried coating by one of the procedures specified in ISO 2808.

A.2 Visual examination

A.2.1 General

Carry out the visual examination by using ISO 13076. If any defects appear, use the applicable standard for examination (e.g. ISO 4628-5, for flaking).

Any inhomogeneity, defects and/or changes (e.g. gloss or roughness) shall be noted in the test report.

A.2.2 Flaking

The assessment for quantity (density) and size is made on each specimen separately according to ISO 4628-5, using a microscope with a magnification of ×10.

Calculate and record the mean value for quantity and size to one decimal place.

A.2.3 Blistering

The assessment for quantity (density) and size is made on each specimen separately according to ISO 4628-2.

Calculate and record the mean value for quantity and size to one decimal place.

A.2.4 Cracking

The assessment for quantity (density) and size is made on each specimen separately according to ISO 4628-4.

Calculate and record the mean value for quantity and size to one decimal place.

A.2.5 Pitting

The assessment for small singular defects which penetrate all or most of the coating is made on each specimen separately according to ISO 4628-1:2016, Table 1 for quantity and Table 2 for size.

Use, alternatively, the adaptive Gaussian thresholding method and record the result.

A.2.6 Chalking

The assessment is made on each exposed specimen separately according to the procedure described in ISO 4628-6. Take care to distinguish between chalking and dust.

Calculate and record the mean value to one decimal place.