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Anodizing of aluminium and its alloys — Measurement of abrasion resistance of anodic oxidation coatings

Anodisation de l'aluminium et de ses alliages — Détermination de la résistance à l'abrasion des couches d'oxyde anodiques

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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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 79, *Light metals and their alloys*, Subcommittee SC 2, *Organic and anodic oxidation coatings on aluminium*.

This third edition cancels and replaces the second edition (ISO 8251:2011), which has been technically revised. The main technical changes are as follows:

— preparation for test specimens has been added;

— for expression of results, loss of mass has been added;

— some expressions of results have been moved to Annex B;

— standard specimen made of PMMA sheet has been added.

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

The resistance of anodic oxidation coatings to abrasion is an important property. As it is dependent upon the composition of the metal, the thickness of the coating and the conditions of anodizing and sealing, it can give information about the quality of the coating, its potential resistance to erosion or wear and its performance in service. For example, the effect of an abnormally high anodizing temperature, which could cause potential deterioration in service by chalking of the surface layers, can be readily detected by means of an abrasive wear resistance test.

The use of the term "abrasion resistance" is a convention of the industry. Strictly, the property should be described as "wear resistance". There are different types of wear including abrasive wear and erosive wear.

Anodizing of aluminium and its alloys — Measurement of abrasion resistance of anodic oxidation coatings

1 Scope

This document specifies the following tests:

a) abrasive-wheel-wear test, determining the abrasion resistance of anodic oxidation coatings with abrasive wheel on flat specimens of aluminium and its alloys;

b) abrasive jet test, determining the comparative abrasion resistance of anodic oxidation coatings with jet of abrasive particles on anodic oxidation coatings of aluminium and its alloys;

c) falling sand abrasion test, determining the abrasion resistance of anodic oxidation coatings with falling sand on thin anodic oxidation coatings of aluminium and its alloys.

The use of abrasive-wheel-wear test and abrasive jet test for coatings produced by hard anodizing is described in ISO 10074.

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 6344-1, *Coated abrasives — Grain size analysis — Part 1: Grain size distribution test*

ISO 7583, *Anodizing of aluminium and its alloys — Terms and definitions*

ISO 7823-1, *Plastics — Poly(methyl methacrylate) sheets — Types, dimensions and characteristics — Part 1: Cast sheets*

ISO 8486-1, *Bonded abrasives — Determination and designation of grain size distribution — Part 1: Macrogrits F4 to F220*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7583 and the following apply.

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

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

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

3.1
standard specimen
specimen produced in accordance with specified conditions

Note 1 to entry: The conditions are specified in Annex A.

4 Characteristics of abrasion tests

4.1 General

In the scope of this document, there are three kinds of abrasion tests: abrasive-wheel-wear test (4.2), abrasive jet test (4.3) and falling sand abrasion test (4.4).

4.2 Abrasive-wheel-wear test

Determination of the abrasion resistance by movement of a test specimen relative to an abrasive paper under a specified pressure. The wear resistance or the wear index of the layers of oxide near the surface, or of the whole oxidation coating thickness, or of any selected intermediate zone may be determined by the test described.

NOTE 1 Abrasive-wheel-wear test determines the resistance to abrasive wear.

This test is applicable to all anodic oxidation coatings of thickness more than 5 µm on flat aluminium or its alloy specimens.

This test does not apply to concave or convex specimens; these may be examined using the abrasive jet test which will give an average value for the abrasive resistance of the coating.

NOTE 2 Minimum test specimen dimensions of 50 mm × 50 mm are normally used.

4.3 Abrasive jet test

Determination of the comparative abrasion resistance by the impact of abrasive particles projected onto a test specimen. The mean specific abrasion resistance of anodic oxidation coatings can be determined.

NOTE 1 Abrasive jet test determines the comparative resistance to erosive wear.

This test is applicable to all anodic oxidation coatings of thickness more than 5 µm on aluminium or its alloys. It is primarily intended for surfaces which are not flat. If suitable flat test surfaces are available, the abrasive-wheel-wear test is the preferred test. Production components may be tested without cutting if the apparatus chamber can accommodate these.

NOTE 2 This test is particularly suitable for small test specimens because the individual test area required is only about 2 mm in diameter.

4.4 Falling sand abrasion test

Determination of the abrasion resistance by the impact of freely falling abrasive particles onto anodic oxidation coatings.

This test is suitable to thin anodic oxidation coatings, generally less than 15 µm.

NOTE Falling sand abrasion test determines the resistance to erosive wear.

5 Abrasive-wheel-wear test

5.1 Principle

The anodic oxidation coatings on a test specimen are abraded, under defined conditions, by reciprocal motion against a strip of silicon carbide paper attached to the outer circumference of a wheel. After each double stroke, the wheel turns through a small angle to bring an unused portion of the abrasive strip into contact with the test area. The decrease in coating thickness or mass obtained is used to calculate the wear resistance, mass wear resistance, wear index or mass wear index. This result is compared with that obtained using a standard specimen or reference specimen.

The measuring method of coating thickness normally requires an eddy-current meter with a probe of less than 12 mm diameter. If this is not available, the method of loss in mass should be used.

NOTE A complete presentation of the wear characteristics of the anodic oxidation coatings can be obtained by progressively abrading the test area, until the substrate metal is revealed, and then constructing a graph to show the relation between the coating thickness removed and the number of double strokes used. This is referred to as a depth survey of the anodic oxidation coatings (see Annex C).

The testing environment should be at room temperature and the relative humidity should be under 65 %.

5.2 Apparatus

5.2.1 Abrasive-wheel-wear test apparatus

The apparatus consists of a clamping device or pressure plate for holding the test specimen level and rigid, and a 50 mm diameter wheel to the outer circumference of which is attached a 12 mm wide strip of silicon carbide paper. The force between the wheel and the test surface shall be capable of being varied from zero to at least 4,9 N with an accuracy of ± 0,05 N. The abrasive action is produced either by the fixed wheel sliding to and fro in a horizontal plane in parallel contact with the test surface over a 30 mm length or, alternatively, by the test specimen sliding in a similar way over the stationary wheel. Typical apparatus is illustrated in Figure D.1.

After each double stroke, the wheel is advanced through a small angle to bring a fresh area of the silicon carbide paper into contact with the specimen surface before making the next double stroke. The angle of rotation is such that, after 400 ds, the wheel will have made one complete revolution. At this stage, the strip of silicon carbide paper shall be renewed. The relative speed of movement shall be (40 ± 2) ds per minute. The number of double strokes can be registered by means of a counter, and provision is normally made for the apparatus to switch off automatically after a preset number of double strokes has been reached (400 ds maximum). The test specimen surface shall be kept free from loose powder or abrasion detritus during the test.

5.2.2 Abrasive strip

The abrasive strip consists of P320 silicon carbide paper (the specification of which shall be in accordance with ISO 6344-1) 12 mm wide. Its length, 158 mm, shall be such that it covers the abrasive wheel without overlapping, and it shall be bonded into position.

NOTE P320 paper is 45 µm grade (320 mesh).

5.2.3 Eddy-current meter

An eddy-current meter with a suitable diameter probe is described in ISO 2360.

5.2.4 Balance

Use a laboratory balance with a readability of 0,1 mg.

5.3 Procedure

5.3.1 Standard specimen

Prepare the aluminium standard specimen specified in Annex A.

If agreed between the interested parties, a standard specimen made of poly(methyl methacrylate) (PMMA) sheet in accordance with ISO 7823-1 may be used.

NOTE Aluminium standard specimen and PMMA standard specimen specified in Annex A have different abrasion resistance, about five times difference. For the purpose of comparison of the loss of mass, PMMA standard specimen is used by adjusting the number of double strokes.

5.3.2 Test specimen

5.3.2.1 Sampling

The test specimen shall be taken from a significant surface of the product, and shall not be taken near an edge of the part for possible distortion and/or non-uniformity.

Where it is impossible to test the product itself, a test specimen may be used. However, in this case, the test specimen used shall be one which is representative of the product, and it shall be made from the same material and prepared under the same conditions of finishing as those used for the preparation of the product.

The aluminium alloy, the manufacturing conditions (kind and temper of the material), and the surface condition before treatment shall be the same as those of the product.

Pretreatment, anodizing and sealing shall be performed in the same baths and under the same conditions as the treatment of the product.

5.3.2.2 Size

The standard size of the test specimen should be 50 mm × 50 mm.

5.3.2.3 Treatment before testing

The test specimen shall be clean, free from dirt, stains and other foreign matters. Any deposits or stains shall be removed with a clean, soft cloth or similar material which is wetted by water or an appropriate organic solvent such as ethanol. An organic solvent which can corrode the test specimen or generate a protective film on the test specimen shall not be used.

5.3.3 Test procedure

5.3.3.1 The standard specimen and/or the test specimen shall be tested by the following procedure. The abrasive strips used for the test specimen shall be the same lot as the one for the standard specimen. A reference specimen may be used by agreement between the interested parties (see Annex B).

5.3.3.2 Select the test area of the standard specimen and/or the test specimen to be abraded. Measure the anodic oxidation coating thicknesses of the standard specimen and/or the test specimen in each of at least three positions along the test area by means of the eddy-current meter and calculate an average thickness value (d_1). For change in mass, weigh the mass (m_1) of the standard specimen and/or the test specimen to the nearest 0,1 mg by means of the balance.

5.3.3.3 Clamp the standard specimen and/or the test specimen into the position on the apparatus. If the test specimen is not rigid, bond it firmly with an adhesive to a rigid metal sheet with a flat surface before carrying out the test.

5.3.3.4 Attach a new abrasive strip to the circumference of the abrasive wheel. Adjust the force between the wheel and the test surface to 3,9 N ± 0,1 N.

5.3.3.5 Allow the apparatus to run for 400 ds or an adequate number of double strokes corresponding to the coating thickness and the kind of aluminium alloys.

5.3.3.6 Remove the standard specimen and/or the test specimen from the apparatus, wipe carefully to remove any debris. Determine the average thickness value (d_2) or weigh the mass (m_2). A 3 mm length at one extremity of the test area can be subject to extra wear because of the continual wheel rotation which takes place at this point; this area should be ignored when taking the thickness measurements.

Freshly exposed anodic oxidation coatings can gain in mass by absorbing water vapour. The determination shall be carried out as early as possible after the test is finished.

5.3.3.7 Carry out at least two further tests on the same standard specimen and/or the test specimen with test areas that are not overlapped. Follow the procedure specified in 5.3.3.2 to 5.3.3.6.

Determine the average thickness and/or mass of at least three standard specimens and/or test specimens, before abrasion (d_1 and/or m_1) and after abrasion (d_2 and/or m_2).

5.4 Expression of results

5.4.1 General

The expression of results should be chosen from 5.4.2 to 5.4.5.

Other expression of results may be chosen by agreement between the interested parties (see Annex B).

5.4.2 Wear resistance

The wear resistance, R_W, in double strokes per micrometre, can be expressed using Formula (1):

$$R_W = \frac{N}{d_1 - d_2} \tag{1}$$

where

N is the number of double strokes;

d_1 is the average thickness, in micrometres, before abrasion;

d_2 is the average thickness, in micrometres, after abrasion.

5.4.3 Mass wear resistance

The mass wear resistance, R_{MW}, in double strokes per milligram, can be expressed using Formula (2):

$$R_{MW} = \frac{N}{m_1 - m_2} \tag{2}$$

where

N is the number of double strokes;

m_1 is the average mass, in milligrams, before abrasion;

m_2 is the average mass, in milligrams, after abrasion.

5.4.4 Wear index

The wear index, I_W, can be expressed using Formula (3):

$$I_W = \frac{d_{1t} - d_{2t}}{d_{1s} - d_{2s}} \tag{3}$$

where

d_{1t} is the average thickness, in micrometres, of the test specimen before abrasion;

d_{2t} is the average thickness, in micrometres, of the test specimen after abrasion;

d_{1s} is the average thickness, in micrometres, of the standard specimen before abrasion;

d_{2s} is the average thickness, in micrometres, of the standard specimen after abrasion.

5.4.5 Mass wear index

The mass wear index, I_{MW}, can be expressed using Formula (4):

$$I_{MW} = \frac{m_{1t} - m_{2t}}{m_{1s} - m_{2s}} \quad (4)$$

where

m_{1t} is the average mass, in milligrams, of the test specimen before abrasion;

m_{2t} is the average mass, in milligrams, of the test specimen after abrasion;

m_{1s} is the average mass, in milligrams, of the standard specimen before abrasion;

m_{2s} is the average mass, in milligrams, of the standard specimen after abrasion.

6 Abrasive jet test

6.1 Principle

Dry silicon carbide particles are projected in a stream of dry air or inert gas under carefully controlled conditions onto a small area of the surface to be tested. The test is continued until the substrate metal is exposed, after which the abrasion resistance of the coating is expressed from either the time taken or the mass of silicon carbide used. The result is compared with that obtained using an aluminium standard specimen or reference specimen.

6.2 Apparatus

6.2.1 Abrasive jet test apparatus

NOTE The abrasive jet test apparatus is shown in Figures E.1 and E.2.

6.2.1.1 Abrasive jet nozzle, consisting essentially of two glass or metal tubes supported rigidly and coaxially. The outer tube is connected to a supply of clean, dry, compressed air or inert gas, which can be delivered at a carefully regulated flow rate. Dry abrasive particles are supplied to the inner tube, at the exit end of which they mix with the air stream to form an abrasive jet which is directed onto the test specimen.

No restriction is placed upon the design of the abrasive jet nozzle, except that it shall give reproducible results in successive tests, and that it shall allow consistent measurements to be made.

NOTE A number of satisfactory designs of the jet nozzle have been constructed but it has proved difficult in practice to manufacture a series of jets which give identical results, or to make any that are not subject to drift and variations. Designs that have proved satisfactory are shown in Annex E.

6.2.1.2 Test specimen support, comprising an inclined platform on which the test specimen is firmly and rigidly supported such that the angle between the plane of the test area and that of the jet axis is in the range 45° to 55°. The jet is usually vertical.

NOTE E.2 describes an apparatus where the angle is 55°. The larger angle produces a less elliptical test area, more rapid abrasion and a sharper end point.

6.2.1.3 Air or inert gas supply, fed to the outer tube from a compressor or gas cylinder and controlled accurately by means of a regulating valve and a manometer situated near the apparatus. The air or inert gas shall be dry, or have constant low humidity.

NOTE 1 The inert gas can be dried by passing it through tubes containing silica gel. Compressed air passed through a holding reservoir where condensed water vapour is collected will have a satisfactory and fairly constant humidity.

NOTE 2 The pressure is typically 7,5 kPa ± 0,5 kPa.

6.2.1.4 Hopper, for storage of the abrading medium and capable of supplying this at a steady rate of 20 g/min ± 1 g/min to 30 g/min ± 1 g/min.

6.2.2 Abrading medium

Silicon carbide particles of a grade recommended by the manufacturer of the apparatus should be used. A suitable grade of abrasive is 125 µm mesh size: F100 in accordance with ISO 565 and ISO 8486-1.

The abrading medium shall be free from moisture and shall be dried before use and passed through a coarse sieve (for example, of 180 µm or 300 µm nominal aperture size) to ensure freedom from large particles or fibres which might interfere with the rate of abrasive flow.

The dried medium may be re-used up to 50 times; after each use, the medium should be dried, passed through a coarse sieve and stored in a clean, tightly closed container.

NOTE Ambient humidity has little effect on the test result, but can have a very considerable effect if the medium is re-used without drying.

The testing environment should be at room temperature and the relative humidity should be under 65 %.

6.2.3 Eddy-current meter

An eddy-current meter with a suitable diameter probe is described in ISO 2360.

6.2.4 Balance

Use a laboratory balance with an accuracy of 1 g.

6.3 Procedure

6.3.1 Standard specimen

Prepare the aluminium standard specimen specified in Annex A.

6.3.2 Test specimen

6.3.2.1 Sampling

See 5.3.2.1.

6.3.2.2 Size

The standard size of the test specimen should be about 100 mm × 100 mm.

6.3.2.3 Treatment before testing

See 5.3.2.3.

6.3.3 Calibration of apparatus

6.3.3.1 Select and mark the areas of the standard specimen to be abraded. Accurately measure the anodic oxidation coating thickness (d) in each test area by means of an eddy-current meter.

6.3.3.2 Fix the standard specimen in position in the test apparatus with the selected test area beneath the jet orifice and at the correct angle to the jet axis.

6.3.3.3 Fill the hopper with sufficient silicon carbide for the test. If the abrasion resistance is being determined in terms of the mass of abrading medium used, weigh the hopper and abrading medium to the nearest 1 g using the balance.

6.3.3.4 Set the air or gas pressure, to the specified (or selected) value, which shall be accurately maintained throughout each test and any series of tests.

The air or gas pressure should be adjusted to give a rate of abrasion that is convenient for both the standard specimen being tested and for the test specimen. The preferred pressure, is normally indicated by the instrument manufacturer but it may be varied this for very soft, hard or thin coatings.

6.3.3.5 Start the flow of abrading medium and simultaneously start a timer. Throughout the test, ensure that the abrading medium flows freely.

6.3.3.6 Keep the standard specimen under observation; when a small black spot appears in the centre of the abraded area and rapidly enlarges to approximately 2 mm in diameter terminate the test by stopping the abrading medium flow and the timer simultaneously. It is recommended that the end point be determined by using a circuit tester to measure the electrical resistance at the abraded area on the standard specimen.

6.3.3.7 Record the time, in seconds, taken for the test. If required, weigh the hopper and residual abrading medium, calculate the mass in grams. The results give the abrasion of the standard specimen (S_S) in either seconds or grams.

6.3.3.8 Carry out at least two further tests on other parts of the standard specimen. Follow the procedure specified in 6.3.3.1 to 6.3.3.7.

6.3.4 Calibration of jet nozzle

6.3.4.1 General

Since individual jets can vary with use and one with another, it is necessary to correct each set of measurements by means of calibration determinations using a standard specimen as in 6.3.3. This enables the abrasive jet factor for the set of measurements to be calculated.

6.3.4.2 Change of jet nozzle or abrasive characteristics with time

For any series of test measurements, repeat the procedure specified in 6.3.3 once or twice daily in order to allow a correction to be made for changes of jet nozzle or abrasive characteristics with time.

6.3.4.3 Jet nozzle replacement

After jet nozzle replacement, repeat the procedure specified in 6.3.3 to allow correction for changes in jet nozzle characteristics.

6.3.5 Determination

Carry out the procedure specified in 6.3.3 using the test specimen instead of the standard specimen.

6.3.6 Use of a reference specimen

Under some circumstances, for example for control purposes, it is common practice to use a reference specimen for comparison and, if this is required, the procedure specified in 6.3.3 shall be followed using the reference specimen in place of the standard specimen.

6.4 Expression of results

6.4.1 General

The expression of results should be chosen from 6.4.2 to 6.4.4.

6.4.2 Abrasive jet factor

The abrasive jet factor, K, can be expressed in micrometres per second or micrometres per gram, using Formula (5):

$$K = \frac{d_s}{S_s} \times 10 \tag{5}$$

where

d_s is the coating thickness, in micrometres, of the standard specimen in the area tested before abrasion;

S_s is the abrasion, in seconds or grams, of the standard specimen.

When the abrasive jet factor has been determined for a jet nozzle used under any specified set of conditions, it is essential that measurements made with that jet nozzle should be multiplied by this factor.

6.4.3 Mean specific abrasion resistance

The means specific abrasion resistance, R, of the coating at any test point with reference to the value obtained on a standard specimen can be expressed using Formula (6):

$$R = \frac{KS_t}{d_t} \tag{6}$$

where

K is the abrasive jet factor;

S_t is the abrasion, in seconds or grams, of the test specimen;

d_t is the coating thickness, in micrometres, of the test specimen in the area tested before abrasion.

The values quoted shall be the mean of not less than three determinations.

NOTE 1 The mean specific abrasion resistance is a ratio with no dimensions.

NOTE 2 Anodic oxidation coatings can be variable through their thickness and the measured value is an average property for the whole coating thickness.

6.4.4 Relative mean specific abrasion resistance

If the abrasive jet apparatus is used for comparison with an agreed reference specimen, the relative mean specific abrasion resistance, R_{rel}, can be expressed as a percentage, using Formula (7):

$$R_{rel} = \frac{S_t}{d_t} \times \frac{d_r}{S_r} \times 100 \tag{7}$$

where

S_r is the abrasion, in seconds or grams, of the reference specimen;

d_r is the coating thickness, in micrometres, of the reference specimen in the area tested before abrasion;

S_t and d_t are as defined in 6.4.3.

The value quoted shall be the mean of not less than three determinations for both the test specimen and the reference specimen.

7 Falling sand abrasion test

7.1 Principle

Dry silicon carbide particles fall onto a small area of the surface to be tested. The test is continued until the substrate metal is exposed, after which the abrasion resistance of the coating is calculated from the time taken.

7.2 Apparatus

7.2.1 Falling sand abrasion test apparatus

The test apparatus for this abrasion test comprises a hopper, a funnel, a shutter plate and a guide tube. The components of the apparatus shall comply with the requirements in Table 1; an example of a test apparatus is shown in Figure F.1.

Table 1 — Requirements for the falling sand abrasion test apparatus

Apparatus	Requirements
Funnel	The funnel shall be made of glass, have an angular aperture of 60°, an inside diameter at the hopper end of 70 mm, a leg length of 50 mm, an inside diameter of the leg of 5,0 mm ± 0,4 mm, with a smooth finish on the inside lower part of the funnel and inside the leg, and be capable of delivering abrasive particles at the rate of 320 g/min ± 10 g/min. The rate of delivery of abrasive particles shall be controlled by moving up and down a control bar suspended at the centre of the funnel.
Guiding tube	The guiding tube shall measure 970 mm in length and 20 mm in inside diameter.
Test specimen-supporting stage	The test specimen-supporting stage shall be capable of fixing a test specimen at 45° ± 1° to the vertical, and of adjusting the distance between the lower end of the guiding tube and the test specimen to 30 mm ± 2 mm.

7.2.2 Ohmmeter

The ohmmeter, which is used for checking the exposed substrate metal surface of the test specimen, shall meet the following conditions:

a) scale of 5 000 Ω shall be accurately indicated;

b) tip of contact probe shall have a smooth, spherical surface.

7.2.3 Abrading medium

The grit designation of abrading mediums shall be silicon carbide of F80 in accordance with ISO 8486-1. The abrading medium shall not be reused more than 50 times.

7.3 Test specimen

7.3.1 Sampling

See 5.3.2.1.

7.3.2 Size

The standard size of the test specimen should be 100 mm × 100 mm.

7.3.3 Treatment before testing

See 5.3.2.3.

7.4 Test environment

The testing environment should be at room temperature and the relative humidity should be under 65 %.

7.5 Test conditions

The angle of the test specimen to the falling sand shall be 45° ± 1°.

The distance through which the abrading mediums fall shall be 1 000 mm.

The rate of delivery of the abrading mediums shall be 320 g/min ± 10 g/min.

7.6 Test procedure

7.6.1 General

The test shall be carried out by either the procedure described in 7.6.2 or in 7.6.3.

7.6.2 Electrical conductivity method

In this method, the end point shall be determined by measurement using an ohmmeter.

a) Put abrading mediums into the hopper and open the shutter to let them fall for about 1 min. Then confirm the quantity of falling abrading mediums to be in the specified range (320 g/min ± 10 g/min). If they are not in this range, adjust the control bar up or down to correct the position.

b) Fix the test specimen on the test specimen-supporting stage, keeping the surface of the specimen to be tested at an angle 45° to the vertical.

c) Fix the test specimen-supporting stage in the position where the surface of the test specimen is 30 mm from the lower edge of the guide tube.

d) Open the shutter to let the abrading mediums fall until the substrate metal surface is exposed (visible by a colour change) and determine the time (t), in seconds, during which the abrading mediums were falling.

e) Repeat the operation described in d) at several places on other areas of the test specimen for times t ± 10 %. Select the subsequent test positions at 15 mm horizontally and 25 mm orthogonally to the horizontal on the specimen surface. It is not permitted to stop the abrading mediums falling during a test.

f) After stopping the sand falling, clean the surface of the test specimen with a soft, dry cloth.

g) Measure the electrical resistance between the substrate metal and the tested surface with the ohmmeter. Measurements shall be carried out three times at each test area using the tip of the contact probe. It shall be deemed that the substrate metal has been exposed if at least one test value is below 5 000 Ω.

7.6.3 Spot diameter method

In this method, the end point shall be determined by visual observation.

a) Put abrading mediums into the hopper and open the shutter to let them fall for about 1 min. Then confirm the quantity of falling abrading mediums to be in the specified range (320 g/min ± 10 g/min). If they are not in this range, adjust the control bar up or down to the correct position.

b) Fix the test specimen on the holder, keeping the surface of the specimen to be tested at an angle of 45° to the vertical.

c) Fix the holder in the position where the surface of the test specimen is 30 mm from the lower edge of the guide tube.

d) Open the shutter to let the abrading mediums fall until the surface of substrate metal is exposed as an area about 2 mm in diameter (visible by a colour change) and record the time (t), in seconds, during which the abrading mediums fell.

e) Repeat the operation as described in d) two or more times at other areas of the test specimen for times t ± 10 %. Select the subsequent test positions at 15 mm horizontally and 25 mm orthogonally to the horizontal on the specimen surface. It is not allowed to stop the abrading medium falling during a test.

7.7 Expression of results

7.7.1 Electrical conductivity method

The test results shall be expressed either as the shortest time (t_{min}), in seconds, needed for the abrasion of the anodic oxidation coatings to expose the substrate metal or as the wear resistance, R_{WF}, in units of s/µm, using Formula (8):

$$R_{WF} = \frac{t_{min}}{d} \tag{8}$$

where

t_{min} is the shortest time, in seconds, for the substrate metal to be exposed;

d is the coating thickness, in micrometres, before the wear resistance test.

7.7.2 Spot diameter method

The test results shall be expressed as the shortest time (t_{min}), in seconds, needed for the abrasion to expose the substrate metal as a small black spot about 2 mm in diameter.

8 Test report

The test report shall include at least the following information:

a) a reference to this document, i.e. ISO 8251:2018;

b) identification of the test specimen and, if appropriate, the standard specimen and/or the reference specimen;

c) the apparatus used;

d) the number of test points and their location on the test surface;

e) any other observations concerning the conduct of the test or the nature of the test specimen or test area;

f) any deviations from the procedure;

g) any unusual features observed;

h) the date of the test;

For the abrasive-wheel-wear test, the following additional information shall be included:

i) the force between the abrasive wheel and test surface;

j) the abrading medium used;

k) the expression of results, as required, of wear resistance, mass wear resistance, wear index, mass wear index or other expressions (see Annex B);

For the abrasive jet test, the following additional information shall be included:

l) the angle between the plane of the test area and the jet axis;

m) the abrading medium and its particle size;

n) the air or gas pressure;

o) the value of the mean specific abrasion resistance or the relative mean specific abrasion resistance;

For the falling sand abrasion test, the following additional information shall be included:

p) the abrading medium used and its particle size;

q) the expression of results of wear resistance in the case of an electrical conductivity method or the shortest abrasive time in the case of a spot diameter method.

Annex A
(normative)

Preparation of the standard specimen

A.1 General

A standard specimen made of aluminium shall be used for change in thickness and mass (see A.2).

Alternatively, if agreed between the interested parties, a standard specimen made of PMMA may be used for change in mass (see A.3).

A.2 Aluminium standard specimen

A.2.1 Aluminium specification

The aluminium standard specimen shall be prepared from polished or bright-rolled aluminium sheet as follows:

Aluminium specification:	Al 99,5	Al min. 99,5 %
Temper:	H14 or H24	
Normal test specimen size:	140 mm × 70 mm	
Thickness:	1,0 mm to 2,0 mm	

A.2.2 Pretreatment

Degreasing only (light caustic etching, electropolishing or chemical polishing is permissible).

A.2.3 Anodizing

Bath composition:

Free sulfuric acid concentration:	180 g/l ± 2 g/l
Aluminium concentration:	2 g/l to 10 g/l
Rest:	deionized water (ion-exchanged water)

Conditions of anodizing:

Temperature:	20 °C ± 0,5 °C
Current density:	1,5 A/dm^2 ± 0,1 A/dm^2
Agitation:	with large volumes of low pressure air from a blower, compressed air and/or solution circulation
Anodizing time:	45 min
Anodic coating thickness:	20 µm ± 2 µm

The aluminium standard specimen shall be anodized vertically with the longer axis horizontal in the bath, maintaining vigorous agitation over the anodic surface and smooth direct current with not more than 5 % ripple. Not more than 20 standard specimens shall be anodized at one time and the volume of the electrolyte shall be not less than 10 l per standard specimen.

NOTE 1 The standard specimens are most accurate and reproducible if anodized singly with careful control of all the conditions.

NOTE 2 The standard specimens have inherent variations of ± 10 %.

A.2.4 Sealing

Sealing shall be carried out for 60 min in boiling deionized water (ion-exchanged water) containing 1 g of ammonium acetate per litre, at pH 5,5 to 6,5.

A.3 PMMA standard specimen

The PMMA standard specimen shall be made of Poly(methyl methacrylate) (PMMA) sheet in accordance with ISO 7823-1.

Annex B
(informative)

Other expressions of results for the abrasive-wheel-wear test

B.1 Reference specimen

B.1.1 General

Due to the relatively high abrasion resistance of integral colour anodized specimens, testing of these finishes normally requires the use of a reference specimen produced by the same process in a comparative-wear-test.

B.1.2 Initial determination

Carry out an initial determination in accordance with 5.3.3. If the thickness loss in the test area is less than 3 µm, adjust the abrasion conditions either by increasing the force between the wheel and the test specimen surface, or by employing a coarser grade of silicon carbide paper. Alternatively, an increased number of double strokes may be used.

Unless a depth survey is being carried out (see Annex C), the abrasion conditions should be adjusted to give a coating thickness loss of (5 ± 3) µm after 400 ds. If loss of mass is to be determined, the mass equivalent of (5 ± 3) µm coating thickness is required to be known. This necessitates an assumption to be made about the coating density or, alternatively, this can be estimated by means of ISO 2106.

B.1.3 Test procedure

B.1.3.1 General

Comparison of the abrasion of the test specimen can be made with that of a reference specimen. In this case, either comparative loss in thickness or comparative loss in mass can be determined. The comparative wear rate and comparative mass wear rate are expressed as a percentage of that of the reference specimen.

B.1.3.2 Comparative loss of thickness

Determine the loss in thickness of the test specimen and of the reference specimen under the conditions established in B.1.2, using the procedure specified in 5.3.3.

Calculate the comparative wear rate in accordance with B.1.4.1.

B.1.3.3 Comparative loss of mass

Determine the loss in mass of the test specimen and of the reference specimen under the conditions established in B.1.2, using the procedure specified in 5.3.3.

Calculate the comparative mass wear rate in accordance with B.1.4.2.

B.1.4 Expression of results

B.1.4.1 Comparative wear rate

The comparative wear rate, R_{CW}, can be expressed using Formula (B.1):

$$R_{CW} = \frac{d_{1r} - d_{2r}}{d_{1t} - d_{2t}} \times 100 \qquad \text{(B.1)}$$

where

d_{1r}	is the average thickness, in micrometres, of the reference specimen before abrasion;
d_{2r}	is the average thickness, in micrometres, of the reference specimen after abrasion;
d_{1t} and d_{2t}	are as defined in 5.4.4.

B.1.4.2 Comparative mass wear rate

The comparative mass wear rate, $R_{CW,\,m}$, can be expressed using Formula (B.2):

$$R_{CW,\,m} = \frac{m_{1r} - m_{2r}}{m_{1t} - m_{2t}} \times 100 \qquad \text{(B.2)}$$

where

m_{1r}	is the average mass, in milligrams, of the reference specimen before abrasion;
m_{2r}	is the average mass, in milligrams, of the reference specimen after abrasion;
m_{1t} and m_{2t}	are as defined in 5.4.5.

B.2 Standard specimen

B.2.1 General

The standard specimen and the test specimen may be tested and expressed by the following.

B.2.2 Test procedure

Determine the average thickness or the average mass of the standard specimen and the test specimen using the procedure specified in 5.3.3.

B.2.3 Expression of results

B.2.3.1 Wear resistance coefficient

The wear resistance coefficient, C_{WR}, can be expressed using Formula (B.3):

$$C_{WR} = \frac{R_{W,t}}{R_{W,s}} = \frac{d_{1s} - d_{2s}}{d_{1t} - d_{2t}} \qquad \text{(B.3)}$$

where

$R_{W,t}$ is the wear resistance, in double strokes per micrometre, of the test specimen;

$R_{W,s}$ is the wear resistance, in double strokes per micrometre, of the standard specimen;

d_{1s}, d_{2s}, d_{1t} and d_{2t} are as defined in 5.4.4.

B.2.3.2 Mass wear resistance coefficient

The mass wear resistance, C_{MWR}, coefficient can be expressed using Formula (B.4):

$$C_{MWR} = \frac{R_{MW,t}}{R_{MW,s}} = \frac{m_{1s} - m_{2s}}{m_{1t} - m_{2t}} \qquad (B.4)$$

where

$R_{MW,t}$ is the wear resistance, in double strokes per milligram, of the test specimen;

$R_{MW,s}$ is the wear resistance, in double strokes per milligram, of the standard specimen;

m_{1s}, m_{2s}, m_{1t} and m_{2t} are as defined in 5.4.5.

Annex C
(informative)

Depth survey of abrasion resistance

C.1 General

It can be necessary to establish the way in which abrasion or wear resistance changes through the thickness of anodic oxidation coatings and to determine this it is necessary to carry out a depth survey. This annex describes methods for determining the resistance to abrasion of anodic oxidation coatings on aluminium, progressively throughout the coating.

C.2 Abrasive-wheel-wear test

C.2.1 Principle

A test specimen is abraded on a single test area with a succession of abrasions until the substrate metal is revealed. The coating thickness is measured at the beginning and after each abrasion.

C.2.2 Apparatus

Use the apparatus specified in 5.2.

C.2.3 Procedure

C.2.3.1 Determination

C.2.3.1.1 Measure the average coating thickness of the test specimen as specified in 5.3.3.2. Locate the test specimen precisely in the apparatus by means of positioning pins or stops attached to the test specimen-supporting stage, so that successive abrasions can be carried out on a single test area.

C.2.3.1.2 Carry out the first abrasion as specified in 5.3.3.4 and 5.3.3.5, using only 20 ds to 50 ds according to the anticipated hardness. Remove the test specimen and determine the average coating thickness in the area as described in 5.3.3.6.

C.2.3.1.3 Relocate the test specimen accurately in the apparatus and repeat the procedure as specified in C.2.3.1.2 for a further appropriate adequate number of double strokes (see Note 1). Repeat the operations of abrasion and thickness determination using an appropriate number of double strokes until the substrate metal is just revealed.

NOTE 1 A typical number of double strokes is: 50 – 100 – 200 – 400 – 800 and 1 200.

NOTE 2 Where accurate relocation of the test specimen is difficult or doubtful, the same result can be achieved by successive tests of increasing duration on a series of adjacent test areas.

C.2.4 Expression of results

Calculate the change in resistance to wear through the coating thickness, and the appropriate wear indices or wear resistance coefficients for any part of the coating using, if required, a graph of coating thickness plotted against the number of double strokes used.

NOTE The result of a depth survey can be related to that carried out on a standard specimen, if required.

C.3 Abrasive jet test and falling sand abrasion test

C.3.1 Principle

A test specimen is abraded at a series of positions for increasing periods of time, the maximum time being that taken to penetrate or reveal the coating completely (see 6.3.3.6 and 7.6). The mean specific abrasion resistance or wear resistance is calculated at required depths through the coating.

C.3.2 Apparatus

Use the apparatus specified in 6.2 and 7.2.

C.3.3 Procedure

C.3.3.1 Test specimen

Use a test specimen not less than 70 mm × 70 mm, prepared as follows.

a) If using the falling sand abrasion test, clean the specimen.

b) Mark the positions of between 6 and 12 test sites on the surface of the test specimen so that they are separated by intervals of 10 mm and 20 mm along and across the test specimen respectively.

c) Using an eddy-current meter fitted with a small probe of tip diameter less than 1 mm, measure the initial coating thickness accurately at each test site, using the method specified in ISO 2360.

C.3.3.2 Determination using the abrasive jet test

C.3.3.2.1 Prepare the apparatus in accordance with 6.3.3 and 6.3.4.

C.3.3.2.2 Position the first test site of the test specimen beneath the jet orifice at the correct angle and abrade the test specimen until the coating is just penetrated completely.

Note the time (t) taken, in minutes, and divide this by the number of remaining test sites (n−1) to derive a unit value for abrasion time, t^*, where $t^* = t / (n-1)$.

C.3.3.2.3 Using the same conditions, abrade the second test site for t^* min, the third test site for $2t^*$ min and so on, until all of the test sites have been abraded. Record the mass of silicon carbide used for each test site.

C.3.3.2.4 After completing abrasion at a given test site, remove the test specimen, clean the test surface with a soft cloth and, using the method specified in ISO 2360, carefully measure the minimum coating thickness remaining at that site. The eddy-current meter used for the measurement should be provided with a probe of diameter less than 1 mm. Confirm the zero thickness using, for example, a low-voltage continuity probe.

C.3.3.2.5 Carry out a separate test on a standard specimen (see Annex A) to determine the abrasive jet factor, K (see 6.4.2).

C.3.3.3 Determination using the falling sand abrasion test

C.3.3.3.1 Prepare the apparatus in accordance with 7.4, 7.5 and 7.6.2 a).

C.3.3.3.2 Position the first test site of the test specimen where the sand will fall on it in accordance with 7.6.2 b) and 7.6.2 c), and abrade the test specimen until the coating is just penetrated completely. This may be verified by using an ohmmeter when the contact resistance is below 5 000 Ω, or by visual observation when the exposed area of the substrate metal surface is about 2 mm in diameter (visible by a colour change). Note the time (t) taken, in minutes, and divide this by the number of remaining test sites (n−1) to derive a unit value for abrasion time, t^*, where $t^* = t / (n-1)$.

C.3.3.3.3 Using the same conditions, abrade the second test site for t^* min, the third test site for $2t^*$ min and so on, until all of the test sites have been abraded. Record the mass of silicon carbide used for each test site.

C.3.3.3.4 After completing abrasion at a given test site, remove the test specimen, clean the test surface with a soft cloth and, using the method specified in ISO 2360, carefully measure the minimum coating thickness remaining at that site. The eddy-current meter used for the measurement should be provided with a probe of diameter less than 1 mm.

C.3.4 Expression of results

C.3.4.1 For each test site calculate

a) the thickness, in micrometres, of the coating removed, and

b) the corresponding abrasion value using Formulae (C.1) and (C.2):

for the abrasive jet test

$$t_S K \text{ or } mK \tag{C.1}$$

for the falling sand abrasion test

$$t_S \text{ or } m \tag{C.2}$$

where

K is the abrasive jet factor;

t_S is the abrasion time, in seconds;

m is the mass, in grams, of silicon carbide powder delivered.

C.3.4.2 Plot a graph with the number of micrometres of coating removed as the abscissa, and the corresponding abrasion values (see C.3.4.1) as the ordinate. The slope at any point on the graph is the specific abrasion resistance of the coating over the depth of the coating.

The abrasive jet test is not applicable to coating of less than 5 µm, in thickness. The portion of the graph immediately below this value should be extrapolated from the point just above it, although results obtained from this part of the graph can be subject to experimental error.

Annex D
(informative)

Design of abrasive-wheel-wear test apparatus

D.1 No restriction is placed upon the design of the abrasion-wheel-wear test apparatus, provided that it conforms with the general principles given in 5.2.

D.2 Figure D.1 shows the basic design and layout of a suitable test apparatus.