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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.

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 8251 was prepared by Technical Committee ISO/TC 79, *Light metals and their alloys*, Subcommittee SC 2, *Organic and anodic oxidation coatings on aluminium*.

This second edition cancels and replaces the first edition (ISO 8251:1987) as well as ISO 8252:1987, which have been technically revised.

The main changes compared to the first edition are as follows:

a) the inclusion of the test previously described in ISO 8252:1987;

b) the inclusion of the falling sand test;

c) the use of the methods for coatings produced by hard anodizing has been moved to ISO 10074:2010.

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, may be readily detected by means of an abrasive wear resistance test.

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

1 Scope

This International Standard specifies the following three test methods:

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

b) **abrasive jet test method**, comparing the resistance to abrasion of anodic oxidation coatings on aluminium and its alloys with that of a standard specimen or, alternatively, a reference specimen, by use of a jet of abrasive particles;

c) **falling sand abrasion method**, determining the abrasion resistance with falling sand applied to thin anodic oxidation coatings.

The use of these methods for coatings produced by hard anodizing is described in ISO 10074.

2 Normative references

The following referenced documents are indispensable for the application 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 565:1990, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings*

ISO 2360:2003, *Non-conductive coatings on non-magnetic electrically conductive basis materials — Measurement of coating thickness — Amplitude-sensitive eddy-current method*

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

ISO 8486-1:1996, *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 following terms and definitions apply.

3.1
test specimen
specimen on which the test is to be carried out

3.2
standard specimen
test specimen produced in accordance with the conditions specified in Annex A

3.3
reference specimen
test specimen produced under conditions agreed between the anodizer and the customer

3.4
double stroke
ds
one complete reciprocal movement made by the abrasive wheel

4 Characteristics of abrasion tests

There are three kinds of abrasion tests: abrasive-wheel-wear test, abrasive jet test and falling sand abrasion test.

4.1 Abrasive-wheel-wear test

Determination of the resistance to abrasion 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 method described. For most purposes the wear index (see 5.4.3) or the mass wear index (see 5.4.4) will be the most appropriate characteristic to determine.

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

This method is not applicable to concave or convex specimens; these may be examined using the abrasive jet test method which will give an average value for the abrasive resistance of the coating (see 4.2 and Clause 6).

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

4.2 Abrasive jet test

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

NOTE 1 Different batches of the same abrasive are liable to give different results and for this reason the test is a comparative one.

NOTE 2 With a suitably designed abrasive jet and film-thickness-measuring devices with a small probe, it is possible to conduct a depth survey which indicates how abrasion resistance varies through the coating thickness (see Annex B). However, this property is preferably measured using the abrasive-wheel-wear test.

The method described 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 method. Production components may be tested without cutting if the apparatus chamber can accommodate these.

NOTE 3 This method is particularly suitable for small test specimens because the individual test area required is only about 2 mm in diameter.

4.3 Falling sand abrasion test

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

The method described is applicable to the thin anodic oxidation coatings.

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 or wear index. This result is compared with that obtained using a standard specimen (see Annex A) or reference specimen (see 3.3).

The method 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 B).

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 (see 5.3.2) 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 (see 5.2.2). 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 C.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 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 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 (in accordance with ISO 6344-1) 12 mm wide. Its length shall be such that it covers the abrasive wheel without overlapping, and it shall be either bonded or mechanically clamped 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.

5.3 Procedure

5.3.1 Standard specimen

Prepare the standard specimen using the method specified in Annex A.

5.3.2 Test specimen

Cut a suitably sized test specimen from the item to be tested without damaging the area to be tested.

Test dimensions of 50 mm × 50 mm are usually required.

5.3.3 Calibration of apparatus

5.3.3.1 Select and mark the area of the standard specimen (see 5.3.1) to be abraded. Accurately measure the anodic oxidation coating thicknesses in each of at least three positions along the test area by means of the eddy-current meter (see 5.2.3) in accordance with the method specified in ISO 2360 and calculate an average thickness value (d_1).

5.3.3.2 Clamp the standard specimen into position on the apparatus (see 5.2.1).

5.3.3.3 Attach a new strip of silicon carbide paper (see 5.2.2) to the circumference of the abrasive wheel. Adjust the abrasive wheel, in accordance with the manufacturer’s instructions, so that it gives uniform abrasion across the width of the test area. Adjust the force between the wheel and the test surface to 3,9 N ± 0,1 N.

5.3.3.4 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. Keep the abrasive action uniform by adjusting and maintaining the alignment of the abrasive wheel in accordance with the manufacturer's instructions. Continuously remove any abrasion detritus by suction, blowing or frequent wiping with a fine brush.

5.3.3.5 Remove the standard specimen from the apparatus, wipe carefully to remove any loose oxide and determine the average thickness of the coating at the test area (d_2) using the eddy-current meter in accordance with 5.3.3.1.

A 3 mm length at one extremity of the test area may 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.

5.3.3.6 Carry out at least two further determinations on the standard specimen in test areas that do not overlap, using the procedure specified in 5.3.3.1 to 5.3.3.5.

5.3.3.7 Calculate the wear rate for the standard specimen (see 5.4.3) from the average of the determinations.

5.3.4 Determination

Take the test specimen (see 5.3.2) and carry out the procedure specified in 5.3.3.1 to 5.3.3.6 using abrasive strips from the same batch as that used for the calibration. 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 determination.

Calculate the wear rate for the test specimen and, from the wear rates for the standard specimen and for the test specimen, calculate the wear index in accordance with 5.4.3.

5.3.5 Use of a reference specimen

5.3.5.1 General

Because of 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 (see 3.3) in a comparative-wear-testing method (see 5.3.6).

5.3.5.2 Initial determination

Carry out an initial determination in accordance with 5.3.4. 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 B), 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 should be estimated by means of ISO 2106.

5.3.5.3 Determination

Determine the loss in thickness or loss in mass of the test specimen and the reference specimen under the conditions established in 5.3.5.2, following the procedure specified in 5.3.6.

Calculate the comparative wear rate in accordance with 5.4.5, or the comparative mass wear rate in accordance with 5.4.6, as appropriate.

5.3.6 Comparative wear testing

5.3.6.1 General

Comparison of the abrasion of the test specimen (see 5.3.2) can be made with that of a reference specimen (see 3.3) or with the standard specimen (see 3.2). In these cases, either comparative loss in thickness or comparative loss in mass can be determined. The comparative wear rate is expressed as a percentage of that of the reference specimen.

5.3.6.2 Comparative loss of thickness

Determine the loss in thickness of the test specimen and of the reference specimen using the procedure specified in 5.3.4.

Calculate the comparative wear rate in accordance with 5.4.5.

5.3.6.3 Comparative loss of mass

5.3.6.3.1 Select and mark the area of the test specimen to be abraded. Weigh the test specimen to the nearest 0,1 mg (m_1). Carry out the procedure specified in 5.3.3.2 to 5.3.3.4.

5.3.6.3.2 Remove the test specimen from the apparatus, wipe to remove any loose oxide and weigh to the nearest 0,1 mg (m_2).

Carry out at least two further determinations on the test specimen in test areas that do not overlap.

NOTE Freshly exposed anodic oxidation coatings can gain in mass by absorbing water vapour. Multiple tests on a single panel can therefore be subject to errors dependent upon variations in atmospheric humidity.

5.3.6.3.3 Repeat the procedure specified in 5.3.6.3.1 and 5.3.6.3.2 on the reference specimen. Calculate the comparative mass wear rate in accordance with 5.4.6.

5.4 Calculation of results

The calculation of results shall be chosen from the following.

5.4.1 Wear resistance

Calculate the wear resistance, WR, in double strokes per micrometre, using Equation (1):

$$\mathrm{WR} = \frac{400}{d_1 - d_2} \qquad (1)$$

where

d_1 is the average thickness, in micrometres, before abrasion (see 5.3.3.1);

d_2 is the average thickness, in micrometres, after 400 ds abrasion (see 5.3.3.5).

5.4.2 Wear resistance coefficient

Calculate the wear resistance coefficient, WRC, using Equation (2):

$$\mathrm{WRC} = \frac{\mathrm{WR_t}}{\mathrm{WR_s}} = \frac{d_{1\mathrm{s}} - d_{2\mathrm{s}}}{d_{1\mathrm{t}} - d_{2\mathrm{t}}} \qquad (2)$$

where

$\mathrm{WR_t}$ is the wear resistance, in double strokes per micrometre, of the test specimen;

$\mathrm{WR_s}$ is the wear resistance, in double strokes per micrometre, of the standard specimen;

$d_{1\mathrm{s}}$ is the average thickness, in micrometres, of the standard specimen before abrasion (see 5.3.3.1);

$d_{2\mathrm{s}}$ is the average thickness, in micrometres, of the standard specimen after 400 ds abrasion (see 5.3.3.5);

$d_{1\mathrm{t}}$ is the average thickness, in micrometres, of the test specimen before abrasion (see 5.3.3.1);

$d_{2\mathrm{t}}$ is the average thickness, in micrometres, of the test specimen after 400 ds abrasion (see 5.3.3.5).

NOTE The wear resistance coefficient is the reciprocal of wear index and is a measure of resistance to abrasive wear. The wear resistance coefficient of a standard specimen is 1. Values greater than 1 indicate a lower degree of wear than that on the standard specimen. Values less than 1 indicate a greater degree of wear than that on the standard specimen.

5.4.3 Wear index

Calculate the wear index, WI, using Equation (3):

$$\mathrm{WI} = \frac{W_\mathrm{t}}{W_\mathrm{s}} = \frac{d_{1\mathrm{t}} - d_{2\mathrm{t}}}{d_{1\mathrm{s}} - d_{2\mathrm{s}}} \qquad (3)$$

where

W_t is the wear rate of the test specimen, in micrometres per 100 ds;

$$W_\mathrm{t} = \frac{d_{1\mathrm{t}} - d_{2\mathrm{t}}}{4}$$

$d_{1\mathrm{t}}$ and $d_{2\mathrm{t}}$ are as defined in 5.4.2.

