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Thermal spraying — Determination of tensile adhesive strength

Projection thermique — Mesure de l'adhérence par essais de traction

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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 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 107, *Metallic and other inorganic coatings*.

This second edition cancels and replaces the first edition (ISO 14916:1999), which has been technically revised.

Introduction

The determination of the tensile adhesive strength of a thermal spray coating can play an important role in the quality control of production. Deviations from the normal and qualified procedure can be recognized when preparing and spraying a component.

If the fracture occurs cohesively in the coating when applying the tensile adhesive strength test, the coating's strength in the direction normal to the surface is supplied. Influences of variations in spray conditions can be identified via proper interpretation of tensile test results. Microscopic investigations of the fractured surface can supply further information for judging the quality of the coating's structure.

A revision of the existing document had been required as a result of the identification of significant influences on the test results caused by the tensile test bonding procedure and by the properties of the adhesive itself. These findings were not adequately covered in the previous version of this document.

Thermal spraying — Determination of tensile adhesive strength

1 Scope

This document specifies the procedure to determine the tensile adhesive strength of thermally sprayed coatings under tension in the direction normal to the surface of the coating by applying a tensile test. By using this procedure, comparability of the test results is ensured.

The test is intended to determine the tensile adhesive strength between the thermally sprayed coating and the substrate material or between the bond and top coat and/or of the cohesive strength of the related coat of the coating system. In some cases, thermally sprayed coatings might have more than two layers. The method specified in this document applies also to determine the tensile adhesive strength between the interfaces of different layers in a coating system which consists of more than two layers.

This test is sufficient to compare coatings manufactured using same or similar feedstock materials and thermal spray processes with each other. The tensile adhesive strength test is not intended to provide absolute values for evaluation of the durability of coatings under operational use.

The test is used to assess the influence of substrate preparation, the spraying conditions and the process parameter on the tensile adhesive strength of thermally sprayed coatings. It can also be employed in order to monitor the consistency of the manufacturing and spraying processes.

NOTE This tensile test can also be applied to very thin coatings. Moreover, the infiltration of bonding agent into the thermally sprayed coatings containing a required level of porosity can be minimized using an appropriate bonding agent (foil rather than liquid). For further instructions, please refer to 6.5.3. This tensile test is inappropriate for determining the adhesive strength of fused spray coatings deposited using self-fluxing alloys due to their inherent high adhesion strength values.

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 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 14917, *Thermal spraying — Terminology, classification*

EN 13507, *Thermal spraying — Pre-treatment of surfaces of metallic parts and components for thermal spraying*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.iso.org/obp

3.1
adhesive strength
R_H
tensile strength measured in the tension test, which is calculated from the quotient of the maximum load F_{max} and the cross-section area of the fractured face

3.2
adhesive failure
fracture, which runs along the interface between coating and substrate

Note 1 to entry: The coating will be totally separated away from the substrate.

Note 2 to entry: The inter-particle bonding (cohesive strength) is higher than the adhesive strength of the coating.

3.3
cohesive failure
fracture, which takes place within the coating

Note 1 to entry: The inter-particle bonding (cohesive strength) is lower than the adhesion strength of the coating.

3.4
adhesive-cohesive failure
fracture, which is partially located in the interface of the coating to the substrate and partially within the coating

3.5
internal adhesive strength
adhesive strength between the layers of a coating system, e.g. between a bond and top coat

3.6
test disc
test specimen formed like a disc coated on one side

Note 1 to entry: This is to be positioned and glued between two loading blocks when preparing the tensile test specimen.

3.7
reference specimen
specimen for determination of the strength of bonding agent

Note 1 to entry: This consists of two uncoated loading blocks glued together using the same joining procedure as for all other tested specimens.

4 Principles

The test methods listed in this document are recommended for quality control or characterization of coatings and/or coating systems in order to improve thermal spray processes or to develop coatings with increased adhesive and cohesive strength as well as with improved microstructure.

Thermally sprayed coatings exhibit as a thumb of rule — inherent to the characteristics of the process — a porous microstructure. Due to the requirements of their targeted application areas, they may contain a high level of porosity. Due to the possibility of infiltration of the coating by the bonding agent, the porous character of a coating can be unfavourable. The development of incorrect types or quantities of bonding agents can lead to significant changes in the coating properties so that the measurement results can be invalid.

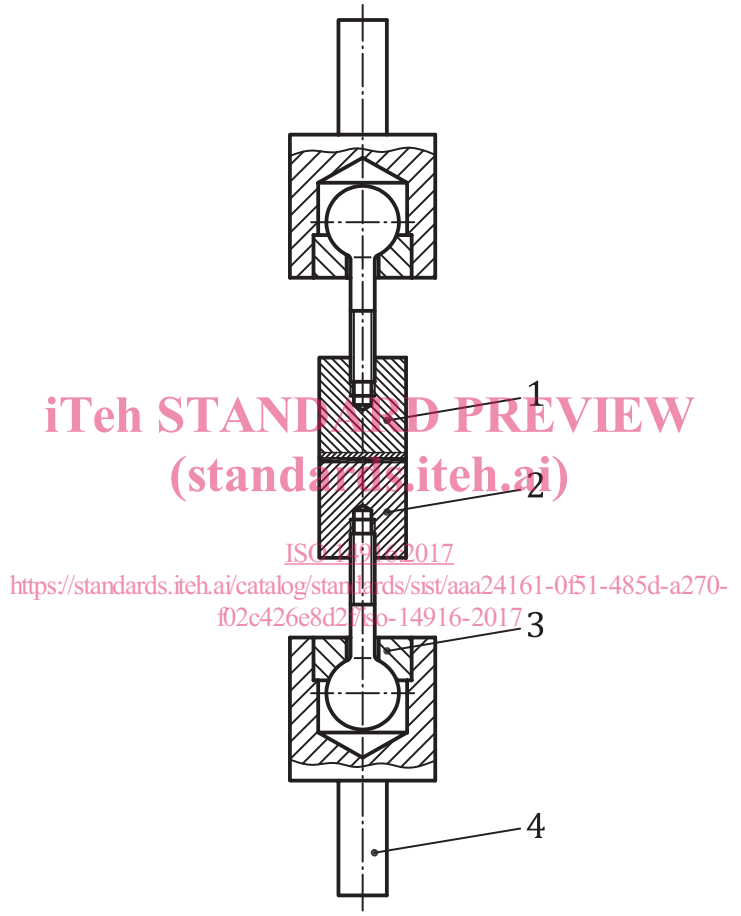
Furthermore, only loads normal to the coating surface, which are free of bending or torsion moments, shall be applied during tensile loading. Therefore, adequate clamping and centring devices shall be used during the entire manufacturing process of the test specimens and during the testing.

5 Equipment for testing and measuring and auxiliary equipment

5.1 Test instruments

A tensile testing machine according to ISO 7500-1, class 1, with a suitable clamping system shall be used, which ensures clamping and loading of the specimens through the centre line following no bending and torsion moments.

This can be achieved by a ball joint which is specified in this document (for details, see Figure 1) or by a universal suspension [examples are according to ASTM C633-13 (see Figure B.4), EN 13144 and ISO 13779-4). The M16 threaded drill hole shall bear and transfer the load to the specimen.].



Key

1 loading block
2 substrate block
3 ball joint
4 clamping part

Figure 1 — Arrangement for the tensile adhesion test with test specimen according to form A

5.2 Measurement instrument

Measurements can be carried out, when preparing the loading block and test specimens, using measurement instruments in accordance with standard commercial practices. Recommendations and examples for special gauges to measure the concentricity (see Figure B.2) and parallelism of specimens with a 25,0 mm diameter are given in Annex B.

5.3 Specimen fixing device for bonding of the tensile adhesive specimen

A fixing apparatus, which keeps the angular and axial deviation of the blocks as low as possible, shall be used in order to glue the loading block to the substrate block (or to the test disc). Furthermore, fixing the apparatus shall ensure the application and maintaining of the required contact pressure over the entire gluing process.

NOTE These objectives can be achieved by using a V-block fixture for centring. Using the fixture, the coaxial alignment and a sufficient contact pressure can be maintained so that substrate and loading block (see Figure 2 for details) or two loading blocks and a test disc (see Figure 3 for details) can be joined together to form a tensile adhesion specimen with required tolerances.

When applying the required contact pressure (generally low), it shall be ensured that neither bending nor torsion moments affect the bonding joint.

Consideration should be given to defining the value of the required contact pressure. The contact pressure shall be possibly constant over the entire temperature range during application and hardening of the bonding agent. If the weight of the top loading block, with respect to the substrate block, is inadequate to create the required load, then loading by means of a spring is recommended.

NOTE In case of a spring with an appropriate thread as an intermediate element, the displacement is controlled, set by the number of screw revolutions, and is transferred into force. In this way, the contact pressure can be set precisely by controlling the total number of screw revolutions. Formula (1) is valid for the calculation of the required revolutions of the screw for setting-up of the necessary contact pressure.

$$n = \frac{p \times \pi \times d^2}{4 \times c \times s} \tag{1}$$

where

- n number of revolutions of the screw;
- p necessary contact pressure (Pa);
- d diameter of the substrate block (m);
- c spring constant (N/m);
- s pitch length (m).

In order to avoid deviations of the spring's force during heating and hardening of the bonding agent, the spring shall be made out of a suitable steel. An adequate device is shown in Figure B.1.

6 Specimens

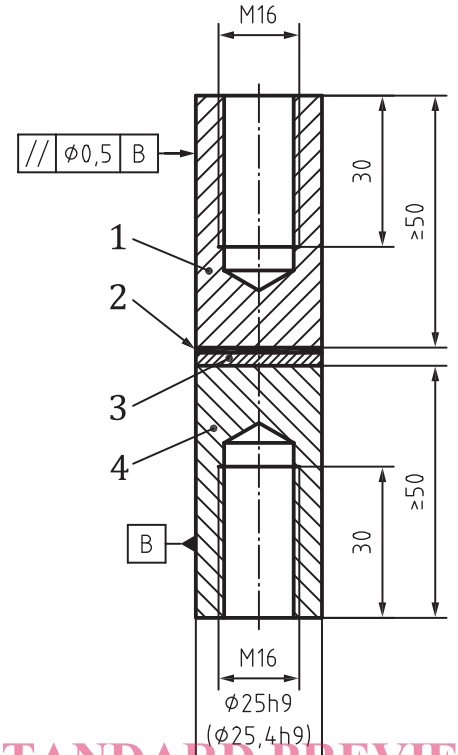
6.1 Shape of specimens

For the determination of the tensile strength when applying the tensile test, specimens of shape A or B with diameters of 25,0 mm (respectively 25,4 mm) or 40 mm shall be used. The smaller diameter (25,0 mm or 25,4 mm) shall be preferred where possible.

Specimen A (see Figure 2) consists of a substrate block, to which the coating is frontally applied, and the loading block which is glued to the surface of the thermally sprayed coating.

Specimen B (see Figure 3) consists of two loading blocks and a test disc. The test disc coated on one side is glued to the two loading blocks.

Dimensions in millimetres

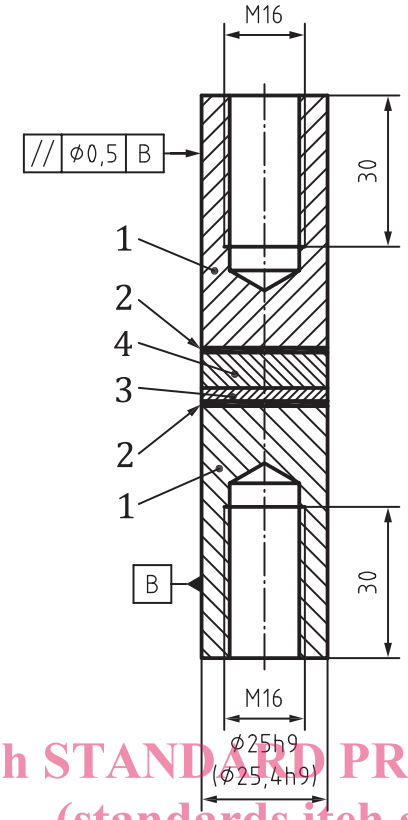


Key

1 loading block
2 adhesive bond
3 coating
4 substrate block

Figure 2 — Specimen A for tensile test

Dimensions in millimetres



Key

1 loading block
2 adhesive bond
3 coating
4 disc (according to Figure 6)

Figure 3 — Specimen B for tensile test

6.2 Material of the specimen

The same material (and surface preparation) shall be used for the specimens as for the actual component. If this is not feasible, a material shall be used which is comparable in strength, chemical and physical properties to the material of the component. Identical surface preparation and coating conditions shall be used.

If the substrate and loading blocks used are made of materials which are prone to work hardening, the deformation of screw threads inside the blocks might lead to invalid results. The acceptance should be arithmetically proofed.

6.3 Preparing the substrate and loading blocks

The parts for the tensile test specimen (loading and substrate blocks) are to be manufactured according to Figure 4. In the case of the test disc, manufacture shall be realized according to Figure 6.

The frontal faces of the blocks or that of the test disc shall be perpendicular to the longitudinal axis. This can be assured using a bevelling edge square.

The flat faces of the test disc according to form B shall be flat and parallel. For details, see Figure 6.