Thermal spraying — Determination of shear load resistance of thermally sprayed coatings

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ICS 25.220.20

National foreword

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Thermal spraying - Determination of shear load resistance of thermally sprayed coatings

Projection thermique - Détermination de la résistance au cisaillement des revêtements obtenus par projection thermique

Thermisches Spritzen - Bestimmung des Scherbeanspruchungswiderstandes bei thermisch gespritzten Schichten

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Foreword

This document (EN 15340:2007) has been prepared by Technical Committee CEN/TC 240 “Thermal spraying and thermally sprayed coatings”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2007, and conflicting national standards shall be withdrawn at the latest by September 2007.

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Introduction

The test is conducted to determine the shear load resistance of the bond between the spray deposit and the parent material (adhesive strength) and/or the strength of the coating itself (cohesive strength). If adhesive strength of the sprayed coating to the base material supersedes the cohesive strength, primarily the cohesive strength of the deposit is determined. During the test the coating is loaded parallel to the interface of coating/substrate.

The test is used to evaluate the effects of parent material and spray material, surface preparation of the work piece before spraying, and the spraying conditions on the adhesive and/or cohesive strength of thermally sprayed coatings, or for quality control and routine supervision of the spray works.

1 Scope

This European Standard specifies the procedure for determination of the shear load resistance of thermally sprayed coatings, provided that a minimum thickness is given.

Additionally this European Standard defines the shear load resistance and the designation of the fracture's structure on the test specimen, which occurs when the shear adhesive or adhesive/ cohesive or cohesive strength of the coating or the coating system will be exceeded.

The test report is the basis for comparative statements regarding shear load resistance and structure of fracture.

NOTE The test for the determination of the shear load resistance is not recommended for sprayed coatings thinner than approximately 150 µm because the adjustment of shear distance becomes critical.

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.

EN 657:2005, *Thermal spraying — Terminology, classification*

EN ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system (ISO 7500-1:2004)*

ISO 1832, *Indexable inserts for cutting tools — Designation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 657:2005 and the following apply.

3.1
shear strength
FSa
maximum force that causes fracture of the specimen in the interface coating/substrate

NOTE This fracture mode is called "Mode 1".

3.2
shear adhesive/cohesive strength
FSa/c
maximum force that causes mixed fracture partially within coating material and partially in the interface coating/substrate

NOTE This fracture mode is called "Mode 2".

3.3
shear cohesive strength
FSc
maximum force that causes fracture of the specimen within the coating material

NOTE This fracture mode is called:

- "Mode 3a"
  - if in case of hard coatings continuous blistering of small or larger pieces of the coating occurs;
  - if soft and/or porous coatings will be compressed and continuously scraped off;
- "Mode 3b"
  - if the fracture path runs within the coating especially parallel to the interface coating/substrate and the coating part under the shear plate detaches in one piece

3.4
shear energy
ES
area below the force displacement curve provided by the shear test

NOTE The energy ES up to the first shear force maximum can be calculated using the force-displacement curve provided by the shear test. The energy ES relates to the energy absorption of the coating-substrate system until failure.

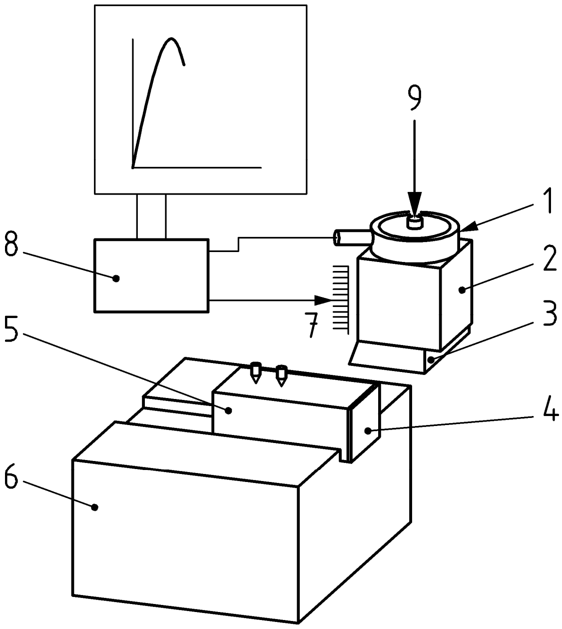
3.5
shear distance
d
distance between interface coating/substrate and the edge of the shear plate

3.6
shear load resistance
value of the first maximum of the load during the shear test process

4 Equipment

The shear test may be performed using a universal testing machine in accordance with EN ISO 7500-1 class 2.5 or using stand alone desk top machine which fulfils the corresponding requirements for accuracy and reproducibility.

The construction of the testing machine shall be able to apply a force required for the operation. The principle of the testing set up is demonstrated in Figure 1.



Key

1 load cell
2 guided punch
3 shear plate (cutting tool)
4 coating
5 specimen
6 specimen holder
7 displacement gauge
8 data processing
9 test load

Figure 1 — Principle of shear test

An exact fixation and alignment of the specimen in the specimen holder is necessary and any movement of the specimen during the shear test shall be avoided.

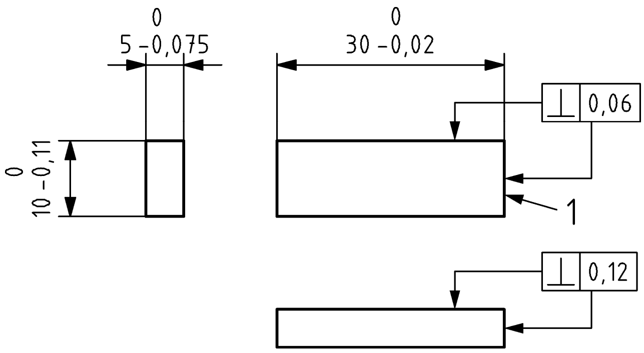
The shear plate is preferentially made of hard metal. A suitable cutting plate without “swarf crusher” (ISO 1832 standardized e.g. SP EW 120408 (turning, 11^0 clearance angle) or LC EW 1904PPF (milling, 7^0 clearance angle) ensures proper test conditions. The shear plate is fixed in a suitable manner to a punch or cantilever that allows a movement during loading in the guide ways without deviations or friction that affects the measured shear force. The edge of the shear plate shall be parallel to the interface coating/substrate and parallel to the upper face of the specimen. Thus a uniform loading of the coating is ensured.

5 Specimens

5.1 Shape

The dimensions of the specimen for the determination of the shear load resistance of sprayed coatings are shown in Figure 2.

Dimensions in millimetres



Key

1 area to be coated

Figure 2 — Dimensions of the specimen

The mentioned tolerances shall be complied with for measuring/adjusting the shear distance even from the back side of the specimens. For tolerances not specified ± 0,1 mm shall apply.

After surface preparation the coating is sprayed to the front area of 5 mm × 10 mm. When the specimens are coated in a rotating specimen holder safe fastening against centrifugal forces shall be ensured e.g. form-locking by pin and hole or notch, as shown in Figure 3.

Dimensions in millimetres

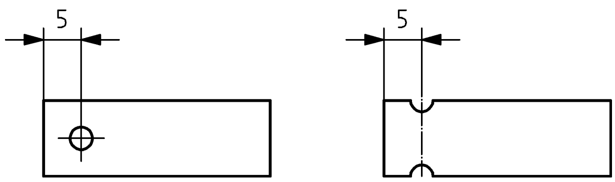


Figure 3 — Examples of specimen layout for form-locking safety of specimens during rotational coating

5.2 Preparation

The specimen is made of the specified material and shall be pre-treated in the same way as the work piece in practice. After surface preparation and before spraying, the length of the specimen has to be measured as a reference. The coating or the coating system is applied to the front face 5 mm × 10 mm. No spray material shall be deposited on the other sides. The coating thickness shall be constant. Spray conditions shall be equal to those of practical work. For spraying a set of specimens they may be inserted as a batch in an adequate specimen holder. In that case it has to be guaranteed that each specimen is mechanically separated, for example by thin copper foils. The separating elements shall not reach the coating area. Unavoidable overspray on the sides of the specimen shall be removed by abrasive paper (120 grit recommended) moving carefully from the coating to the substrate. Care shall be taken to ensure the perpendicular position of specimen faces after cleaning. Other post treatments should be done only if it belongs to the treatment of the work piece in practice.

Before carrying out the test, the coating thickness should be measured non-destructively or by metallographic examination on an accompanying specimen. Care shall be taken when measuring the coating thickness by slide gauge in order to avoid that measured values are not overestimated due to coating roughness and/or loosely bonded particles on the surface.

5.3 Number of specimens to be tested

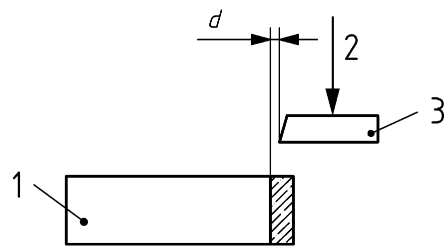
For statistical reasons, at least five specimens, spray deposited in one cycle, should be tested.

6 Procedure

Before performing the tests, the edge of the shear plate shall be inspected to prove that no damage has occurred during the preceding loading.

The coated specimen is inserted into the specimen holder of the test device. Concerning shear distance the roughness of the specimen shall be taken into account. Thus, the shear distance d shall be 50 µm ± 20 µm (see Figure 4). Within this range the distance does not have a significant influence on the result.

Then the specimen is securely clamped. Any movement of the specimen during loading, lateral, back, or tilting shall be avoided. The coating is loaded according to Figures 1 and 4 by thrust of the shear plate at a constant rate and without jerks until fracture occurs and the recorded load decreases. A suitable speed of the shear plate is about 50 µm/s.



Key

1 specimen

2 shear force

3 shear plate

d shear distance

Figure 4 — Shear distance *d*

7 Results

The shear load resistance is taken from the first maximum of the force displacement curve.

Typical force displacement curves are schematically shown in Annex A, Figures A.1 to A.5.

After completing the tests, the arithmetic mean value [in N] and standard deviation of the determined shear forces (FSa, FSc, or FSa/c) for all evaluated specimens shall be calculated.

The standard deviation of the test shall be less than 10 %. Otherwise the test shall be repeated.

The fracture's structure is important for the evaluation of the shear load resistance. Therefore the fracture mode shall be indicated in the test report.

8 Test report

The test report shall contain the following information for every specimen tested in accordance with this European Standard:

a) inspection body, inspector, date;

b) specimen material;

c) coating thickness;

d) coating material;

e) shear distance *d*;

f) shear plate geometry according to ISO 1832;

g) speed of shear plate;

h) list of all single measurement results of the shear load resistances [N] including type of fracture:

“Mode 1”: FSa (failure at interface between coating and substrate);

“Mode 2”: FSa/c (mixed fracture, portion of the coating peeled off in [area-%]);

“Mode 3a” / “Mode 3b”: FSc (failure within the spray deposit);

i) arithmetic mean value and standard deviation of results;

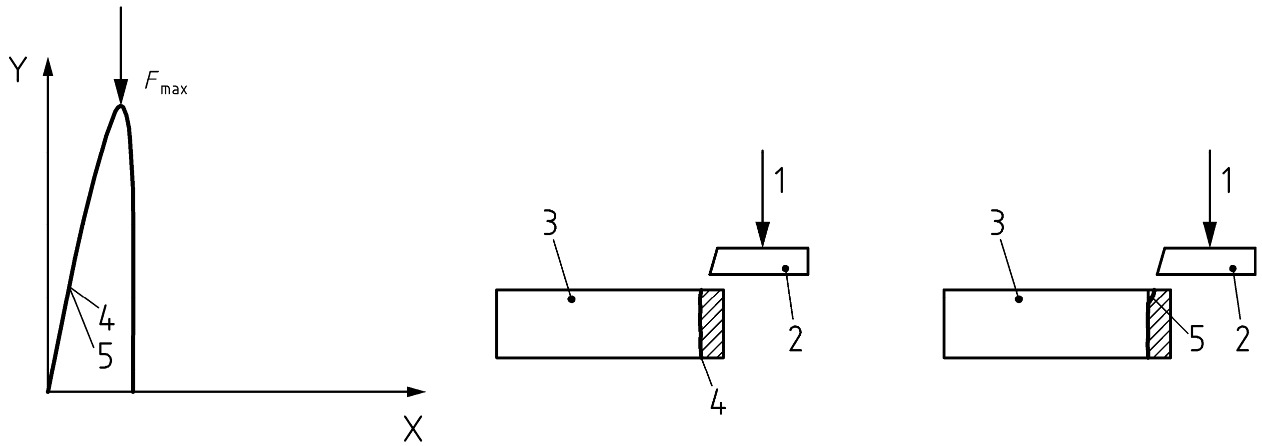
j) any particularities.

Annex A
(informative)

Evaluation

Depending upon the coating material and its adhesion to the substrate and cohesion between the splats, different modes of fracture can be distinguished. This can be seen from the load-displacement curves. Typical curves and sketches of crack configuration are shown schematically in Figures A.1 to A.5.

Mode 1 coating adhesion < coating cohesion



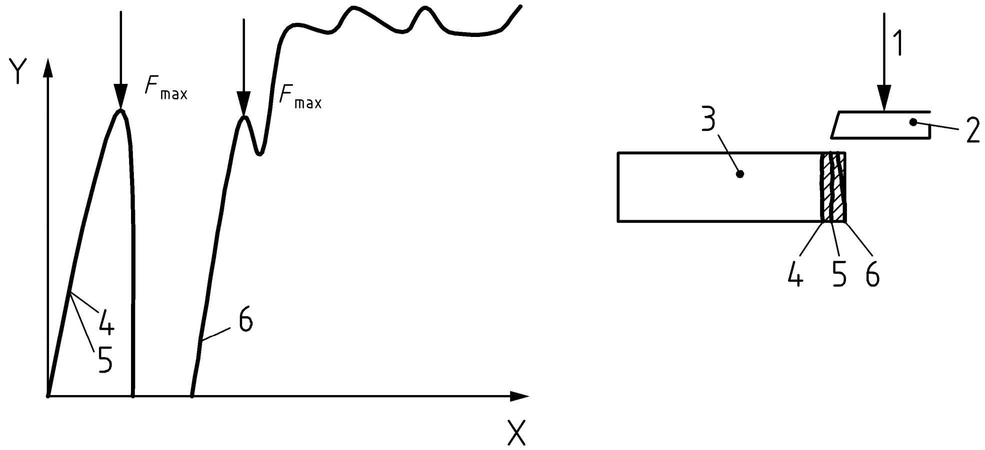
Key

Y	shear load [N]	3	specimen
X	displacement	4	crack path a
1	shear load	5	crack path b
2	shear plate		

Figure A.1 – Typical schematic load displacement curves and crack paths which are likely to result during shear testing for Mode 1 failure

Coating chips off totally and instantly when reaching the maximum shear forces. The delamination propagates almost completely along the interface between coating and substrate (crack path a). Even if the fracture starts with some distance it will run into the interface (crack path b).

Mode 2 coating adhesion ≅ coating cohesion



Key

Y	shear load [N]	3	specimen
X	displacement	4	crack path a
1	shear load	5	crack path b
2	shear plate	6	crack path c

Figure A.2 – Typical schematic load displacement curves and crack paths during shear testing for Mode 2 failure

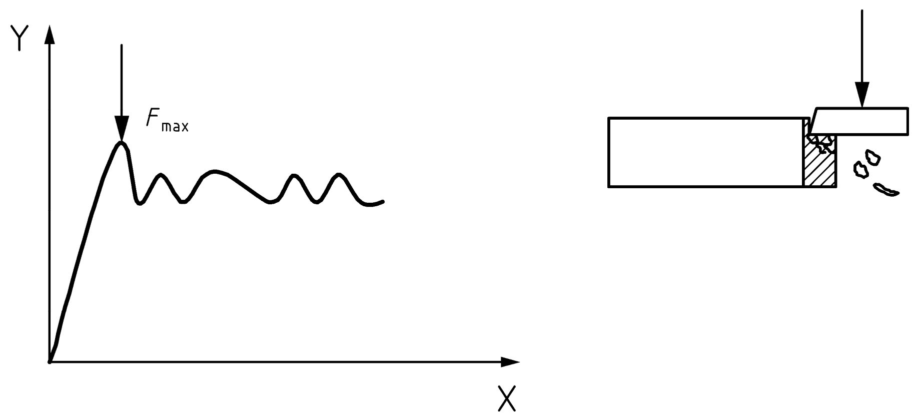
The failure may propagate along the interface between coating and substrate (crack path a) as well as within the coating itself (crack path b and c). The shear forces may start rising again after reaching a first maximum if fracture path proceeds within the coating (cohesive failure) due to frictional forces (load displacement and crack path c).

Mode 2 has to be considered if different crack pathways a, b and/or c occur within one batch of test samples manufactured and tested in the same way.

Mode 2 is distinguishable safe from mode 3 only when corresponding series of samples are tested with different shear distance.

Mode 3 coating adhesion > coating cohesion

Mode 3a – coating disintegrates (crumbles) into small particles

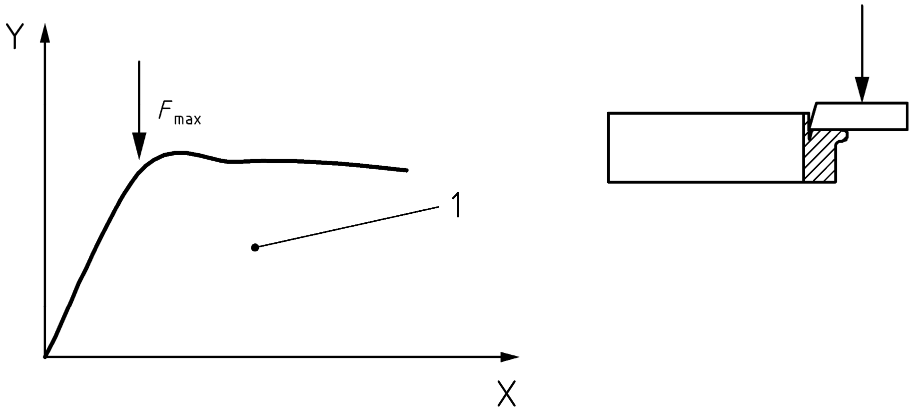


Key

Y shear load [N] X displacement

Figure A.3 – Typical schematic load displacement curve and crack configuration during shear testing for Mode 3a failure of hard coatings

During shear testing of hard coatings continuous blistering of small or larger pieces of the coating may happen.



Key

Y shear load [N]

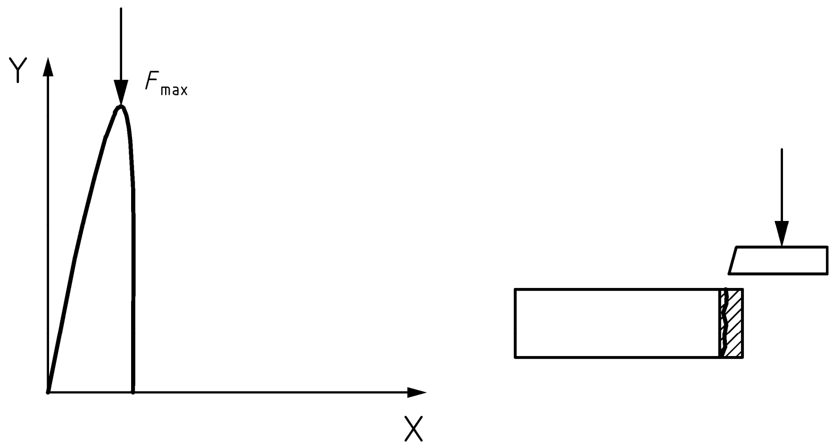
X displacement

1 ductile behaviour (no peak, but deviation form linear curve)

Figure A.4 – Typical schematic load displacement curve and crack configuration during shear testing for Mode 3a failure of soft and/or porous coatings

During shear testing coatings will be compressed and continuously scraped off.

Mode 3b – coating chips off in large parts



Key

Y shear load [N] X displacement

Figure A.5 – Typical schematic load displacement curve and crack path during shear testing for Mode 3b failure

Fracture path runs within the coating along the coating/substrate interface and the coating part under the shear plate detaches prompt like in Mode 1.

Annex B
(informative)

Coating systems and sources of error

B.1 Coating systems (bond/top coat)

In case of coating systems which e.g. consist of bond and top coat – especially in case of coating evaluation by testing a sequence with variable shear distance is recommended, so that a curve of the shear load resistance can be drawn up. The interesting values of the shear load resistance at the interface between bond and top coat are to be determined out of the curve's run.

B.2 Faults in testing

Possible faults in the preparation of specimen and in testing can be:

a) surfaces of the specimen are not cleaned properly from overspray;

b) angular and positional displacement of specimen in the specimen holder;

c) movement of the specimen during loading;

d) shear distance is too low; shear plate scrapes the substrate material;

e) shear distance is too large, only the coating surface is scraped.

Bibliography

[1] EN 582, *Thermal spraying — Determination of tensile adhesive strength*

[2] EN ISO 2064, *Metallic and other inorganic coatings — Definitions and conventions concerning the measurement of thickness (ISO 2064:1996)*

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

[4] EN ISO 3882, *Metallic and other inorganic coatings — Review of methods of measurement of thickness (ISO 3882:2003)*

[5] EN 22768-1, *General tolerances — Part 1: Tolerances for linear and angular dimensions without individual tolerance indications (ISO 2768-1:1989)*

[6] EN 22768-2, *General tolerances — Part 2: Geometrical tolerances for features without individual tolerance indications (ISO 2768-2:1989)*

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