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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for determining bonding strength of ceramic coatings

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Foreword

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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 206, *Fine ceramics*.

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.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for determining bonding strength of ceramic coatings

1 Scope

This document specifies the testing method for the determination of the bonding strength of ceramic coatings at ambient temperature by the compression tests on the cross-joined test pieces. Methods for test piece preparation, test mode and rate, data collection and reporting procedures are addressed.

This document applies primarily to any ceramic coatings, thick or thin, bonded onto substrates of various materials. The test method described can be used for materials research, quality control, characterization and design data generation purposes.

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 3611, *Geometrical product specifications (GPS) — Dimensional measuring equipment: Micrometers for external measurements — Design and metrological characteristics*

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*

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:

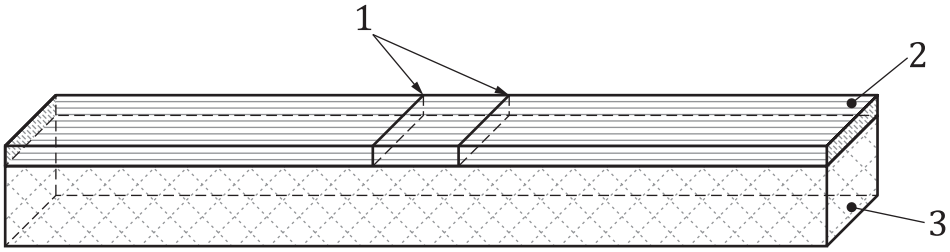
— ISO Online browsing platform: available at https://www.iso.org/obp

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

3.1
ceramic coating
coating of ceramics onto a substrate, via a physical or chemical technique, which creates an interface or boundary between the coating and the substrate

3.2
interface
smooth or rough boundary generated between coating and substrate that results from one or several bonding mechanisms, for example mechanical anchorage, interatomic or intermolecular bonds

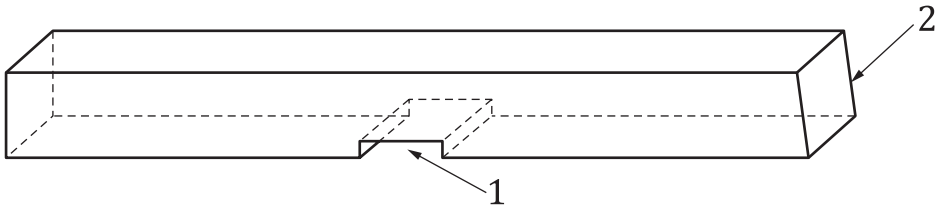
3.3
cross-joined test piece
test piece prepared by joining coating sample (see Figure 1 and 7.1.1) and coupling bar (see Figure 2 and 7.2.2) perpendicularly to each other at middle, by means of high-strength adhesive, as shown in Figure 3



Key

1 notch
2 coating
3 substrate

Figure 1 — Schematic of the coating sample



a)

b)

Key

1 groove
2 sloped end

Figure 2 — Schematic of the coupling bar

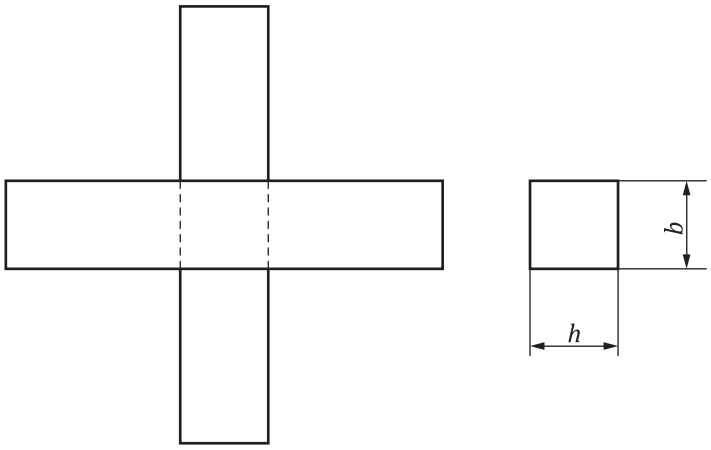


Figure 3 — Schematic of the cross-joined test piece

3.4
tensile failure load
maximum load applied to the horizontally placed cross-joined test piece during a test by subjecting load normal to interface between coating and substrate

3.5
tensile bonding strength
tensile stress calculated from the tensile failure load and the cross-joined area

3.6
shear failure load
maximum load applied to the vertically placed cross-joined test piece during a test by subjecting load parallel to interface between coating and substrate

3.7
shear bonding strength
shear stress calculated by using the shear failure load and the cross-joined area

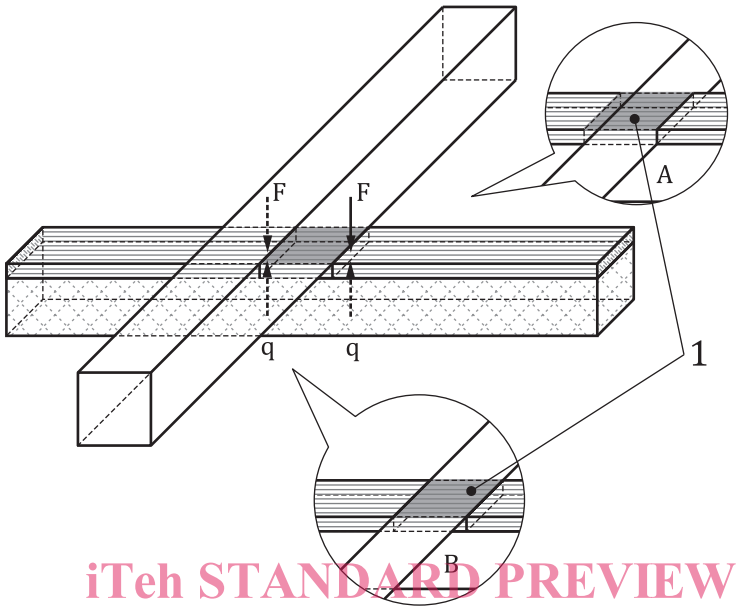
4 Symbols

Symbol	Designation	Unit	References
A_0	Cross-joined area ($=b^2$)	mm^2	Formulae (1) and (2)
A_c	True coating debonded area	mm^2	8.5
b	Test piece width	mm	Table 1
b_1	Groove width of sample holder	mm	Figure 6 b)
b_2	Sample holder width	mm	Figure 6 b)
b_3	Pressure head width ($=b$)	mm	Figure 6 a)
c_1	Pressure head length ($<l_2$)	mm	Figure 6 a)
c_2	Slot span of pressure head ($>b$)	mm	Figure 6 a)
d	Space of two notches ($=b$)	mm	Table 1
h	Test piece thickness	mm	Table 1
h_1	Sample holder height	mm	Figure 6 b)
h_2	Pressure head height	mm	Figure 6 a)
h_3	Slot depth of pressure head ($>b$)	mm	Figure 6 a)
l	Test piece length	mm	Table 1
l_1	Sample holder length	mm	Figure 6 b)
l_2	Groove length of sample holder ($>c_1$)	mm	Figure 6 a)
P_c	Failure load to debonding	N	Formulae (1) and (2)
σ_t	Tensile bonding strength by calculation	MPa	Formula (1)
σ_{ct}	Tensile bonding strength of ceramics coating	MPa	9.1
τ	Shear bonding strength by calculation	MPa	Formula (2)
τ_c	Shear bonding strength of ceramics coating	MPa	9.2

5 Principle

A cross-joined test piece is subjected to an increasing compression load giving a tensile or shear stress on the area that is joined until the coating is debonded. Two different forms of mounting the cross-joined test piece in a fixture are conducted to measure the tensile and shear bond strength, respectively. In the case of the tensile test, a uniaxial tensile stress is generated when the cross-joined test piece is subjected to compressive load, as shown in Figure 4. The tensile strength of the coating–substrate interface, or the cohesive strength of the ceramic coating, will be obtained. In the case of the shear strength test, a cross-joined test piece is loaded in compression to induce failure by shear at the interface, as shown in

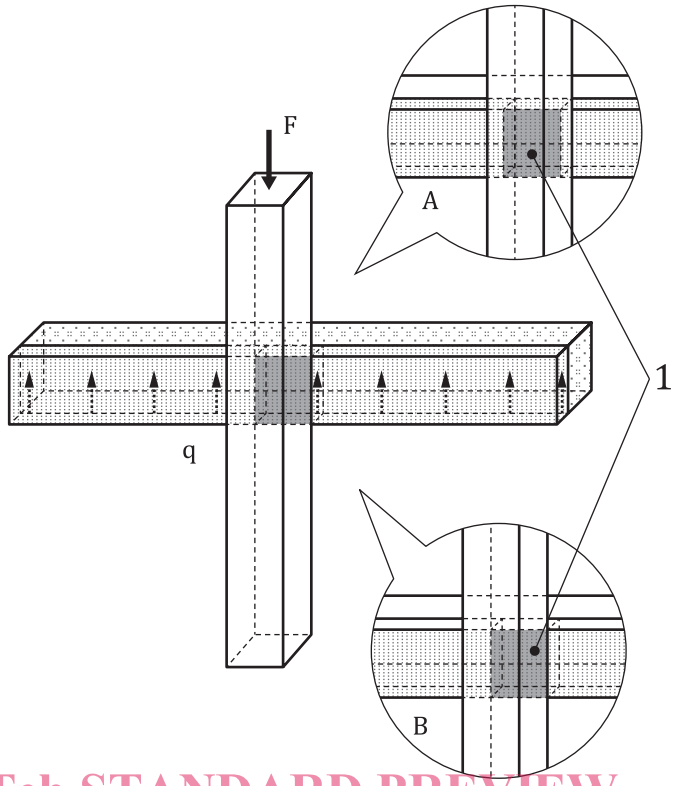
Figure 5. Owing to the groove, the failure will not occur in the adhesive interface, and thus the shear bonding strength shall be that of ceramic coating to be characterized. On the other hand, if that coating sample is joined with a flat coupling bar, the adhesive may also lead to the removal of the coating from substrate under shear stress. The test is performed at a constant cross-head displacement rate. The load at fracture and the cross-joined area are used to calculate the tensile and shear bonding strengths by calculation.



Key

F loading
q supporting
1 joined area (dark)
A grooved coupling bar
B flat coupling bar

Figure 4 — Schematic of loading, supporting and jointed area (dark) for cross-joined test piece in the test of the tensile bonding strength



Key

F loading
q supporting
1 joined area (dark)
A grooved coupling bar
B flat coupling bar

Figure 5 — Schematic of loading, supporting and jointed area (dark) for cross-joined test piece in the test of the shear bonding strength

There are three possible fracture modes during either tensile or shear testing: a) complete removal of the coating from substrate (debonded at the interface between coating and substrate); b) the coating itself fractures (cohesive failure inside the coating); and c) adhesive joint fails. A combination of these three modes can occur. For mode a), the calculated strength value represents the real bonding strength of the coating. For mode b) and mode c), the strength calculated with the failure load and the jointed area shall be lower than the real bonding strength between the coating and the substrate.

6 Apparatus

6.1 Testing machine

A suitable testing machine capable of applying a uniform cross-head speed shall be used. The testing machine shall be in accordance with ISO 7500-1, Class 1, with an accuracy of 1 % of indicated load at compression or tension tests.

6.2 Data acquisition

Obtain an autographic record of the applied load versus cross-head displacement or versus testing time, so that the maximum load to debonding (P_c) is determined.