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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at elevated temperature in air atmospheric pressure — Determination of in-plane shear strength

Céramiques techniques (céramiques avancées, céramiques techniques avancées) — Propriétés mécaniques des composites céramiques à température élevée sous air à pression atmosphérique — Détermination de la résistance au cisaillement dans le plan

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Foreword

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This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at elevated temperature in air atmospheric pressure — Determination of in-plane shear strength

1 Scope

This document specifies a method for the determination of in-plane shear strength of continuous fibre-reinforced ceramic composites at elevated temperature in air or inert atmosphere by the asymmetric four-point bending test on double-edge notched specimens. The shear strength in plane (1,2) can be evaluated, where direction 1 is that of the greater fraction of reinforcement and direction 2 is perpendicular to direction 1. Methods for test piece fabrication, testing modes and rates (load or displacement rate), data collection and reporting procedures are addressed.

This document applies to all ceramic matrix composites with continuous fibre-reinforcement: unidirectional (1D), bidirectional (2D) and tridirectional (xD, with $2 \le x \le 3$).

This document is for material development, material comparison, quality assurance, characterization, reliability and design data generation.

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*

ISO 19634, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Ceramic composites — Notations and symbols*

ISO 20507, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Vocabulary*

IEC 60584-1, *Thermocouples - Part 1: Reference tables*

IEC 60584-2, *Thermocouples. Part 2: Tolerances*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19634 and ISO 20507 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
initial gauge section
S_0
initial area of test piece between notch roots

3.2
test temperature
T
temperature measured at the centre of the gauge section

3.3
applied force
F
force applied to a test piece

3.4
shear failure force
F_{max}
maximum force required to fracture a shear-loaded test piece

3.5
shear strength
τ_m
maximum shear stress which a material is capable of sustaining

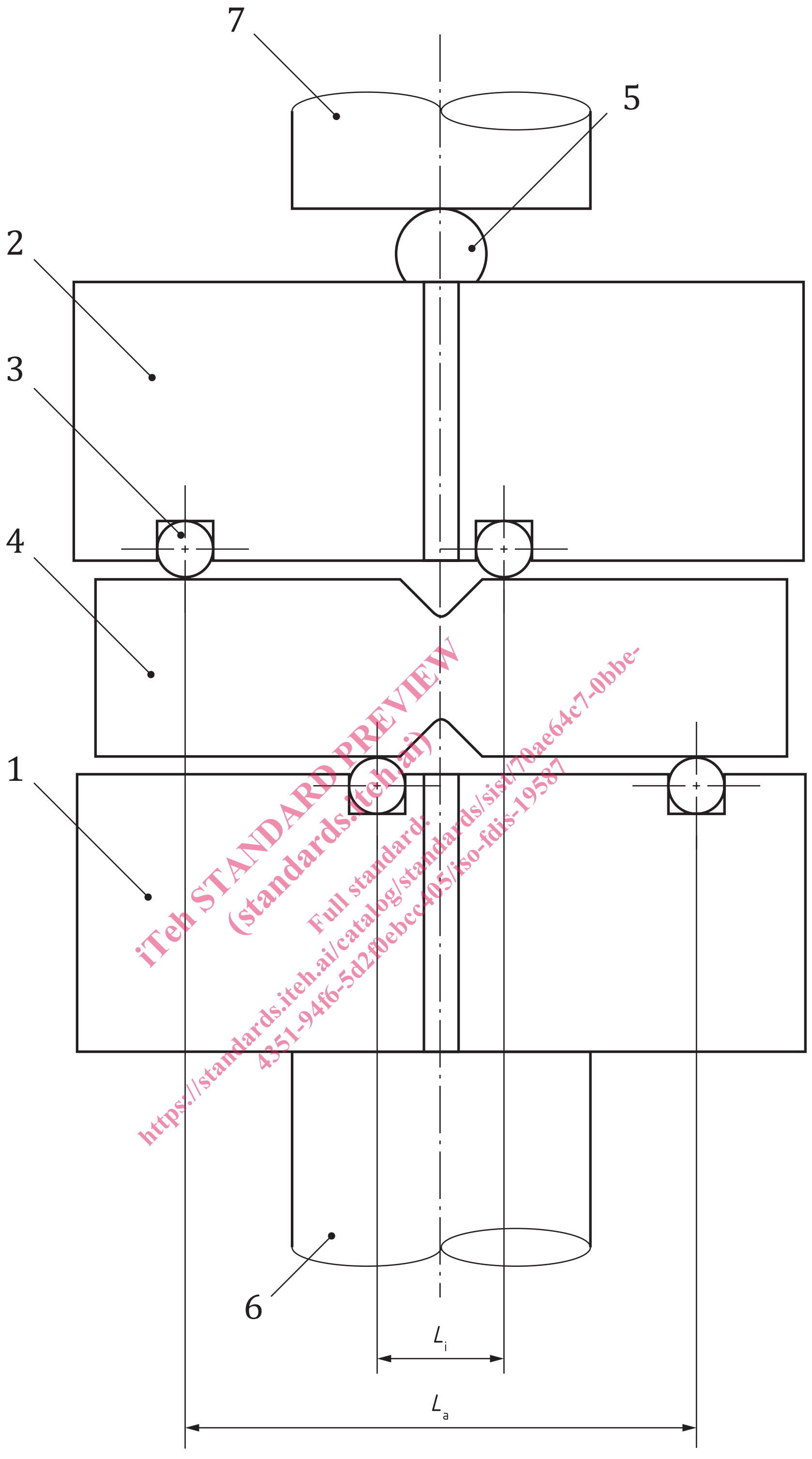
Note 1 to entry: Shear strength is calculated from the shear failure force and the gauge section.

3.6
inner span
L_i
centre distance between two inner loading pins

3.7
outer span
L_a
centre distance between two outer loading pins

4 Principle

The in-plane shear strength of continuous fibre-reinforced ceramic composites, as determined by this document, is measured by the asymmetric four-point bending test at elevated temperature in air or inert atmosphere. According to this test, the shear strength is determined by loading a test coupon in the form of a rectangular flat strip with symmetric, centrally located V-notches using a mechanical testing machine and an asymmetric four-point bending fixture. Failure of the test piece occurs by shear force between the V-notches. Schematics of the test set-up and the test piece are shown in Figures 1 and 2, respectively. The free body, bending moment and shear force diagrams by the asymmetric four-point bending flexure are illustrated in Figure 3.



Key

1 lower fixture
2 upper fixture
3 loading pin
4 test piece
5 loading ball
6 lower ram
7 upper ram

Figure 1 — Schematics of asymmetric four-point bending test set-up

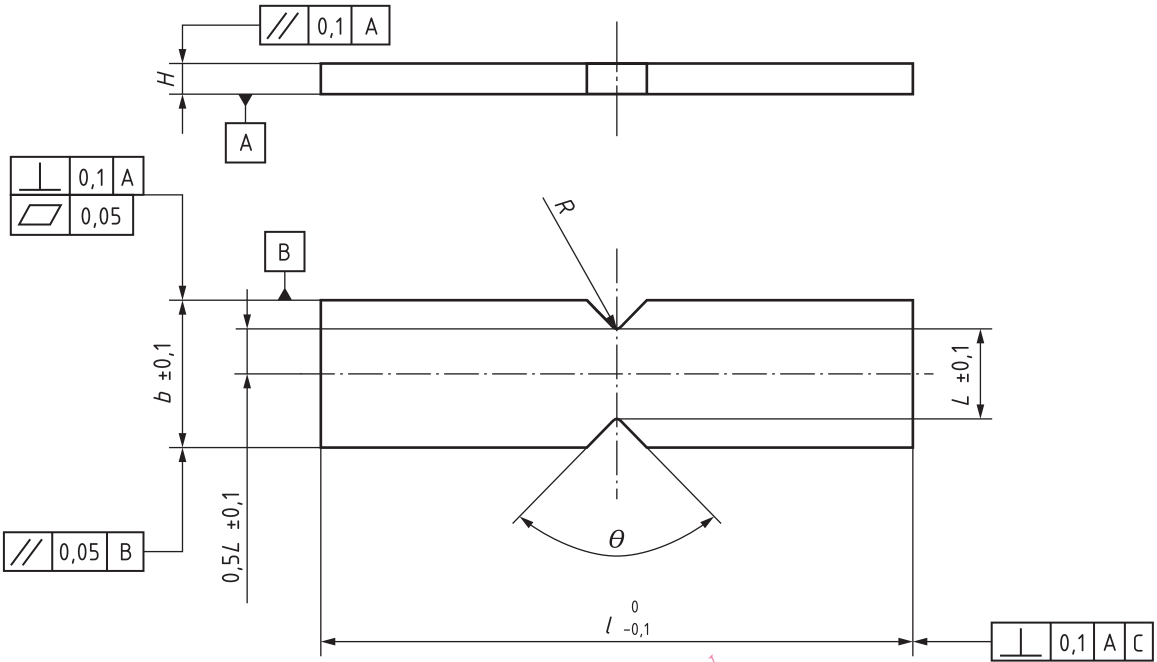
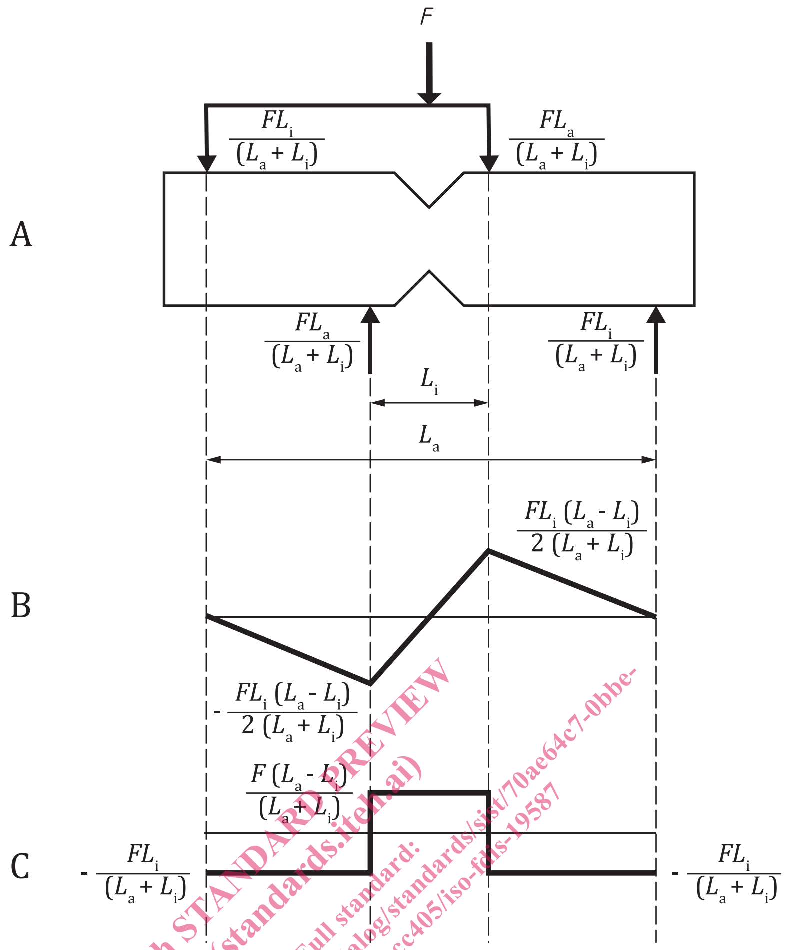


Figure 2 — Geometry and dimensions of test piece



Key

A free body diagram

B bending moment diagram

C shear force diagram

Figure 3 — Free body, bending moment and shear force diagrams of asymmetric four-point bending

5 Significance and use

5.1 Test environment

The test environment can have an influence on the measured shear strength. In particular, the behaviour of materials susceptible to slow-crack-growth fracture will be strongly influenced by the test environment and testing rate. Testing to evaluate the maximum strength potential of a material shall be conducted in inert environments, at sufficiently rapid testing rates or both, so as to minimize slow-crack-growth effects. Conversely, testing can be conducted in environments and testing modes and rates representative of service conditions to evaluate material performance under those conditions. When testing is conducted in uncontrolled ambient air with the objective of evaluating maximum strength potential, water partial pressure and temperature shall be monitored and reported, if the tested materials are sensitive to these parameters.

5.2 Material orientation

In this method, the shear strength in plane (1,2) can be evaluated, where direction 1 is that of the greater fraction of reinforcement and direction 2 is perpendicular to direction 1. Either direction 1 or direction 2 should be along the length of the test piece. The material properties in plane (1,3) or plane (2,3) can be interlinear properties for laminated materials. Thus, this method is targeted for evaluation of the shear strength in plane (1,2).

NOTE For the definition of material orientation, see ISO 19634.

5.3 Preparation of test pieces

Preparation of test pieces, although normally not considered a major concern with continuous fibre-reinforced ceramic composites, can introduce fabrication flaws which can have pronounced effects on the mechanical properties and behaviour (e.g. shape and level of the resulting load-displacement curve and shear strength). Machining damage introduced during test piece preparation can be either a random interfering factor in the determination of shear strength of pristine material or an inherent part of the strength characteristics to be measured. Universal or standardized test methods of surface preparation do not exist. Final machining steps can negate machining damage introduced during the initial machining. Thus, the history of the test piece fabrication can play an important role in the measured strength distributions and shall be reported.

5.4 Failures outside gauge section

Fractures that initiate outside the gauge section of a test piece can be due to extraneous stresses introduced by improper loading configurations or strength-limiting features in the microstructure of the test piece. Such non-gauge section fractures constitute invalid tests.

5.5 Thin test pieces

Thin test pieces (width to thickness ratio of more than 10) can suffer from splitting and instabilities, rendering, in turn, invalid test results.

6 Apparatus

6.1 Test machine

The test machine shall be equipped with a system for measuring the force applied to the test piece conforming to grade 1 or better according to ISO 7500-1.

6.2 Loading devices

The main purpose of the loading devices is to allow for uniform axial compression. Loading devices shall consist of rigid lower and upper rams with flat smooth faces vertical to axial force line.

6.3 Test fixture

The test fixture consists of upper and lower fixtures, loading pins and a loading ball, as shown schematically in Figure 1. Annex A gives detailed information on the test fixture. The bottom surface of the lower fixture should be smooth and flat. The test piece is positioned between the upper and lower fixtures. The loading pins are placed at the contact points between each fixture and the test piece. The force is transmitted from the test machine to the fixture by the loading ball. If the test piece collapses at the contact positions with the loading pins, buffering spacers given in A.3 can be inserted between the test piece and the loading pins. Table 1 contains symbols, nomenclature and recommended dimensions for the test fixture (Figure 1), where the tolerances for L_a and L_i after assembly are ± 0,2 mm. Centrality is the length equality between the centre of the fixture and each pin. A.1 gives an example of the test fixture to satisfy the recommended dimensions in Table 1. The tolerances for the diameters of the

