FINAL DRAFT

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at room temperature — Determination of the interlaminar shear strength and shear modulus of continuous-fibre-reinforced composites by the compression of double-notched test pieces and by the Iosipescu test

Céramiques techniques — Propriétés mécaniques des céramiques composites à température ambiante — Détermination de la résistance au cisaillement interlaminaire et du module de cisaillement des composites renforcés par des fibres continues, par la compression d'éprouvettes à double entaille et par l'essai Iosipescu

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Foreword

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

This second edition cancels and replaces the first edition (ISO 20505:2005), which has been technically revised.

The main changes are as follows:

— Scope revised to include the possibility of measuring the interlaminar shear modulus through the use of a gauges-instrumented Iosipescu sample;

— new entries added to Clause 3;

— 5.3 and 7.2 specify requirements on the gauges-instrumented Iosipescu sample;

— 9.3, 9.4 and 9.5 define formulae to determine the shear modulus;

— material orientation added to Figure 2 and Figure 3;

— subclause on test validity added (8.4);

— Table 1 and Table 2 updated;

— Annex A replaced by a method to verify the shear stress field in the Iosipescu test to ensure that that there are no coupling effects that make this document unsuitable for determining the interlaminar shear properties of the material;

— minor editorial corrections;

— structure revised;

— symbols and notation modified in accordance with ISO 19634.

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) — Mechanical properties of ceramic composites at room temperature — Determination of the interlaminar shear strength and shear modulus of continuous-fibre-reinforced composites by the compression of double-notched test pieces and by the Iosipescu test

1 Scope

This document specifies a method for the determination of interlaminar shear strength at ambient temperature by the compression of a double-notched test piece and a method for the determination of interlaminar shear strength and modulus at ambient temperature by the Iosipescu test. This document applies to all ceramic matrix composites with a continuous fibre reinforcement, having unidirectional (1D), bidirectional (2D) and multidirectional (xD, with x > 2) fibre architecture, where a major part of reinforcements is a stack of plies.

This document is applicable to material development, material comparison, quality assurance, characterization, reliability and design data generation. The simpler compression test method of a double-notched test piece is applicable only when the shear strength has to be measured.

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 17161, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Ceramic composites — Determination of the degree of misalignment in uniaxial mechanical tests*

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

ISO 20507, *Advanced ceramics — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20507 and ISO 19634 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

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

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

3.1
shear section
section located between the notches of test sample

Note 1 to entry: Due to the orientation of the test sample (see Figures 2 and 3), the shear plane is orthogonal to direction 3 and parallel to the stack of plies (plane 1, 2). Therefore, the shear mechanism occurs between the composite plies and the resulting shear properties, with respect to the definition given in ISO 20507, are labelled as "interlaminar".

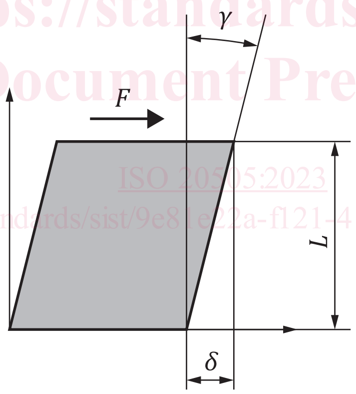
3.2
initial shear section area
S_0
shear section area before test between the notches of the test piece at room temperature

3.3
shear section area
S_e
effective shear loaded section area of the test piece at room temperature

Note 1 to entry: This effective shear loaded section area is determined when a valid failure occurs in a plane parallel to the shear plane in an Iosipescu test sample.

3.4
shear force
F
force parallel to the shear section carried by the test specimen at any time during the shear test

Note 1 to entry: See Figure 1.



Key

F	shear force	L	height of the cubic element
γ	shear strain	δ	displacement

Figure 1 — Shear force and shear strain

3.5
maximum shear force
F_m
maximum force parallel to the shear section during a test or at fracture

3.6
interlaminar shear strength
$\sigma_{ILSS,m,i,3}$
ratio of the maximum shear force to the initial shear section area

Note 1 to entry: With respect to the material orientation defined in ISO 19634, subscript "i" is for the direction of the load with respect to the material orientation and subscript "3" is for the material orientation orthogonal to the shear plan (see Figures 2 and 3).

3.7
shear strain
γ
change in angle between two adjacent sides of a cubic-shaped stress element submitted to a shear force

Note 1 to entry: Although shear strain is defined as an angle, for small strains this measure becomes the ratio of displacement δ to the height of the stress element L (see Figure 1).

3.8
strain
ε_{ij}
ε_{θ}
ratio of deformation to initial strain gauge length

Note 1 to entry: The subscripts "ij" and "θ" indicate the orientation of the strain gauge with respect to test sample orientation.

3.9
shear stress
$\sigma_{ILSS\ i,3}$
ratio of the shear force to the initial shear section area at any time during the test

Note 1 to entry: With respect to the material orientation defined in ISO 19634, subscript "i" is for the direction of the load with respect to the material orientation and subscript "3" is for the material orientation orthogonal to the shear plan (see Figures 2 and 3).

3.10
measurement zone
part of the test piece, in the plane perpendicular to direction 1 or 2 (see Figures 2 and 3), between the notches

3.11
elastic shear modulus
$G_{i,3}$
ratio of shear stress to corresponding shear strain

Note 1 to entry: For general use the reference plane for $G_{i,3}$ is defined by the axes i and 3.

Note 2 to entry: If the plane is defined by the normal axis, the elastic modulus is noted G_i.

3.12
pseudo-elastic shear modulus
$G_{p,i,3}$
slope of the linear section not starting from the origin of the shear-stress-shear-strain curve, if any $G_{p,i,3}$ is defined as the proportionality ratio:

$$G_{p,i,3}\left(\sigma'_{ILSS,},\sigma''_{ILSS,}\right)=\frac{\sigma'_{ILSS,}-\sigma''_{ILSS,}}{\gamma''-\gamma'}$$

where (γ', σ'_{ILSS}) and (γ'', σ''_{ILSS}) lie on the linear section of the shear-stress-shear-strain curve

Note 1 to entry: For general use the reference plane for $G_{p,i,3}$ is defined by the axes i and 3.

Note 2 to entry: If the plane is defined by the normal axis, the elastic modulus is noted G_{pi}.

Note 3 to entry: For material with nonlinear shear stress-strain behaviour, only stress-strain couples can be fixed.

4 Principle

4.1 General

The interlaminar shear strength of continuous-fibre reinforced ceramic composites, as determined by this document, can be measured by the compression of double-notched test pieces or by the Iosipescu test. The interlaminar shear modulus shall be measured by the Iosipescu test.

NOTE The test is performed at constant displacement rate, up to failure.

4.2 Double-notched test

A double-notched test piece of uniform width is loaded in compression to induce failure by shear between two centrally located notches machined halfway through the thickness and spaced a fixed distance apart on opposing faces (see Figure 2).

NOTE Some attempts to measure shear strain and shear modulus on a double-notched test piece with the use of a virtual strain gauge through digital image correlation analysis have been investigated, but results are not consistent enough to validate shear modulus determination with this test method.

4.3 Iosipescu test

A test specimen with two centrally located V notches (see Figure 3) is submitted to a translation of its part B parallel to the plies plane while its part A is kept still.

The displacement of part B with respect to part A results in an assumed uniform shear field in the measurement zone.

Force and strain are measured and recorded simultaneously, from which shear modulus and shear strength can be determined.

NOTE Before the failure, for high levels of shear stress, debonding of strain gauges often occurs. Consequently, this test method is not suited to provide a valid shear-stress-shear-strain curve in the vicinity of the interlaminar shear strength.

Schematics of the test pieces are shown in Figures 2 and 3.

Considering the orientation of the stack of plies with respect to the notches and the material orientation definitions defined in ISO 19634, $\sigma_{ILSS,13}$, and G_{13} (or G_1) as well as $\sigma_{ILSS,23}$, and G_{23} (or G_2) can be determined.