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Second edition
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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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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 document 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 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*.

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”.

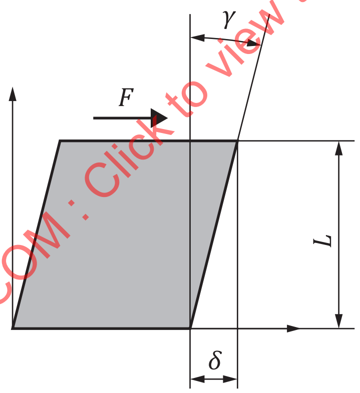
3.2
initial shear section area
S_0
shear section area before test between the notches of the test piece at room temperature

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
γ shear strain
L height of the cubic element
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.

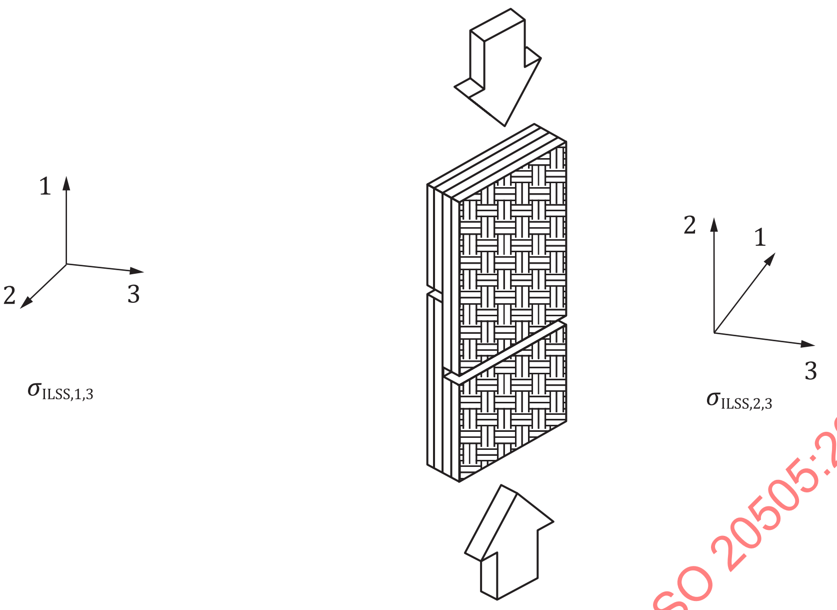


Figure 2 — Schematic of double-notched test piece subjected to compressive loading

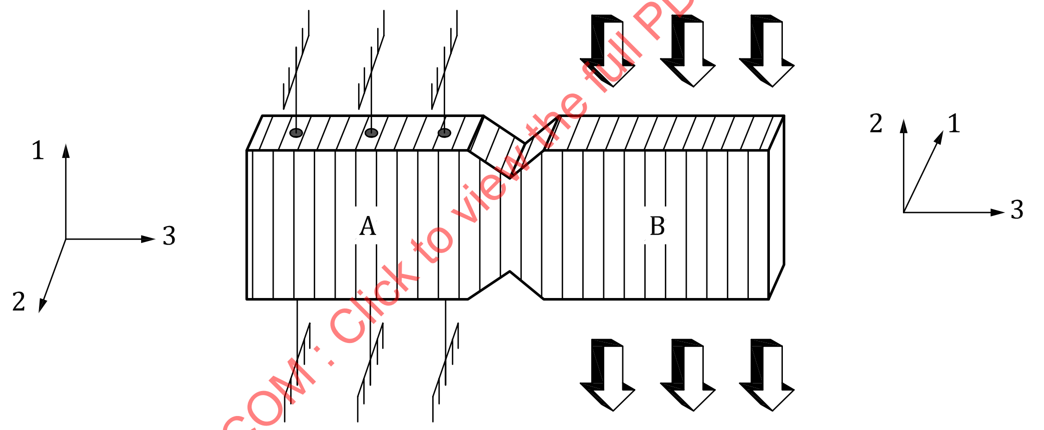


Figure 3 — Schematic of Iosipescu test piece

5 Apparatus

5.1 Test machine

The machine shall be equipped with a system for measuring the force applied to the test specimen which shall conform to grade 1 or better in accordance with ISO 7500-1.

5.2 Load train

5.2.1 Generalities

The load train configuration shall ensure that the load indicated by the load cell and the load experienced by the test specimen are the same.

The load train shall align the shear plane with the direction of load application. The misalignment of the specimen shall be verified at room temperature and documented in accordance with the procedure described in ISO 17161.

5.2.2 Test fixtures

5.2.2.1 Double-notched compression test specimen

Bending of uniaxially loaded shear test pieces (during the compression of double-notched test pieces) can cause or promote non-uniform stress distributions that can alter the desired uniform state of stress during the test.

There are various types of anti-buckling fixtures for the compression of double-notched test pieces. One type consists of a stationary element mounted on a base plate, an element that attaches to the cross-head of the testing machine, and two jaws to fix the test piece in position. A schematic description of such a test fixture is shown in Figure 4. Another type is a simple anti-buckling test fixture, where the test piece is held in position using a plate that clamps the test piece against a stationary element mounted on a base plate. Figure 5 shows a schematic of such a fixture.

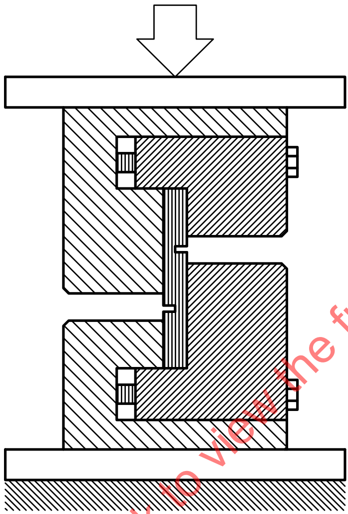


Figure 4 — Example of anti-buckling fixture for compression of double-notched test piece

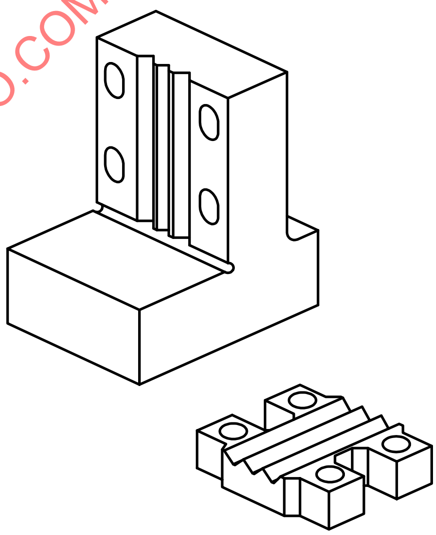


Figure 5 — Example of anti-buckling fixture for compression of double-notched test piece

5.2.2.2 Iosipescu test specimen

This fixture consists of a stationary element mounted on a base plate and a movable element capable of vertical translation guided by a stiff post. The movable element is attached to the cross-head of the testing machine. Each element clamps half of the test piece into position, with a wedge-action grip that is able to compensate for minor variations in test piece width. A span of 13 mm is left unsupported between fixture halves. An alignment tool is recommended to ensure that the test piece notch is aligned with the line-of-action of the loading fixture. Figure 6 shows a photograph of a commercially available Iosipescu fixture, while Figure 7 shows a schematic of it.

For the Iosipescu test, the test fixtures shall be designed so that the force is applied in the shear plane, normal to the longitudinal axis of the test piece. It shall allow the displacement of part B relative to part A (see Figure 3).

The fixtures shall allow accurate mounting of the specimen so that the notches are midway between the loading points.

The fixtures shall prevent out-of-plane loading of the specimen. This shall be verified using a dummy specimen made of a homogenous isotropic material equipped with strain gauges on the front and back faces located as specified in 5.3.

The dummy test piece shall be loaded to at least 50 % of the expected failure load of the material to be tested, and readings taken from all four strain gauges. The average strain gauge reading shall be calculated.

Individual strain gauge readings at any load shall not differ by more than 5 % from the average of that load.

The dummy test piece shall remain linear elastic during this verification.

Because the purpose of the jaws is to maintain the test piece in place and to prevent buckling, excessive clamping force with the jaws of the fixture during the compression of double-notched test pieces will reduce the stress concentration around the notches and therefore artificially increase the measured interlaminar shear strength. In the case of the Iosipescu fixture, avoid over-tightening the jaws because it induces undesirable pre-loading and can damage some materials.

NOTE Many fixtures for both the compression of double-notched test pieces and the Iosipescu test incorporate an alignment mechanism in the form of a guide rod and a linear roller bearing. Excessive free play or excessive friction in this mechanism can introduce spurious moments that will alter the ideal loading conditions.

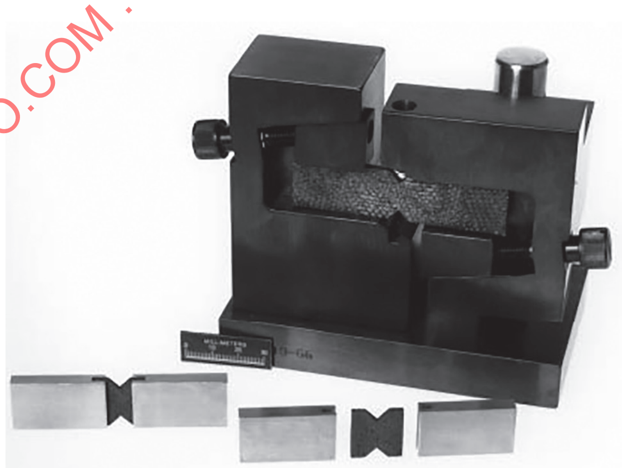
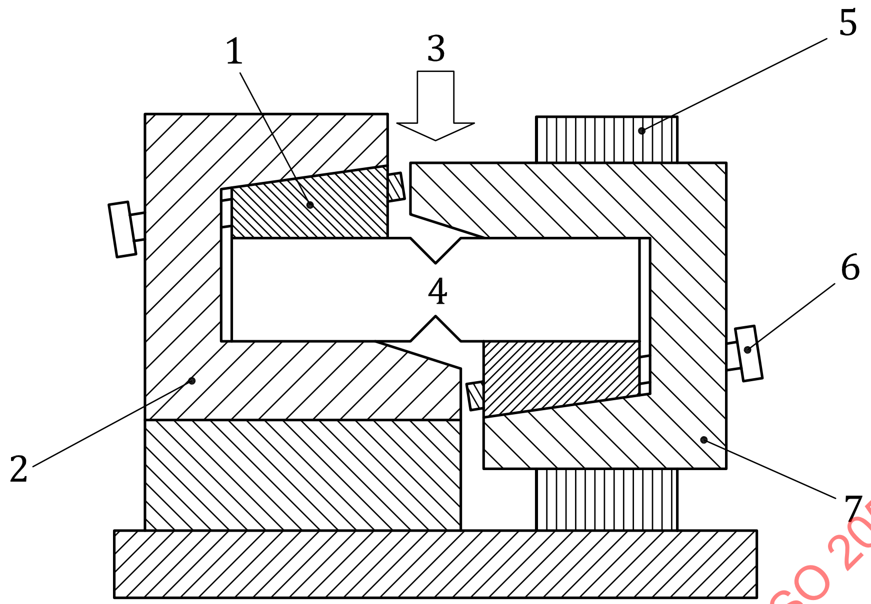


Figure 6 — Commercially available fixture for Iosipescu test

In Figure 6, the test pieces in the foreground illustrate the use of adhesively bonded end-tabs for evaluating specimens obtained from thin plates.



Key

1 adjustable wedge to tighten the specimen
2 stationary portion of fixture
3 load
4 specimen
5 fixture guide rod
6 wedge-adjusting screw
7 fixture attached to guide rod by linear rolling bearing

Figure 7 — Schematic of Iosipescu test fixture

5.3 Strain gauges for Iosipescu test specimen

At least one face of the specimen shall be equipped with two strain gauges in the measurement zone. The gauge shall be orientated at ±45° with respect to the longitudinal axis of the specimen (see example in Figure 8).

The gauges length shall be at least equal to the length of the representative volume element of the material structure in the direction of the gauge and compatible with the size of the measurement zone.

NOTE Typically, 5 x 3 mm strain gauges are used for this purpose.

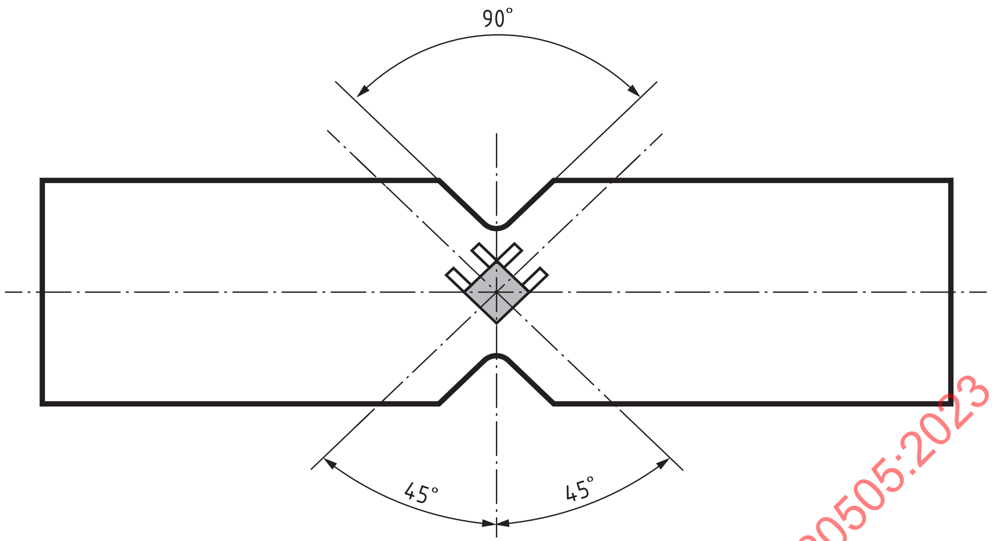


Figure 8 — Example of test specimen equipped with strain gauges: superposed strain gauges, bonded in the centre and at 45° from the axis

5.4 Data acquisition

A calibrated recorder can be used to record the applied load and cross-head displacement versus time for the double-notched compression test, and the force-deformation curves for the Iosipescu test. The use of a digital data recording system combined with an analogue recorder is recommended. Recording devices shall be accurate to within +/−1 % of the selected range for the testing equipment, including readout unit, and have a minimum data acquisition rate of 4 Hz with a response of 50 Hz deemed more than sufficient.

5.5 Dimension-measuring devices

Micrometers and other devices used for measuring linear dimensions shall be accurate and precise to at least 0,01 mm and shall be in accordance with ISO 3611. To obtain consistent measurements of test piece dimensions, use a flat, anvil-type micrometer. Ball-tipped or sharp anvil micrometers are not recommended for woven continuous-fibre-reinforced ceramic composites, because the resulting measurements can be affected by the peaks and valleys of the weave. Measure test piece dimensions to within 0,02 mm.

6 Test specimens

6.1 Double-notched test piece

Double-notched test pieces shall conform to the shape and tolerances shown in Figure 9. The double-notched test piece consists of a rectangular plate with notches machined on both sides. The depth of the notches shall be at least equal to one-half of the test piece thickness, and the distance between the notches shall be determined considering the requirements to produce shear failure in the shear section. Test piece sides used to apply the forces shall be flat and parallel and the edges shall be smooth, but not rounded or bevelled.

The distance between the notches has an effect on the maximum load and therefore on the interlaminar shear strength. It has been found that the stress distribution in the test piece is independent of the distance between the notches when the notches are far apart. However, when the distance between the notches is such that the stress fields around the notches interact, the measured interlaminar shear strength increases. Because of the complexity of the stress field around each notch and its dependence on the properties and homogeneity of the material, it is recommended that a series of tests are performed on test pieces with different spacing between the notches, to determine their effect on the measured interlaminar shear strength. The distance between notches should be set at least at the lowest value where an increase does not lead to a significant decrease in the shear strength.

As 10 % is a generally common accepted average scattering value for CMC properties, the recommended criteria value to be considered for this significant decrease is 10 %

Table 1 contains recommended values for the dimensions associated with the test piece shown in Figure 9.

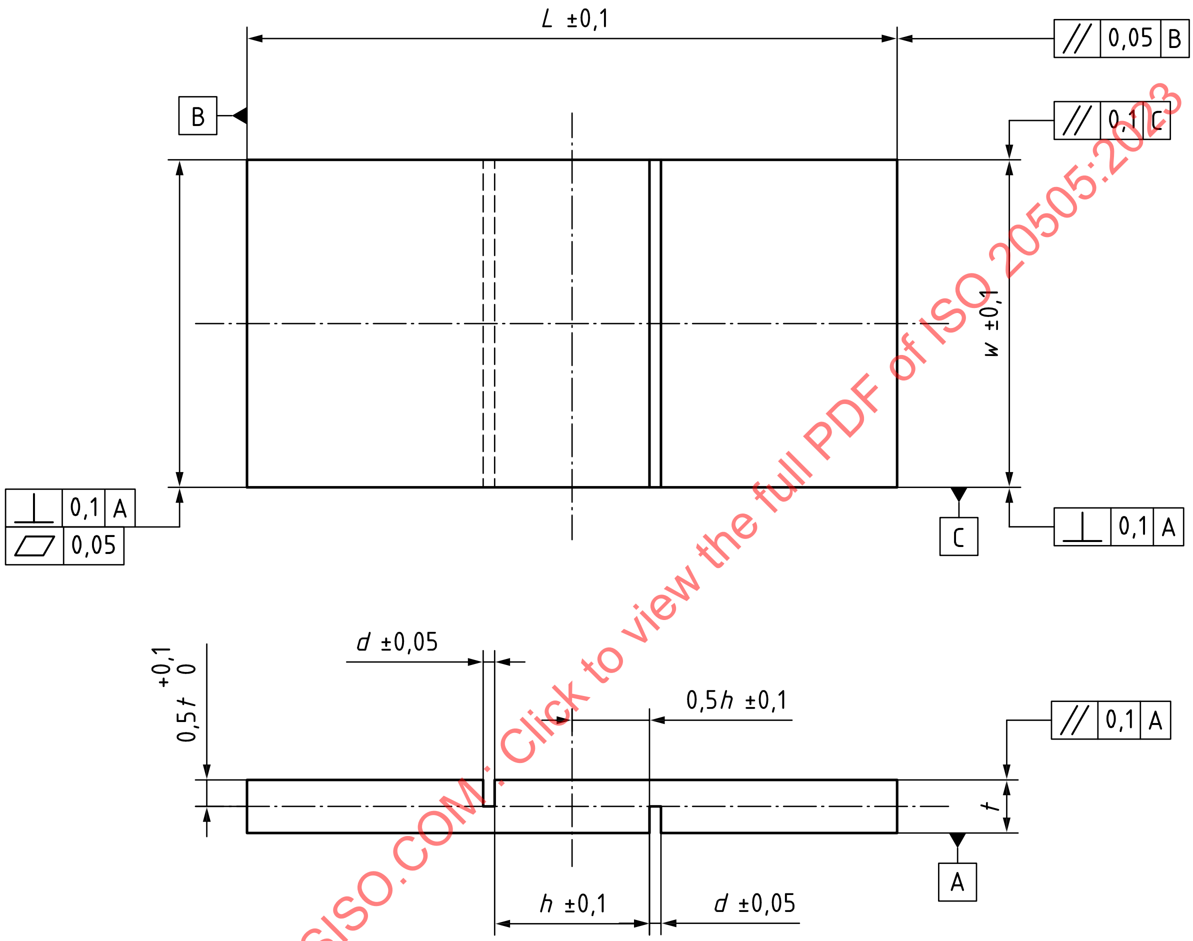


Figure 9 — Geometry and dimensions of double-notched test piece

Table 1 — Recommended dimensions for double-notched compression test pieces

Dimension	Description	Range value mm	Typical value mm	Allowance mm
L	Test piece length	20,0 to 32,0	32,0	±0,1
h	Distance between notches	6,0 to 13,0	12,7	±0,1
w	Test piece width	10,0 to 15,0	12,7	±0,1
d	Notch width	0,50 to 1,30	0,5	±0,05
	Notch depth	*t*/2	t/2	+0,05/-0
t	Test piece thickness			

The allowance on the notch depth should ensure that the shear plane located at *t*/2 of test sample thickness is effectively crossed by the notch.

The height of the overlapping zone between the two notches should be equivalent to the ply thickness.

NOTE The largest dimensions are mainly used for thick test pieces.

6.2 Iosipescu test piece

The required shape and tolerances of the Iosipescu test piece are shown in Figure 10, while Table 2 contains recommended values for the dimensions of the test piece. If required, the dimensions of the test piece, particularly the notch angle, notch depth and notch radius, may be adjusted to meet special material requirements, but any deviation from the recommended values listed in Table 2 shall be reported with the test results, although the standard tolerances shown in Figure 10 still apply.

Due to limitations in material processing, it can sometimes be difficult to produce thick sections that conform to the dimensions and geometry shown in Table 2 and Figure 10, respectively. Therefore, the test piece geometry may be modified to obtain appropriate results. In this case, adhesively bonded end-tabs may be used, and the depth and angle of the notches shall be selected to promote shear failure between the V-notches. Such a specimen is shown in the foreground in Figure 6.

Bonded tabs on front face and rear face should help prevent buckling and/or damage from the application of load.

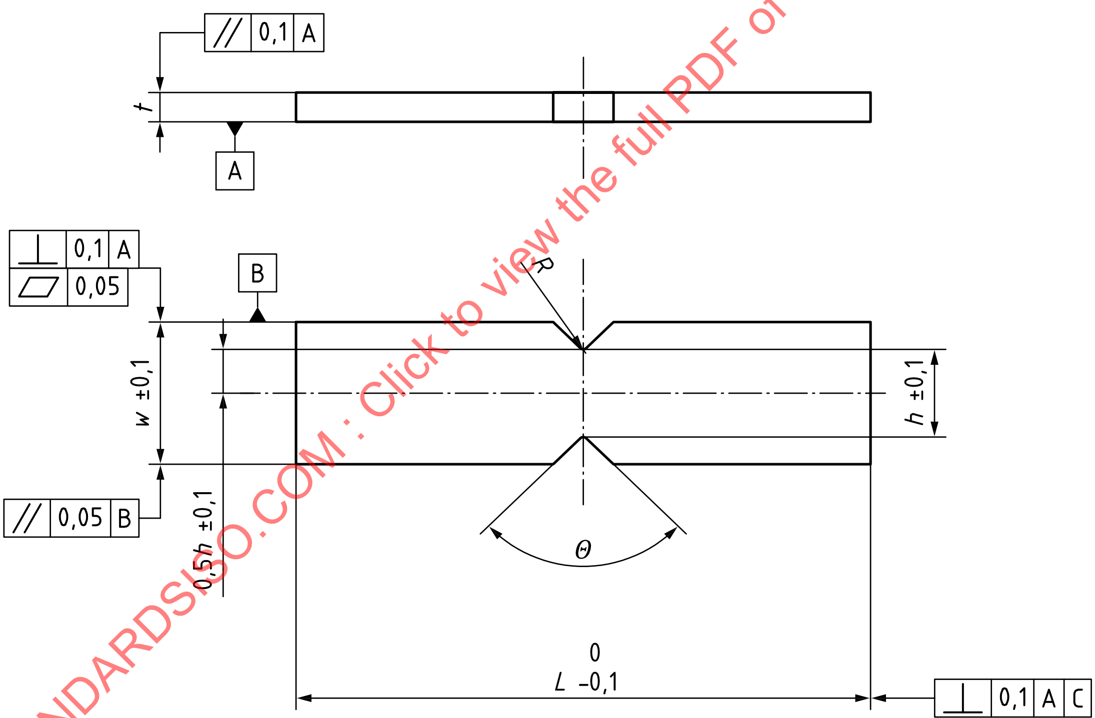


Figure 10 — Geometry and dimensions of Iosipescu test piece

Table 2 — Recommended dimensions for Iosipescu test pieces

Dimension	Description	Value mm	Allowance mm
L	Test piece length	50,0 to 100,0	±0,5
h	Distance between notches	60 % of *w*	±0,2
w	Test piece width	>12 and *w*/*L* <=0,25	±0,2
R	Notch radius	1 to 1,5	±0,2
Θ	Notch angle	90° to 120°	±2°
t	Test piece thickness		

Table 2 *(continued)*

Dimension	Description	Value mm	Allowance mm
	Parallelism between machined parts and notch root	0,05	
	Perpendicularity between machined parts and notch root	0,05	

The test piece length proposed in Table 2 should be adapted to the size of jaws (grips) in order to avoid the sample buckling

7 Test specimen preparation

7.1 Machining and preparation

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).

During cutting out, care shall be taken to align the test specimen axis with the desired fibre-related loading axis.

Diamond tools shall be used for cutting and machining of the test specimens. Machining parameters which avoid damage to the material shall be established and documented. These parameters shall be adhered to during test specimen preparation. Use of waterjet or laser cutting for specimen preparation is not adequate as this can lead to surface damage and reduced interlaminar shear strength.

7.2 Bonding of the gauges

The gauges shall be positioned as close as possible to the centre of the measurement zone and the orientation at +/-45° with respect to the longitudinal axis of the specimen (see Figure 8) should be respected within +/-10°.

If the material is porous, care shall be taken that penetration of adhesive into the material does not modify its behaviour.

If the test is being performed on a specific material for the first time, then strain shall be measured on both test piece faces, as explained in 8.3.2. The shear strains calculated as described in 9.3 shall not differ by more than 5 % of the average of the two shear strains at any applied load.

7.3 Number of test specimens

At least three valid test results, as specified in 8.4, are recommended for any condition.

If statistical evaluation of the test results is required, the number of test specimens should be chosen according to accepted statistical procedures and guidelines.

8 Test procedures

8.1 Displacement rate

Displacement-rate-controlled tests are preferred to those at controlled force rate that cause catastrophic failure. Displacement rate that allows specimen rupture within 1 min shall be used (usually 0,05 mm/s). The displacement rate and the loading mode shall be reported.

8.2 Measurement of test specimen dimensions

For double-notched test pieces, determine the thickness and width of the shear section of each test piece to within 0,02 mm.

Avoid damaging the critical shear-section area by performing these measurements, either optically (e.g. using an optical comparator) or mechanically using a flat, anvil-type micrometer. In either case, the resolution of the instrument shall be as specified in 5.5. Record and report the measured dimensions and locations of the measurements for use in the calculation of the shear stress. Use the average of multiple measurements in the stress and modulus calculations.

8.3 Testing technique

8.3.1 Specimen mounting

8.3.1.1 Compression of double-notched test pieces

Loosen the jaw of each grip sufficiently to allow the test piece thickness to be freely inserted into the fixture with clearance. Place the test piece loosely in the centre of the fixture and then press the back side of the test piece against the back wall of the fixture, while aligning the bottom of the test piece against the bottom of the fixture. The test piece should be centred in the fixture so that the line-of-action of the load acts directly through the mid-plane of the test piece. Lightly tighten the jaws to fix the test piece in the fixture.

Do not over-tighten the jaws. The purpose of the jaws is to maintain the test piece in place and to prevent buckling, not for clamping. Over-tightening the jaws will result in artificially high shear strengths.

Slowly move the cross-head of the testing machine until the upper surface of the fixture just makes contact with the upper surface of the test piece.

8.3.1.2 Iosipescu test pieces

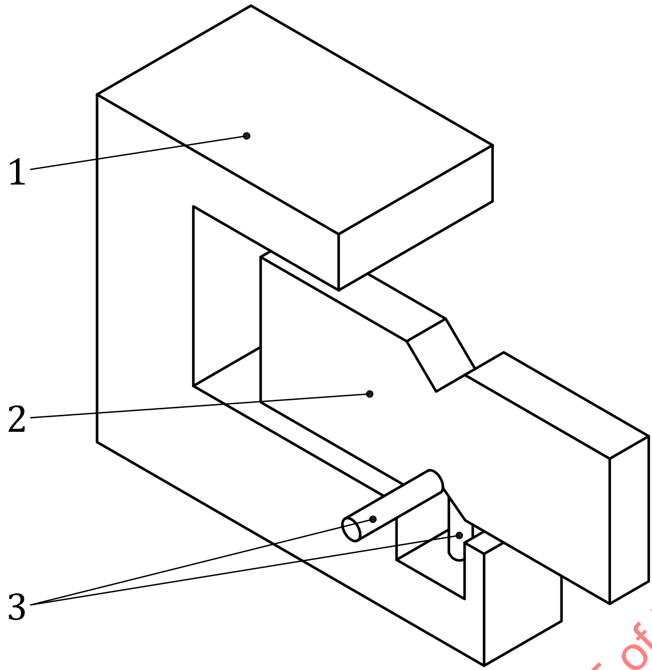
Loosen the jaw of each grip sufficiently to allow the specimen width to be freely inserted into the grip with clearance. Adjust the movable head position until the grips are approximately aligned vertically. Place the specimen loosely into both grips. Press the back side of the specimen flat against the back wall of the fixture. Pull the specimen alignment tool vertically up into the notch to centre the specimen V-notch relative to the fixture in accordance with Figure 11. While keeping the specimen centred, lightly tighten the left-hand-side jaw on the stationary grip.

There should now be some clearance between the specimen and the movable grip and no load showing in the test machine. If there is no clearance, or if load in the specimen is indicated, adjust either the head or the jaw of the movable grip, or both, until there is both clearance and zero load. Recheck the specimen placement in the stationary grip. Repeat if necessary. Move the testing machine cross-head until the upper surface of the movable grip just makes contact with the upper surface of the right-hand side of the specimen, without loading it. Lightly tighten the jaw of the upper right-hand grip onto the right-hand side of the specimen.

Do not over-tighten the jaw; over-tightening induces undesirable pre-loading and can damage some materials. Pre-loading should be minimized; however, a small amount of pre-loading (20 N to 50 N) can be unavoidable.

The specimen should now be centred in the fixture so that the line-of-action of the load acts directly through the centre of the notch on the specimen.

When the Iosipescu test is performed for the first time on a new material, it should be verified that the shear stress field is not disturbed by the normal stress field. A procedure is proposed in Annex A.



Key

1 fixture

2 specimen

3 alignment tool

Figure 11 — Schematic of alignment tool for Iosipescu test

8.3.2 Measurements

8.3.2.1 Double-notched test specimen

— Zero the load cell.

— Set the cross-head speed or displacement rate so that failure occurs within 60 s.

— Load the test specimen.

— Record continuously the shear force versus time.

— Note the position of fracture location relative to the notches.

8.3.2.2 Iosipescu test specimen

— Zero the load cell.

— Zero the gauge readings.

— Set the cross-head speed or displacement rate so that failure occurs within 60 s.

— Load the test specimen.

— Record continuously shear force and strains versus time.

Optionally, carefully remove the test piece halves from the test piece mount and determine the dimensions of the failed sheared area to the nearest 0,02 mm, by measurement of this surface with respect to either half of the ruptured test piece. This technique affords the most accurate determination of the length of the sheared plane defined by the separation of the notches machined in the test piece.

8.4 Test validity

The following circumstances invalidate a test:

— failure to specify and record test conditions;

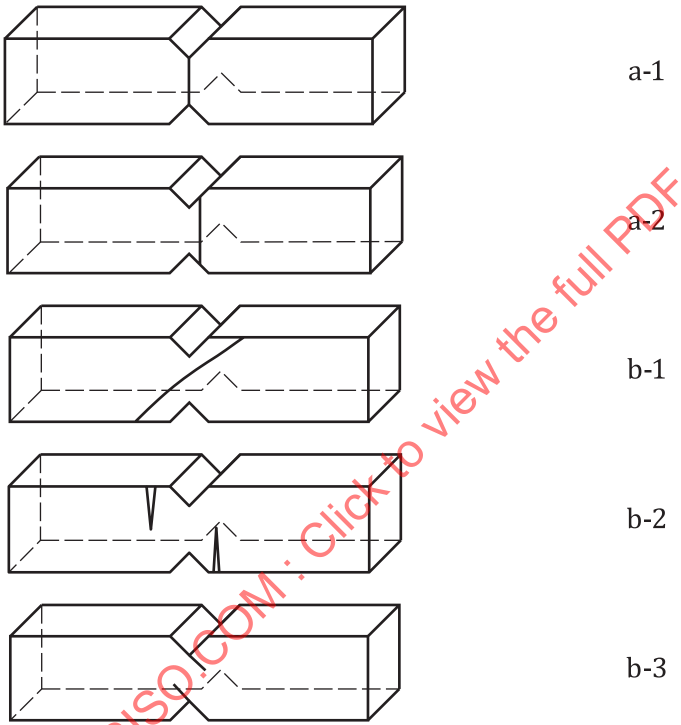
— failure to meet specified test conditions;

— rupture initiated outside the measurement zone (see Figures 12 and 13);

— slipping or buckling of the test specimen.

The following circumstances partially invalidate a test:

— a strain gauge debonding which can be detected through a move back of the gauge response invalidate the shear stress –shear- strain curve after the debonding.

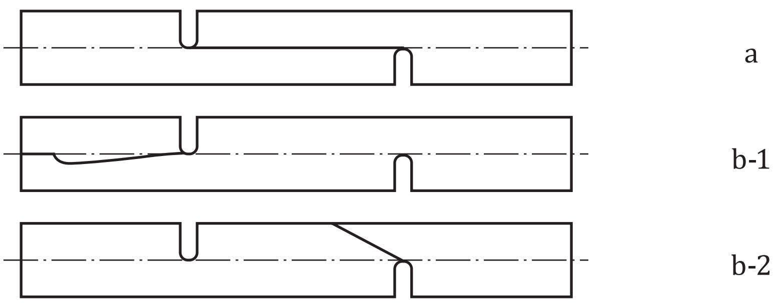


Key

a valid ruptures

b invalid ruptures

Figure 12 — Examples of valid and invalid ruptures for the Iosipescu test



Key

a valid ruptures

b invalid ruptures

Figure 13 — Examples of valid and invalid ruptures for the double notch test

9 Calculation of results

9.1 Shear strength

9.1.1 Double-notched test piece

For the compression of double-notched test pieces, calculate the shear strength according to Formula (1):

$$\sigma_{\text{ILSS,m,i,3}} = \frac{F_m}{S_0} \quad (1)$$

where

subscript "i"	is for the direction of the load with respect to the material orientation;
subscript "3"	is for the material orientation orthogonal to the shear plan;
F_m	is the applied maximum shear force;
S_0	is the initial shear section area, which is calculated according to Formula (2):

$$S_0 = wh \quad (2)$$

where

w	is the width of the test piece;
h	is the distance between the notches (see Figure 9).

9.1.2 Iosipescu test piece

For Iosipescu test pieces, calculate the shear strength according to Formula (3):

$$\sigma_{\text{ILSS,m,i,3}} = \frac{F_m}{S_0} \quad (3)$$

where

subscript "i"	is for the direction of the load with respect to the material orientation;
subscript "3	is for the material orientation orthogonal to the shear plan;
F_m	is the applied maximum shear force;
S_0	is the initial shear section area, which is calculated according to Formula (4):

$$S_0 = th \quad (4)$$