BRITISH STANDARD

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658-4:2003

Advanced technical ceramics — Mechanical properties of ceramic composites at room temperature —

Part 4: Determination of interlaminar shear strength by compression loading of notched test specimens

The European Standard EN 658-4:2003 has the status of a British Standard

ICS 81.060.30

National foreword

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The UK participation in its preparation was entrusted to Technical Committee RPI/13, Advanced technical ceramics, which has the responsibility to:

— aid enquirers to understand the text;

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— monitor related international and European developments and promulgate them in the UK.

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Advanced technical ceramics - Mechanical properties of ceramic composites at room temperature - Part 4: Determination of interlaminar shear strength by compression loading of notched test specimens

Céramiques techniques avancées - Propriétés techniques des céramiques composites à température ambiante - Partie 4: Détermination de la résistance au cisaillement interlaminaire par compression d'éprouvettes entaillées

Hochleistungskeramik - Mechanische Eigenschaften von keramischen Verbundwerkstoffen bei Raumtemperatur - Teil 4: Bestimmung der Scherfestigkeit von gekerbten Proben unter Druckbeanspruchung

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Contents

Foreword

This document (EN 658-4:2003) has been prepared by Technical Committee CEN/TC 184 "Advanced technical ceramics", the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by August 2003, and conflicting national standards shall be withdrawn at the latest by August 2003.

This document supersedes ENV 658-4:1992.

Annex A is informative.

EN 658 'Advanced technical ceramics – Mechanical properties of ceramic composites at room temperature' has six parts:

— *Part 1 : Determination of tensile properties*

— *Part 2 : Determination of compressive properties*

— *Part 3 : Determination of flexural strength*

— *Part 4 : Determination of interlaminar shear strength by compression loading of notched test specimens*

— *Part 5 : Determination of interlaminar shear strength by short span bend test (three-points)*

— *Part 6 : Determination of interlaminar shear strength by double-punch shearing*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This part of EN 658 specifies the conditions for determination of the interlaminar shear strength of ceramic matrix composite materials with continuous fibre reinforcement at room temperature, by loading a notched test specimen in compression. This method applies to all ceramic matrix composites with a continuous fibre reinforcement unidirectional (1D) and bidirectional (2D) and tridirectional (xD, with $2 < x < 3$) as defined in ENV 13233, loaded along one principal axis of reinforcement.

Two other methods for the determination of shear strength are given in further parts of EN 658.

NOTE 1 The interlaminar shear characteristics can vary significantly depending on test specimen preparation and dimensions, rate of application of the test force, surface condition, etc.

NOTE 2 However, results obtained by this part of EN 658 cannot be compared with results obtained by the two other methods.

NOTE 3 Care should be exercised in interpreting the results of the proposed testing methods to obtain absolute values of the interlaminar shear strength of ceramic matrix composites for design purposes.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ENV 13233:1998, *Advanced technical ceramics — Ceramic composites — Notations and symbols*.

EN ISO 7500-1:1999, *Metallic materials — Verification of static uniaxial testing machines — Part 1 : Tension/compression testing machines (ISO 7500-1:1999).*

ISO 3611, *Micrometer callipers for external measurements*.

3 Principle

The test consists of measuring the force required to fracture a transversely notched test specimen of defined shape and dimensions, subjected to compressive loading in direction 1 or 2, such that failure occurs by interlaminar shear in plane (1,2), as defined in ENV 13233. The test is performed at constant crosshead displacement rate.

4 Terms, definitions and symbols

For the purposes of this European Standard, the following terms, definitions and symbols and those given in ENV 13233:1998 apply.

4.1
shear failure force, F
maximum force required to produce interlaminar shear failure when double notched test specimen is subjected to compression under monotonic loading

4.2
interlaminar shear strengh, $ILLS_C$
ratio calculated on the basis of the shear failure force and the shear loaded area

NOTE The notation $ILSS$ is supplemented by a small letter referring to the test method described; in this case $ILSS_c$ for the interlaminar shear strength obtained from a compression loading test.

5 Apparatus

5.1 Test machine

The test machine shall be equipped with a system for recording the force applied to the test specimen. The machine shall conform to grade 1 in EN ISO 7500-1:1999.

5.2 Load train

The load train configuration shall allow the alignment of the test specimen axis with the direction of the load. Care shall be taken to maintain proper alignment of the test specimen during loading and to avoid buckling of the test specimen.

Two techniques are possible:

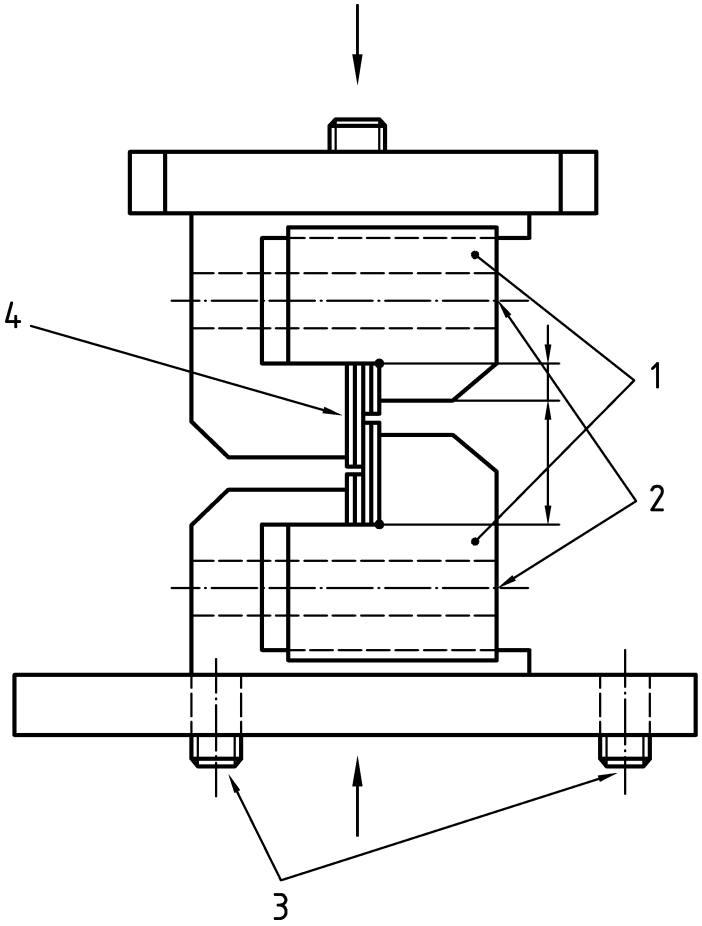
— compression between platens without a guide ;

— compression between platens with a guiding tool.

In both cases, compression platens are connected to the load cell and on the moving crosshead. The parallelism of these platens shall be better than 0,01 mm in the loading area and they shall be perpendicular to the load direction.

NOTE 1 A compliant interlayer material between the test specimen and platens can be used for testing macroscopically inhomogeneous materials to ensure uniform contact pressure.

NOTE 2 When test specimens to be tested have a thickness less than 3 mm, the use of a guiding tool is recommended, to avoid buckling. This guide should not cause any parasitic effect during the test. An example is given in Figure 1.



Key

1 Clamping jaws
2 Fixing screws
3 Adjusting screws
4 Test specimen

Figure 1 — Guiding tool

5.3 Dimension measuring devices

Devices used for measuring linear dimensions of the test specimen shall be accurate to ± 0,1 mm. Micrometers shall be in accordance with ISO 3611.

NOTE The distance between the notches can for example be measured by using an optical comparator.

6 Test specimen

The test specimen is shown in Figure 2. Notches are machined, one of each side of the test specimen. The recommended test specimen dimensions are given in Table 1. The distance between notches measured between the inner flanks of the notches (see Figure 2) shall be determined, taking into account the requirements to obtain shear failure.

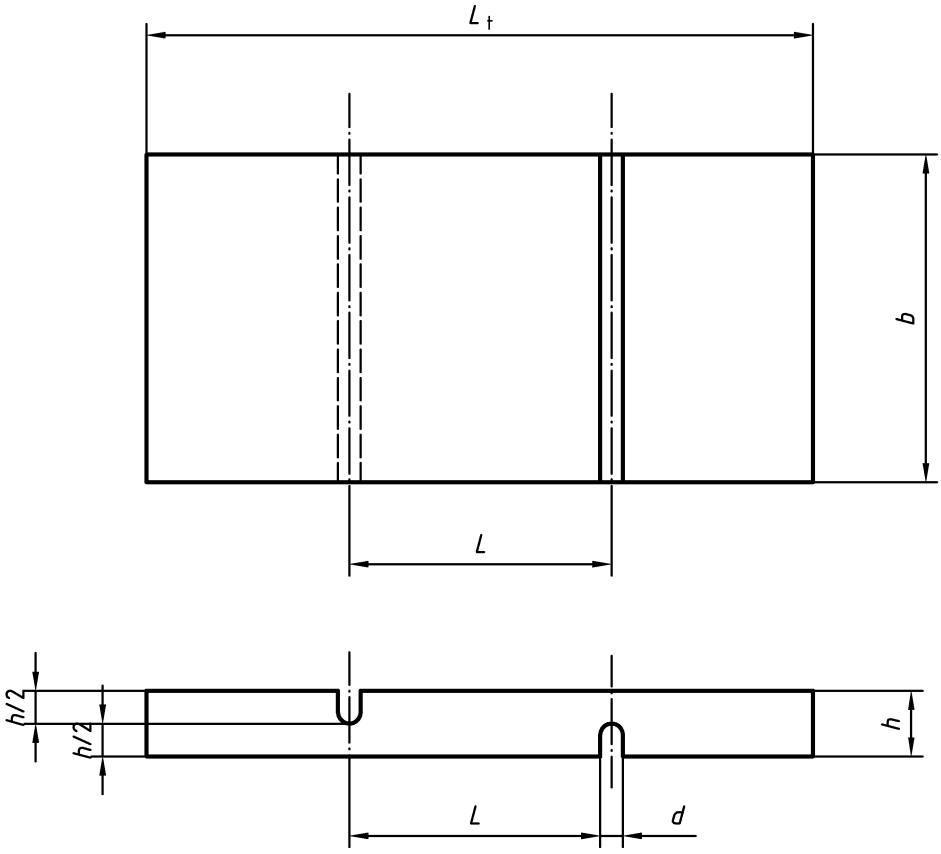


Figure 2 — Double notched interlaminar shear test specimen

Table 1 — Recommended test specimen dimensions

Dimensions in millimetres

	1D, 2D, xD	Tolerance
l_t, total length	25 to 30	± 1
h, thickness	2 to 10	± 1
b, width	10 to 13	± 0,1
L, distance between notches	8 to 13	± 0,1
Notch depth	h/2 + 0,1	± 0,05
d, notch width	0,5	± 0,1
Plane parallelism of machined parts	0,05	

NOTE If the proposed notch depth (h/2 + 0,1) does not lead to a rupture in plane (1,2), then the depth of the notch can be increased to:

$$\frac{h(n+1)}{2n} + 0{,}1$$

where

n is the number of plies.

7 Test specimen preparation

7.1 Machining

During cutting out, care shall be taken to ensure that the test specimen axes coincide with the fibre directions. Machining parameters which avoid damage to the material shall be established and documented. These parameters shall be adhered to during test specimen preparation.

7.2 Number of test specimens

At least five valid test results (see 8.4) are required.

NOTE If statistical evaluation is required, the number of test specimens should be in accordance with ENV 843-5.

8 Procedure

8.1 Displacement rate

Use a constant crosshead displacement rate which allows test specimen failure within 1 min. The displacement rate shall be reported.

NOTE Generally, a displacement rate between 0,5 mm/min and 1 mm/min is used.

8.2 Measurement of test specimens

Measure the width and thickness to the nearest 0,1 mm in the centre and at each end of the test specimen and report the arithmetic means of the measurements. Measure the distance between the notches to the nearest 0,1 mm.

8.3 Testing technique

Install the test specimen in the test machine and set the crosshead speed. Make a record of force versus time during the test. Verify the failure location and failure mode (see 8.4).

8.4 Test validity

The following circumstances will invalidate a test:

a) failure to specify and record test conditions;

b) failure to note the mode and location of fracture;

c) test specimen failure not occurring in a shear plane close to the median plane delineated by the notches (examples are given in annex A);

d) visible bending of the test specimen or test specimen slippage occurring during the test.

9 Calculation

9.1 Test specimen origin

A diagram illustrating the reinforcement directions of the material with respect to the longitudinal axis of the test specimen shall always accompany the test results.

9.2 Interlaminar shear strength

The following expression shall be used to calculate the interlaminar shear strength:

$$ills_c = \frac{F}{bL}$$

where

$ILSS_c$ is the interlaminar shear strength, in plane (1,2), in megapascal (MPa);

F is the shear failure force, in newton (N);

b is the mean test specimen width, in millimetre (mm);

L is the distance between the notches, in millimetre (mm).

10 Test report

The test report shall contain at least the following information:

a) name and address of the testing establishment;

b) date of the test, unique identification of report and of each page, customer name and address and signatory;

c) a reference to this European Standard, i.e. "determined in accordance with EN 658-4";

d) test specimen drawing or reference;

e) description of the test material (material type, manufacturing code, batch number);

f) the area and orientation of test specimens taken from a sample of material;

g) displacement rate;

h) number of tests carried out and the number of valid results obtained;

i) force versus time record;

j) individual results and arithmetic means;

k) mode and failure location of all the test specimens used for obtaining the above results;

l) any comments about the test or test results.

Annex A
(informative)

Examples of rupture

A.1 Valid rupture

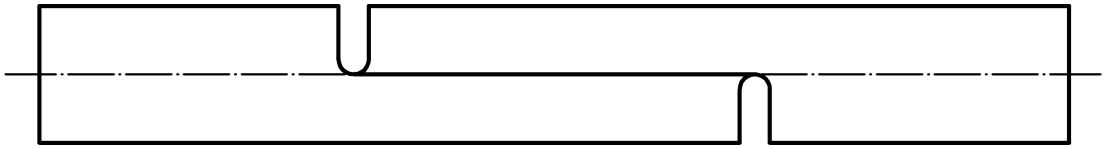
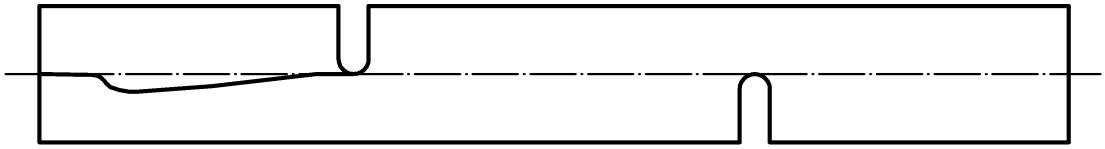


Figure A.1 - Valid rupture

A.2 Non-valid rupture



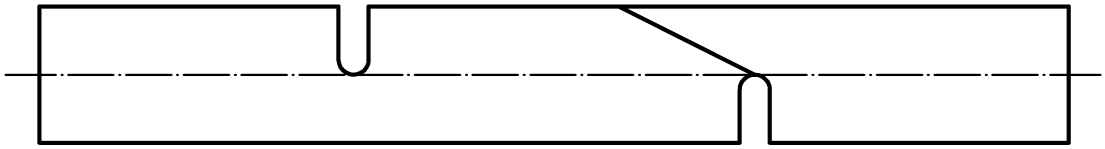


Figure A.2 - Non-valid rupture

Bibliography

ENV 843-5, *Advanced technical ceramics - Monolithic ceramics - Mechanical tests at room temperature - Part 5: Statistical analysis*

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