BS ISO 18558:2015

BSI Standards Publication

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for determining elastic modulus and bending strength of ceramic tube and rings

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of ISO 18558:2015.

The UK participation in its preparation was entrusted to Technical Committee RPI/13, Advanced technical ceramics.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 81870 7

ICS 81.060.30

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2015.

Amendments issued since publication

Date	Text affected

BS ISO 18558:2015

INTERNATIONAL STANDARD

ISO 18558

First edition
2015-05-15

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for determining elastic modulus and bending strength of ceramic tube and rings

Céramiques techniques — Méthode d'essai pour la détermination du module élastique et de la résistance en flexion des tubes et anneaux en céramique

Reference number
ISO 18558:2015(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 206, *Fine ceramics*.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for determining elastic modulus and bending strength of ceramic tube and rings

1 Scope

This International Standard specifies the testing method for determining the elastic modulus and bending strength of ceramic tubes or rings at ambient temperature by the compression tests on split ring pieces. Methods for test piece preparation, test modes and load rates, data collection, and reporting procedures are addressed.

This International Standard applies primary to the ceramic materials including monolithic fine ceramic, glass, whisker- or particulate reinforced ceramic composites, but not available for fibre reinforced ceramic composites. This test method may be used for material research, quality control, and characterization and design data generation purpose.

2 Normative references

The following referenced documents, in whole or in part, are normatively in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
elastic modulus
ratio of stress to strain, also known as Young's modulus

3.2
bending strength
maximum tensile stress at fracture of a split ring under compression

3.3
split ring
test piece which has the shape of a split ring, prepared by cutting a gap from a ring piece

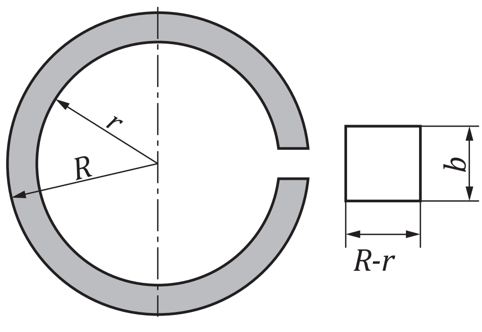

Figure 1 — Schematic diagram of a split ring piece

3.4
fracture load
compression load applied on the split ring piece at fracture

4 Principle

Install a split ring test-piece on the fixture and keep the gap at the middle height. Under a symmetrically compressive load, stiffness of the split ring reflects the elastic modulus and the critical load to fracture reflects the fracture strength. For a given test piece in the range of elasticity, the elastic modulus could be obtained from the slope of the loading-displacement curve and the test piece dimensions. Bending strength is computed from the critical load at fracture and the test piece dimensions.

5 Apparatus

5.1 Testing machine

A suitable testing machine capable of applying a force to the test piece at a uniform displacement or loading rate shall be used. The testing machine shall comply with the values in ISO 7500-1. The measuring accuracy is 1 % or better and the calibration shall have been checked recently.

5.2 Data acquisition

Obtain the maximum load and at least autographic record of the applied load versus the displacement of the split ring for elastic modulus tests. Obtain the critical load at fracture for strength tests.

Digital chart recorders or data collection systems shall be used. The data acquisition system shall be with a precision of 1 % or better for load, and a precision of at least 0,001 mm or better for displacement measurement.

5.3 Dimension-measuring device

For the determination of the test piece dimensions, a calibrated calliper or an alternative calibrated device with a resolution of 0,02 mm shall be used.

6 Test pieces

6.1 Test piece size

Test piece geometry shall meet with $\frac{9}{11} < \frac{r}{R} < 1$ for the validity of the calculation formulae. The gap of the split ring shall be sufficiently large (usually 2 mm to 3 mm) so that the ring will not be closed during the test before fracture in the strength test, but less than the one half of the inner diameter, as shown in Figure 1.

The suitable width (axial length) for the split ring shall be satisfied with $0{,}2 \le b/R \le 1{,}0$ and $1{,}0 \le b/(R-r) \le 5{,}0$.

Measure the width, the outer radius, and the inner radius of each test piece in several places using a calibrated calliper. Compute the mean value of each one.

6.2 Test piece preparation

6.2.1 General

This International Standard permits two options for surface treatment in test piece preparation.

I: Tubes property: no further surface preparation for evaluating the mechanical properties of existing ceramic tubes or rings, including as-fired, surface polished, or surface machined tubes.

Cut the ceramic tube into several rings according to the size requirement in 7.1. Then grind and polish the cutting section faces of the ring to a parallelism of 0,02 mm or better. Clean the test pieces with alcohol or pure water, etc. The edges of the test pieces shall be chamfered to avoid edge damage for strength tests. Chamfering is not important for the tests of elastic modulus. Then a slot width about 0,2 r is cut by using a cutting machine for ceramics.

II: Material property: test piece is machined from tubes or bulk ceramics, surface shall be ground and polished before cutting into rings.

For a given ceramic tube, if surface treatment is in need, the grinding and polishing shall be performed parallel to the tangent direction of the tube first. Cut the ceramic tube into several rings according to the size requirement in 7.1. And then, grind and polish the cutting section faces of the ring to a parallelism of 0,02 mm or better. Clean the test pieces with alcohol or pure water, etc. The edges of the test pieces shall be chamfered to avoid edge damage for strength tests. Chamfering is not important for the tests of elastic modulus. Then a slot width about 0,2 r is cut by using a cutting machine for ceramics.

NOTE The aim of polishing is to minimize the damage created in the test pieces due to the preparation process.

6.2.2 Test piece storage

The test pieces shall be handled with care to avoid the introduction of damage after test piece preparation. Test pieces shall be stored separately and not allowed to impact or scratch each other.

6.2.3 Number of test pieces

A minimum of 6 test pieces is required for the tests. For a more detailed statistical analysis of the strength (e.g. Weibull analysis), at least 30 pieces are recommended.

7 Test procedures

7.1 Testing machine and loading speed

Use universal mechanical testing machine with a crosshead speed of 0,1 mm/min for the elastic modulus tests and 0,5 mm/min for the strength tests, respectively. The test piece shall contact well with the supporting and loading anvils.

NOTE Suitable loading rate actually depends on the ring size, the test can be performed by position or load control so that the time to failure will be between 10 s to 60 s for the split ring test piece.

7.2 Elastic modulus measurement

To measure the elastic modulus, put each test piece in the fixture, as shown in Figure 2. The middle of the gap shall be, as possible as, at the half height of ring. The test piece shall contact well with the supporting and loading anvils. Apply the test force at a specified rate of 0,1 mm/min and record the load increment in the scope of elastic deformation and the corresponding compressive displacement of the piece. The displacement increment is measured by digital micrometer or other devices with high accuracy in accordance with 5.2. The elastic modulus of the material is calculated according to the Formula (1).

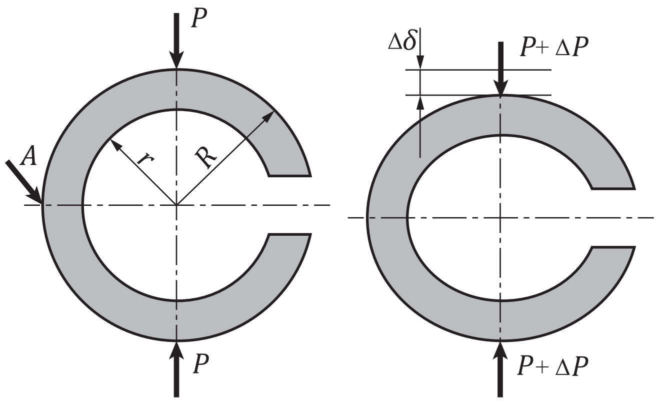

Figure 2 — Schematic diagram of the split ring, loading mode and deformation

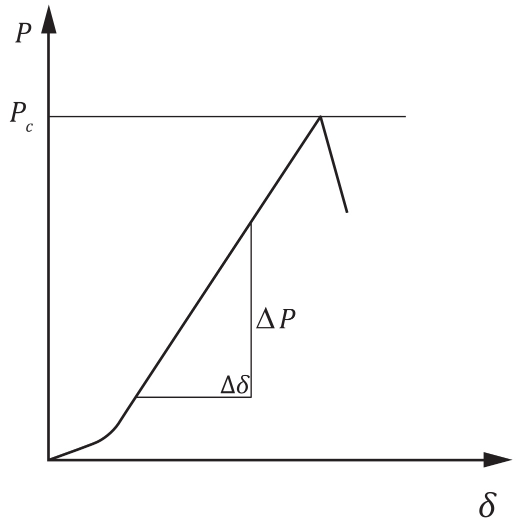

Figure 3 — Schematic diagram of a load-displacement curve

7.3 Bending strength measurement

To measure the bending strength of the split ring, put each test piece in the fixture. The middle of the gap shall be at the half height of ring. The test piece shall contact well with the anvils. Apply the symmetrical test force at 0,5 mm/min crosshead rate, as shown in Figure 2, and record the peak value of the load. The typical loading-displacement curve is shown in Figure 3. The fracture starting point is usually near point A (maximum bending stress point) as shown in Figure 2. Otherwise, this strength test is invalid. The bending strength of the test piece can be calculated by the Formula (4).

7.4 Temperature and relative humidity

Measure and record the laboratory ambient temperature and relative humidity during the test process.

8 Calculation of results

8.1 Calculation of elastic modulus for split ring

8.1.1 Calculation of the elastic modulus

The standard formula for elastic modulus is:

$$E = \frac{3\pi}{4000b} \times \frac{\Delta P}{\Delta \delta} \times \left(\frac{R+r}{R-r} \right)^3 \tag{1}$$

where

- E is the elastic modulus, in GPa;
- ΔP is the load increment in the scope of elastic deformation, in Newton (N);
- $\Delta \delta$ is the corresponding compressive displacement resulted from the ΔP, in mm;
- R is the mean outer radius of split ring, in mm;
- r is the mean inner radius of split ring, in mm;
- b is the mean width of test pieces, in mm.

8.1.2 Mean value and standard deviation for elastic modulus

The mean elastic modulus, $\overline{E}$, and the standard deviation, S_e, are given by Formulae (2) and (3):

$$\overline{E} = \frac{\sum_{i=1}^{n} E_{,i}}{n} \tag{2}$$

$$S_e = \left[\frac{\sum_{i=1}^{n} (E_i - \overline{E})^2}{n-1} \right]^{1/2} \tag{3}$$

where

- E_i is the elastic modulus of the ith test piece;
- n is the total number of test piece.

8.2 Calculation of bending strength for split ring

8.2.1 8.2.1 Standard formula for bending strength

The standard formula for the bending strength is:

$$\sigma_{\mathrm{br}} = \frac{P_c}{bR\left[\ln(R/r) \times \frac{R+r}{R-r} - 2\right]} \tag{4}$$

where

σ_{br} is the bending strength, in MPa;

P_c is the maximum load to fracture, in N;

R is the mean outer radius of split ring, in mm;

r is the mean inner radius of split ring, in mm;

b is the mean width of test pieces, in mm.

8.2.2 Mean value and standard deviation for bending strength

The mean bending strength, $\bar{\sigma}_{br}$, and the standard deviation, S_s, are given by Formulae (5) and (6):

$$\bar{\sigma}_{br} = \frac{\sum_{i=1}^{n} \sigma_i}{n} \tag{5}$$

$$S_s = \left[\frac{\sum_{i=1}^{n} (\sigma_i - \bar{\sigma}_{br})^2}{n-1}\right]^{1/2} \tag{6}$$

where

σ_i is the bending strength of the *i*th test piece;

n is the total number of test piece.

9 Test report

The test report shall contain at least the following information:

a) a reference to this International Standard, i.e. ISO 18558:2014;

b) the name and address of the testing laboratory;

c) the temperature and humidity of the laboratory;

d) the date of the test, the customer name, address and signatory one one page and a unique identification of report and page size on each page;

e) surface finishing of the test piece;

f) the description and test material (material type, manufacturing code, batch number);

g) the displacement rate or load rate;

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

i) the valid results, mean value and standard deviations of the elastic modulus or bending strength.

Bibliography

[1] ISO 14704, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for flexural strength of monolithic ceramics at room temperature*

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

[3] BSI EN 843-7: 2010, *Adavanced technical ceramics-mechanical properties of monolithnic ceramics at room temperature part 7: C ring tests*

[4] ASTM C 1323-10: 2010, *Standard Test Method for Ultimate Strength of Advanced Ceramics with Diametrally Compressed C-Ring Specimens at Ambient Temperature*

[5] ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

[6] WAN D.T.. BAO Y.W., LIU X.G., ZHAO H., TIAN L., Evaluation of elastic modulus and strength of glass and brittle ceramics by compressing a notched ring specimen. Key Eng. Mater. 2011, **177** pp. 114–117

[7] Wereszczak A., Caspe R.J., Swab J.J., Duffy S.F., Baker E.H. C-ring strength of advanced monolithic ceramics. Ceram. Eng. Sci. Proc. 2003, **24** (4) pp. 483–490

ICS 81.060.30

Price based on 8 pages

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™