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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

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Foreword

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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
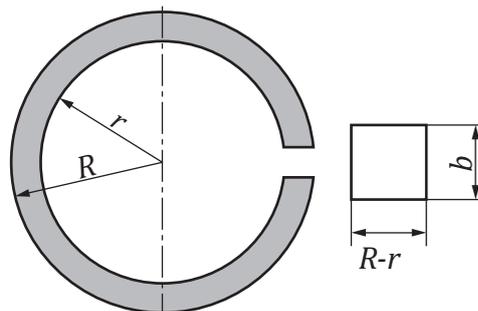

Figure 1 — Schematic diagram of a split ring piece

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 $\dfrac{9}{11} < \dfrac{r}{R} < 1$ 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).
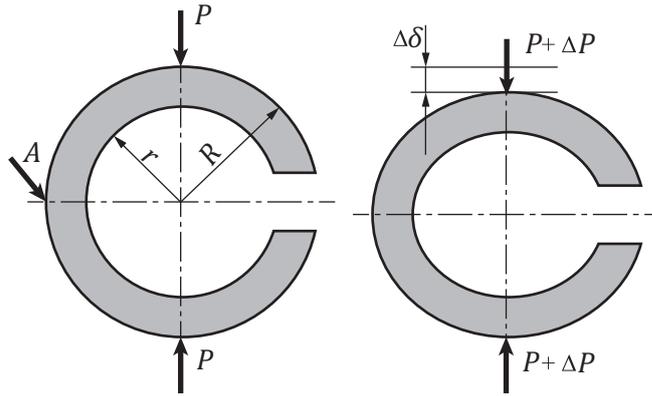
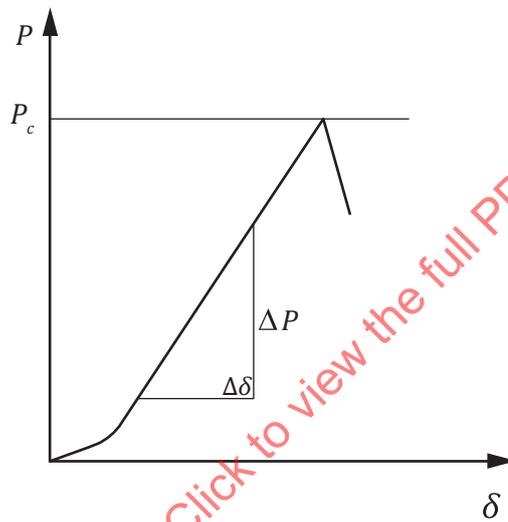**Figure 2 — Schematic diagram of the split ring, loading mode and deformation**

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, $\bar{E}$, and the standard deviation, S_e, are given by Formulae (2) and (3):

$$\bar{E} = \frac{\sum\limits_{i=1}^{n} E_{,i}}{n} \tag{2}$$

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

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:

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

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):

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

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

where

σ_i is the bending strength of the ith 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.