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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of monolithic ceramics at room temperature — Determination of flexural strength by the ring-on-ring test

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Céramiques techniques — Propriétés mécaniques des céramiques monolithiques à température ambiante — Détermination de la résistance à la flexion à l'aide de doubles anneaux

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

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of monolithic ceramics at room temperature — Determination of flexural strength by the ring-on-ring test

1 Scope

This document specifies a method for the determination of the nominal equibiaxial flexural strength by the ring-on-ring test of advanced monolithic technical ceramic materials at room temperature.

This document is applicable to materials with a grain size less than 100 µm.

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 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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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3 Terms and definitions

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

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

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

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

3.1
equibiaxial flexural strength
σ_{rr}
maximum nominal stress at the test piece surface supported by the material at the instant of failure when loaded in linear elastic equibiaxial bending by the ring-on-ring test

Note 1 to entry: The ring-on-ring test for the determination of flexural strength is often referred to as biaxial bending test or equibiaxial bending test (see Reference [1]). These names should not be used without the reference to the ring-on-ring test conditions as there are some other test arrangements for which the term is used or could also be used, such as the ball-on-three-balls test, the punch-on-three-balls test, the ball-on-ring test and the punch-on-ring test.

4 Principle

A round discoidal test piece with a constant thickness is positioned between two concentric rings of different diameters and loaded by an axial force.

The nominal equibiaxial flexural strength is calculated from the axial force which acts during the moment of fracture, the geometry of the test piece and the test arrangement, as well as the Poisson ratio of the test piece material.

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5 Significance and use

This test is intended to be used for material development and characterization, quality control and design data acquisition purposes. The strength level determined by the test is calculated on the basis of linear elastic bending behaviour of a round, disk-like thin plate on the assumption that the material being tested is elastically homogeneous and isotropic and shows a linear (Hooke) stress-strain behaviour.

The result obtained from a strength test is determined by a large number of factors associated with the microstructure of the material, the surface finishing procedure applied in preparation of the test pieces, the size and shape of the test piece, the mechanical function of the testing apparatus, the rate of load application and the relative humidity (RH) of the ambient atmosphere. As a consequence of the brittle nature of ceramics, there is usually a considerable range of results obtained from a number of nominally identical test pieces. These factors combined mean that caution in the interpretation of test results is required. For many purposes, and as described in this document, the results of strength tests can be described in terms of a mean value and a standard deviation. Further statistical evaluation of results is required for design data acquisition and can be desirable for other purposes (see ISO 20501).

This method places closely defined restrictions on the size and shape of the test piece and on the function of the test apparatus in order to minimize the errors that can arise as a consequence of the test procedure.

NOTE The basis for the choice of dimensions and tolerances of test pieces and of the requirements of the test jig can be found in ISO 6474-1, ASTM C1499 and Reference [1].

All other test factors are required to be stated in the test report (see Clause 10) in order to allow inter-comparison of material behaviours. It is not possible rigorously to standardize particular surface finishes since these are not absolutely controllable in mechanical terms. The inclusion of a standard grinding procedure (see 7.3) as one of the surface finish options in this method is intended to provide a means of obtaining a minimum amount of residual grinding damage to the test material.

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WARNING — The extrapolation of equibiaxial flexural strength data to other geometries of stressing, to single-axial stressing, to other rates of stressing or to other environments should be viewed with caution.

The information about the origin of fracture in an equibiaxial flexural strength test can be a valuable guide to the nature and position of strength-limiting defects. Fractography of test pieces is highly recommended (see e.g. ASTM C1499, Reference [1], Reference [2]) and Annex A. In particular, the test can identify fracture origins as being edge defects (caused by edge preparation), surface defects (caused by surface preparation) or internal defects (caused by manufacturing inhomogeneities such as pores, large grains or impurity concentrations). Not all advanced monolithic technical ceramics are amenable to clear fractography.

6 Apparatus

6.1 Test machine

The test machine shall be capable of applying a force over a ball or a suitable articulation device in that way that the loading ring acts perpendicular to the surface of the test piece so that the two rings (loading ring and support ring) have uniform contact to the face surfaces of the test piece.

The machine shall be capable of applying the force shock-free and with controlled force or displacement. The test machine shall be equipped for recording the maximum force applied to the test piece. The accuracy of the test machine shall be in accordance with ISO 7500-1, grade 1.

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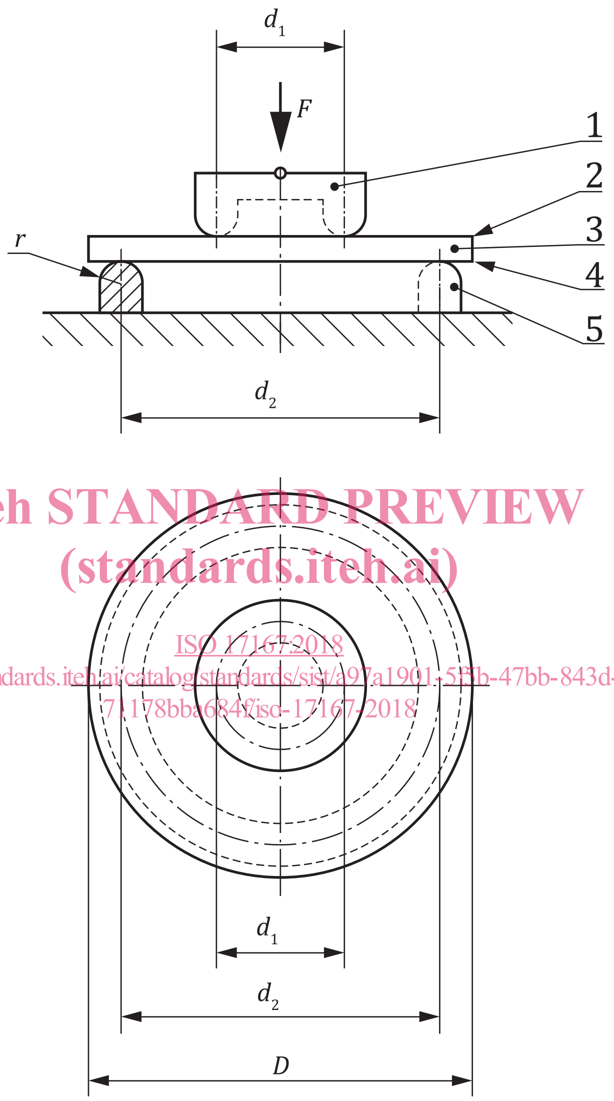
6.2 Test jig

The test jig for the ring-on-ring test shall be as specified below in order to minimize misalignments and frictional forces applied to the test piece.

NOTE 1 The precise construction of the test jig is not fixed in this document but the function is.

A schematic test setup for the examination of the nominal equibiaxial flexural strength by the double-ring flexural test is shown in Figure 1.



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Key

1	loading ring	d_1	contact diameter of the loading ring
2	thin adhesive film on the test piece	d_2	contact diameter of the support ring
3	test piece	D	diameter of the test piece
4	rubber film under the test piece	F	force applied
5	support ring	r	contact radius

Figure 1 — Example of a test setup for the determination of flexural strength by the ring-on-ring test

The test jig shall consist of two concentric rings of different diameters, namely the support ring (large), and the loading ring (small), see Figure 1.

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The following standard dimensions shall be observed:

— contact diameter of the loading ring, d_1: (12 ± 0,1) mm;

— contact diameter of the support ring, d_2: (30 ± 0,1) mm;

— radius of curvature of the rings in the region of contact with the test piece surface, r: (2 ± 0,2) mm.

NOTE 2 This test setup has been used for decades to characterize the stress of advanced technical alumina ceramics for orthopaedic implants (see ISO 6474-1).

A suitable centring device or procedure for the test jig shall be used ensuring a centred positioning of the loading ring, the test piece and the support ring to one another within 0,2 mm.

Either the support ring or the loading ring shall be fixed to the punch of the test machine used so that an adjustment of the rings to the test piece is also possible if the test piece is not perfectly coplanar flat.

The two rings shall be made from hardened steel with a Vickers hardness greater than 500 HV or greater than 40 HRC (Rockwell C-scale), or another material with at least the hardness of the material tested (e.g. hard metal, ceramic) to minimize damage to the rings which can occur during the fracture.

To compensate small deviations of the surface flatness of the discoidal test piece, a thin rubber film with a thickness of (0,6 ± 0,1) mm and a shore A hardness of (60 ± 5) shall be positioned between the support ring and the test piece.

The flatness (and/or waviness) of the loading and the supporting rings shall be equal or smaller than 0,02 mm.

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6.3 Calliper or alternative calibrated device for the measurement of the test piece thickness

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For the determination of the test piece dimensions, a calibrated calliper or an alternative calibrated device with a resolution ≤ 0,1 % of the dimension to be measured shall be used.

It means that the resolution of the measurement device for the test piece thickness shall be ≤ 0,002 mm and for the test piece diameter ≤ 0,04 mm.

6.4 Device for measuring the temperature and humidity

A device for measuring the temperature with a resolution of at least 1 °C and a humidity measuring device with a resolution of at least 5 % RH shall be used.

7 Test pieces

7.1 General

The test pieces shall be prepared by processes in accordance with the technologies used during the production of the products. They may either be specially processed to, or close to, the final required dimensions specified in 7.2, or may be machined from larger blocks or components.

NOTE 1 The strength of many types of advanced monolithic technical ceramics is strongly influenced by the machining procedure used for the preparation of the test pieces. Low strengths might be caused by grinding with coarse diamond grit sizes and, conversely, very high strengths might be obtained if care is taken in surface preparation. Some materials, especially those containing transformable zirconia, could be markedly strengthened by appropriate grinding schedules. The definition of surface preparation conditions is therefore an important aspect of this test method.

Because of the different surface preparation conditions there are no limits specified for the flatness (and/or waviness) for the test pieces.

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If as-fired samples, especially very flat samples, have to be tested (e.g. substrates, semiconductor wafers), there could be some contact issues with asymmetric loading if the dimensions of the sample are not well described. For example, the maximum of total thickness variation (TTV), warp, bow and sori should be defined or at least considered.

On the compressive stressed surface of the test piece (the side of the test piece which is turned to the loading ring), a thin adhesive film shall be fixed to compensate unevenness of the test piece surface and to keep the fracture pieces together after the fracture of the test piece.

NOTE 2 A first visual fracture analysis is possible immediately after the bending test. The intention of this fracture analysis is to decide whether the fracture origin lies at or inside the loading ring region (regular fracture) or outside the loading ring region (irregular fracture).

7.2 Dimensions and tolerances

Dimensions and tolerances of test pieces shall be as shown in Table 1 and Figure 2 unless otherwise agreed between the parties.

Table 1 — Dimensions and tolerances of the test pieces

Test piece type	Final surface preparation condition	Parameter	Diameter *D* mm	Thickness *H* mm
Standard version	I, II, III (all conditions)	Dimensional range	36 ± 0,5	2,0 ± 0,1
	II, III (machined)	Parallelism tolerance	—	±0,02
	I (as-fired)	Parallelism tolerance	—	±0,05

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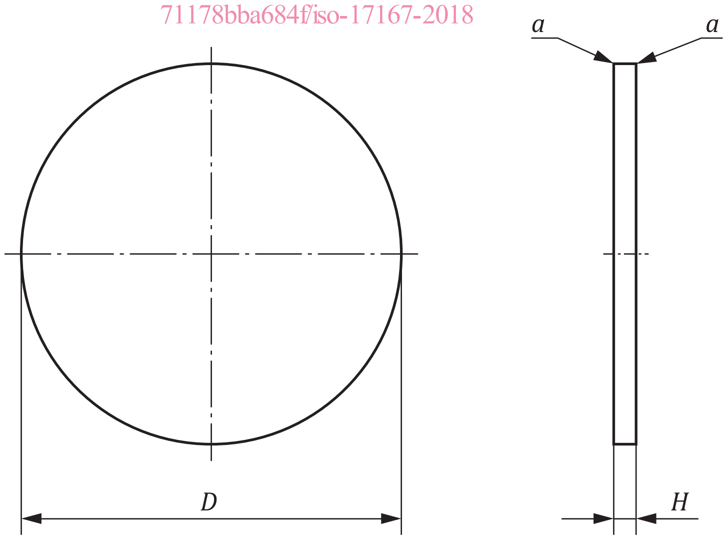

a) Top view **b) Side view**

Key

D diameter of the test piece

H thickness of the test piece

a edges: sharp, chamfered or rounded

Figure 2 — Dimensions, chamfers and tolerances of test pieces for the ring-on-ring test

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