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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test methods for fracture toughness of monolithic ceramics — Single-edge V-notch beam (SEVNB) method

Céramiques techniques — Méthodes d'essai pour la détermination de la ténacité à la rupture des céramiques monolithiques — Méthode sur éprouvette à entaille en V sur une seule face (Méthode SEVNB)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 23146 was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

This second edition cancels and replaces the first edition (ISO 23146:2008), of which it constitutes a minor revision.

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test methods for fracture toughness of monolithic ceramics — Single-edge V-notch beam (SEVNB) method

1 Scope

This International Standard specifies a method for the determination of the fracture toughness of advanced technical ceramics. The procedure makes use of single-edge V-notched bars, which are loaded in four-point bending until failure. It is applicable to monolithic ceramics with a grain size or major microstructural feature size larger than about 1 µm.

The use of this International Standard for yttria tetragonal zirconia polycrystal material (Y-TZP) is not recommended. The method might also be unsuitable for some other very tough or soft ceramics in which a sharp crack does not form at the root of the V-notch.

2 Normative references

The following referenced documents are indispensable for the application 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.

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ISO 3611, *Geometrical product specifications (GPS) — Dimensional measuring instruments; Micrometers for external measurements — Design and metrological characteristics*

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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*

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

ISO 15732, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for fracture toughness of monolithic ceramics at room temperature by single edge precracked beam (SEPB) method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15732 apply.

4 Principle

This method of conducting a fracture toughness test is based on the preparation and fracture of bar test pieces in which a sharp-tipped notch is machined. Using the technique of a reciprocating razor blade and diamond paste, a narrow notch can be honed into a test piece using either a manual method or a simple machine. Under well-controlled conditions, a notch-tip radius in the range of 1 µm to 20 µm can be prepared depending on the grain size of the test material. For many materials, this is a close approximation to a sharp crack, and the method has been found to give fracture toughness values very close to those of other methods such as the single-edge precracked beam method (ISO 15732) or the surface crack in flexure method (ISO 18756), provided that a sharp crack forms at the root of the notch either during its preparation or during the subsequent fracture sequence. The method has the advantage of simplicity of notch production compared with using a sharp-tipped diamond saw or a diamond impregnated wire in which the tip radius is normally greater than 50 µm. The method is often

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easier to undertake compared with other methods of precracking and is applicable to a wider range of materials outside the scope of these methods.

The method has been extensively researched (see the Bibliography) and has been evaluated in an ESIS (European Structural Integrity Society)/VAMAS (Versailles Agreement on Advanced Materials and Standards) round robin, the results of which are summarized in Annex B. This recommended practice is based upon the ESIS/VAMAS SEVNB round robin.

The method may have some limitations for materials with grain sizes of less than 1 μm, for which the assumption that the notch approximates to a sharp crack may not be valid (see Annex C). Users should strive to minimize the notch-root radius in the test pieces. This International Standard places a provisional criterion that the notch-root radius should be similar to or less than twice the average grain size of the material.

The method is complementary to other methods of measuring fracture toughness described in ISO 15732 (single-edge precracked beam method), ISO 18756 (surface crack in flexure method), and ISO 24370 (chevron notch method); see the Bibliography.

5 Apparatus

5.1 Ordinary razor blades, preferably with a support along one edge but alternatively inserted in a suitable holder.

NOTE 1 Razor blades thinner than about 0,2 mm are not ideal for this task unless stiffened by a support, such as by gluing or screwing between two steel plates, leaving only about 2 mm of edge showing. A razor blade with a tip angle of 30° or smaller is ideal.

NOTE 2 Although it is possible to machine the notches entirely by hand, the use of a simple device in which the test pieces are mounted and in which a razor blade primed with diamond paste is moved in a reciprocating motion across the mounted test pieces has a distinct advantage, as this provides controlled loading and directional stability to the razor blade, and sharper notches are produced. An example is shown in Annex A.

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5.2 Metallographic diamond paste, in a viscous organic carrier and of fine grain size, typically 1 μm to 3 μm.

5.3 Lubricant, a light lubricating oil for lubricating the razor blade, e.g. clock oil.

5.4 Test piece support, consisting of a flat plate or other suitable device for mounting test pieces during notch honing.

5.5 Flexural-strength test fixture, preferably a four-point flexural-strength test fixture operating in accordance with the requirements of ISO 14704, i.e. either 1/4-point flexure (preferred) or 1/3-point flexure. Alternatively, a three-point flexural-strength test jig may also be used, but the alignment of the V-notch with the central loading roller is more critical.

The test piece is supported on two bearing edges perpendicular to its length. The outer-support bearing edges shall be parallel rollers of diameter 5,0 mm ± 0,2 mm and shall be capable of rolling outward on flat support surfaces. Preferably, one of the rollers shall additionally be capable of rotating about an axis parallel to the length of the test piece such that torsional loading is minimised. The two rollers shall be positioned initially with their centres 40,0 mm ± 0,5 mm (1/4-point flexure) or 30 mm ± 0,5 mm (1/3-point flexure) apart with their axes parallel to within 1°. The separation of the centres of the rollers in their starting positions shall be measured to the nearest 0,1 mm with a travelling microscope. The rollers shall be made from hardened steel or other hard material with a hardness greater than 40 HRC (Rockwell C-scale). The rollers shall have a smooth burr-free surface finish with roughness less than 0,5 μm *Ra* and shall have a diameter uniform to ± 0,02 mm.

For four-point flexure, the two loading rollers are located at the 1/4-points (or 1/3-points), with an inner span of 20 mm ± 0,2 mm (or 10 mm ± 0,2 mm for 1/3-point flexure) and are free to roll inwards. The

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rollers are free to rotate separately about an axis parallel to the length of the test piece to allow alignment. For three-point flexure, the single loading roller, which need not rotate, shall be positioned centrally between the outer-support rollers. The distances between the rollers shall be measured to the nearest 0,1 mm along the length of the specimen perpendicular to the direction of loading, using a travelling microscope or other suitable device. The loading rollers in four-point flexure shall be symmetrically positioned to within ± 0,1 mm. The arrangement for loading shall ensure that equal forces are applied to the two loading rollers. The single loading roller in three-point flexure shall be centrally located to within ± 0,2 mm.

5.6 Mechanical testing machine, capable of applying a force at a constant rate of displacement or constant loading rate to the test piece in the flexural-strength test jig and of recording the force at which the test piece fractures. The force measuring device shall be in accordance with ISO 7500-1 and shall have an accuracy of ≤ 1 %.

NOTE The test facility can, with advantage, be equipped with a capability for recording the force/displacement behaviour of the test piece, ideally a sensitive system directly contacting the test piece. Provided that the load-train stiffness is sufficient, machine displacement recording can be adequate.

5.7 Ultrasonic cleaning bath, for cleaning the test pieces after notching, suitable for insertion of a beaker or other receptacle containing solvent.

5.8 Calibrated micrometer, similar to the one in accordance with ISO 3611, but capable of being read to a precision of 0,002 mm using a vernier or electronic readout.

5.9 Optical microscope, with calibrated magnifications over the range 50 × to 500 × , suitable for observing the notch-tip shape, and fitted with photomicrographic facilities.

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5.10 Notch-measuring device, a calibrated device for measuring the depth of the sawn notch after fracture with a reading precision of 0,002 mm.

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NOTE This can be achieved by the use of an appropriate travelling microscope, or a conventional metallurgical microscope with calibrated stage movement, or a microscope with a calibrated micrometer eyepiece.

5.11 Drying oven, capable of maintaining 120 °C ± 5 °C for drying test pieces after cleaning.

5.12 Diamond slitting saw or **slitting machine**, capable of preparing a shallow notch in a set of test pieces of width no more than 0,5 mm and depth of about 0,5 mm. See 6.3 for guidance.

6 Test piece preparation

6.1 Number of test pieces

At least seven test pieces shall be prepared for notching, of which five are required for testing and two are dummy test pieces for protecting the others during notch preparation.

NOTE If a machine is used for preparing the V-notches, it might not be necessary to employ the dummy test pieces to protect a test set of five test pieces.

Operators with no experience of preparing the sharp V-notches used in this method are highly recommended to try out the technique and equipment first with surplus test pieces.

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