SLOVENSKI STANDARD
SIST-TS CEN/TS 14425-1:2005

01-januar-2005

Sodobna tehniļ na keramika ï Preskusne metode za ugotavljanje odpornosti monolitske keramike proti lomljenju ï 1. del: Vodilo za izbiro preskusne metode

Advanced technical ceramics - Test methods for determination of fracture toughness of monolithic ceramics - Part 1:Guide to test method selection

Hochleistungskeramik - Prüfverfahren zur Bestimmung der Bruchzähigkeit von monolithischer Keramik - Teil 1: Leitlinie zur Auswahl des Prüfverfahrens

Ta slovenski standard je istoveten z: CEN/TS 14425-1:2003

ICS:

81.060.30	Sodobna keramika	Advanced ceramics

SIST-TS CEN/TS 14425-1:2005 en

TECHNICAL SPECIFICATION
SPÉCIFICATION TECHNIQUE
TECHNISCHE SPEZIFIKATION

CEN/TS 14425-1

July 2003

ICS 81.060.30

English version

Advanced technical ceramics – Test methods for determination of fracture toughness of monolithic ceramics – Part 1:Guide to test method selection

Céramiques techniques avancées

Hochleistungskeramik – Prüfverfahren zur Bestimmung der Bruchzähigkeit von monolithischer Keramik – Teil 1: Leitlinie zur Auswahl des Prüfverfahrens

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. CEN/TS 14425-1:2003 E

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Foreword

This document (CEN/TS 14425-1:2003) has been prepared by Technical Committee CEN/TC 184 “Advanced technical ceramics”, the secretariat of which is held by BSI.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: 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.

CEN/TS 14425 'Advanced technical ceramics — Test methods for determination of fracture toughness of monolithic ceramics' consists of five parts:

Part 1: *Guide to test method selection*

Part 2: *Single-edge pre-cracked beam (SEPB) method*

Part 3: *Chevron notched beam (CNB) method*

Part 4: *Surface crack in flexure (SCF) method*

Part 5: *Single-edge vee-notch beam (SEVNB) method*

1 Scope

1.1 This part of CEN/TS 14425 provides information on the comparative value, and guidance on the selection, of test methods for determining the apparent fracture toughness of monolithic advanced technical ceramics. For the purposes of this Technical Specification, the term monolithic includes particle, platelet and whisker reinforced advanced technical ceramics which can be regarded as macroscopically homogeneous. It does not include long-fibre reinforced ceramics.

1.2 Reference is made in this part of CEN/TS 14425 to specific test methods described in other parts of this Technical Specification.

2 Normative references

This Technical Specification 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 Technical Specification only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 843-1 Advanced technical ceramics - Monolithic ceramics - Mechanical properties at room temperature: Part 1: Determination of flexural strength.

3 Terms and definitions

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

3.1
stress intensity factor (*K*)
magnitude of the factor determining the ideal crack tip stress field (a stress-field singularity) for a particular mode in a homogeneous linear-elastic body. This Technical Specification deals primarily with opening mode behaviour, K_I.

3.2
critical stress intensity factor (K_c)
magnitude of the stress intensity factor required to cause a crack to propagate at high velocity.

3.3
crack extension resistance
resistance to propagation of a crack expressed as either (1) the stress intensity factor for crack propagation (commonly referred to as fracture toughness), or (2) the force per unit crack width required to extend a crack, or (3) the value of *J*, the so-called J-integral.

3.4
fracture toughness
resistance displayed by a material to the propagation of a crack through it.

NOTE This term should normally be qualified with the conditions under which the test is performed since the value obtained may depend on the crack size, geometry, stress field, crack velocity and test method.

3.5
apparent fracture toughness
fracture toughness determined by a particular method under the conditions imposed by that method.

3.6
work of fracture
external mechanical work performed on a test piece to produce unit area of new macroscopic crack face.

3.7
plane-strain fracture toughness
fracture toughness under conditions of crack tip plane-strain, i.e. where all strains are confined to a plane normal to the crack front and containing the crack propagation direction.

3.8
stable crack growth
growth of a crack under known and controlled conditions by virtue of the experimental technique employed.

3.9
unstable crack growth
growth of a crack under conditions where the acceleration of the crack front is uncontrolled by virtue of the experimental technique employed.

3.10
pop-in
sudden jump of a pre-existing crack front from an initial position or the development of a new crack to a stable position on application of a force without catastrophic failure of the test-piece.

3.11
R-curve
plot of crack extension resistance as a function of stable crack extension.

4 Significance and use

The toughness of a brittle, nominally crack-free material is not an engineering design parameter in the same sense as might be the case for more ductile materials. The reason is that the microscopic flaws, such as grain boundaries, large grains, pores, inclusions or processing defects, are too small to be measured non-destructively in a meaningful way. Despite this, the toughness of relatively brittle materials is an important guide to other mechanical properties, such as defect tolerance, abrasive wear and erosion resistance, impact resistance, fatigue resistance, and thermal shock damage resistance.

5 Test methods

5.1 Background

It is recognised that the apparent plane strain fracture toughness of advanced technical ceramics may not be a unique material property. The numerical value obtained in any particular test may be controlled by factors associated with the test method, by the length of the crack, and by the velocity at which the crack propagates. Thus the results from different types of test may not be numerically equivalent. Some of the important factors in test method selection are given below.

NOTE The Bibliography contains a list of fracture toughness method assessments for advanced technical ceramics.

5.2 Test methods

5.2.1 The wide variety of possible test methods for determining opening mode apparent fracture toughness (K_{Ic}) fall into two groups:

1) those which are considered to give good-quality determinations of critical stress intensity factor with accurate and reliable calibrations;

2) those which are in wide-spread use but which are considered to have considerable calibration uncertainties associated with them, or where the crack cannot be well characterised, or is pre-stressed by the method by which it is introduced; such tests might be used for comparative purposes only.

5.2.2 This Technical Specification covers a total of six methods which can be applied to flexural test-pieces as described in EN 843-1. Some of these are considered to behave in accordance with the first group, and some in accordance with the second group. Table 1 lists the methods and their level of quality for apparent fracture toughness determination. Figure 1 illustrates schematically the test-piece and crack geometries.

5.2.3 Methods which involve pre-cracks or developing cracks longer than a few tens of micrometres may be influenced by so-called rising crack resistance (R-curve) behaviour. This occurs particularly in materials in which crack face separation is incomplete behind the developing crack. This has been found to occur in coarse-grained materials such as alumina, and in materials containing whiskers or platelet reinforcement, and in materials containing metallic phase reinforcement. The effect may also be found in materials which undergo phase transformation close to the crack tip as the crack propagates, e.g. in some zirconias. The R-curve effect may be test piece geometry dependent, and is not a uniquely quantifiable material characteristic.

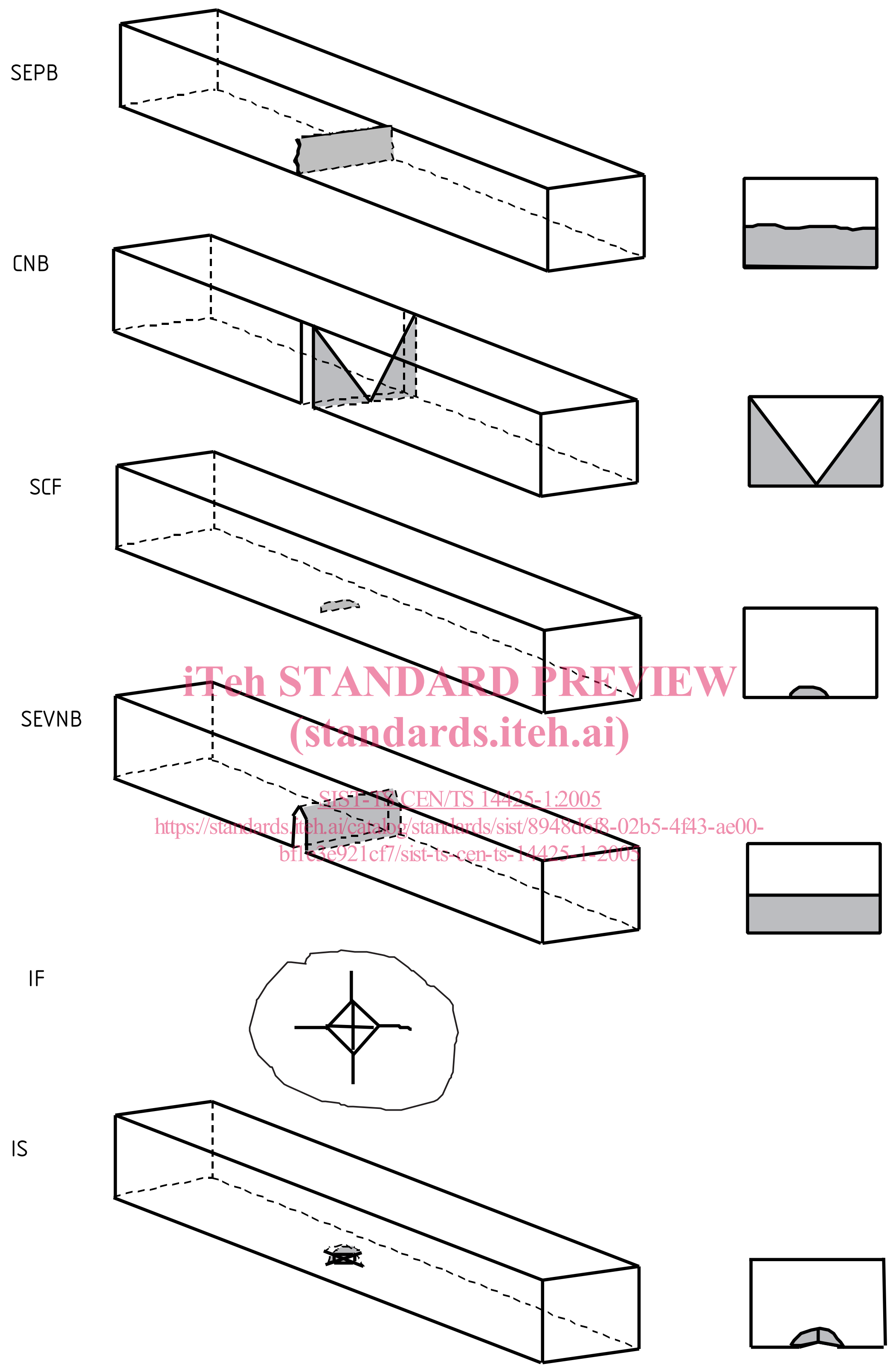

Figure 1 — Schematic diagrams of the range of apparent fracture toughness test methods.

For abbreviations see table 1

Table 1 — Apparent fracture toughness tests performed on small test-pieces

Method	Description	Calibrations	Uncertainties or difficulties
Single-edge pre-cracked beam (SEPB) (CEN/TS 14425-2)*	A flexural test on a beam into the tensile side of which a short straight sharp crack has been introduced	Accurate calibrations available for wide range of pre-crack lengths; toughness at a defined crack length	Pre-cracking requires some skill to obtain straight-fronted cracks. Results are influenced by rising crack resistance behaviour
Chevron notched beam (CNB) (CEN/TS 14425-3)*	A flexural test on a beam with two coplanar angled notches leaving a sharp-tipped triangular shaped region to fracture	Accurate calibrations	Toughness at an ill-defined crack length; crack initiation difficult in some materials; result influenced by rising crack resistance behaviour
Surface crack in flexure (SCF) (CEN/TS 14425-4)*	A flexural test on a beam in which a small semicircular flaw has been introduced by indentation on the tensile side, and with the indentation damage removed.	Accurate calibrations, assuming the pre-crack shape approximates to an ellipse after removal of surface damaged region.	Requires observation and measurement of pre-crack dimensions, which may not always be clearly visible; limited to materials in which indentation produces good quality cracks. Result typical for small cracks.
Single-edge vee-notch beam (SEVNB) (CEN/TS 14425-5)*	A flexural test on a beam in which a narrow notch has been made on the tensile side, with the notch tip sharpened by honing with diamond paste.	Accurate calibrations assuming a sharp crack (same as SEPB).	Assumes that if the tip radius of the sharp notch is of the order the grain size the notch is equivalent to a sharp crack and the SEPB calibration can be used.
Indentation fracture (IF)	A test in which the length of cracks emanating from the corners of a Vickers hardness indentation is measured	Poor calibrations owing to uncertainties in stress fields developed by indentation methods of cracking. Wide variety of different calibrations available.	Effective only in materials which do not chip or flake when indented. Inappropriate for tough or for porous materials. Result typical for small cracks.
Indentation strength (IS)	A flexural test on a beam into which has been placed an indentation on the tensile side.	Poor calibrations owing to uncertainties in residual stress fields developed by indentation which are not removed.	Reproducible test if well-defined cracks are developed by indentation. Result typical for small cracks, but may be indentation force dependent. Inappropriate for porous materials.

* In preparation