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Céramiques techniques — Céramiques composites — Notations et symboles

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Foreword

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

Fine ceramics (advanced ceramics, advanced technical ceramics) — Ceramic composites — Notations and symbols

1 Scope

This document defines the symbols to be used to represent physical, mechanical and thermal characteristics, as determined by methods described in relevant ISO publications, for ceramic matrix composites. It is aimed at avoiding confusion in reporting measurements and characteristics of products.

Where possible, the definitions are in accordance with the relevant parts of ISO 80000. In addition, the symbols used in undertaking measurements of these characteristics are also defined.

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 80000-4, *Quantities and units — Part 4: Mechanics*

ISO 80000-5, *Quantities and units — Part 5: Thermodynamics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 80000-4 and ISO 80000-5 and the following apply.

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

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

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

3.1
ceramic matrix composite
ceramic, carbon or glass matrix containing reinforcement distributed in one or more spatial directions

Note 1 to entry: Composites with continuous reinforcements constitute a specific class of these materials. Several subclasses of ceramic matrix composites with continuous reinforcements can be distinguished.

3.2
nomenclature
The symbol F/I/M applies usually to ceramic matrix composites:

— F indicates the chemical nature of fibrous reinforcement: C stands for carbon, SiC for silicon carbide, Al_2O_3 for alumina, etc.

— I indicates the chemical nature of fibre/matrix interphase: C stands for carbon, BN for boron nitride, $LaPO_4$ for monazite, etc.

— M indicates the chemical nature of matrix: C for carbon, SiC for silicon carbide, Al_2O_3 for alumina.

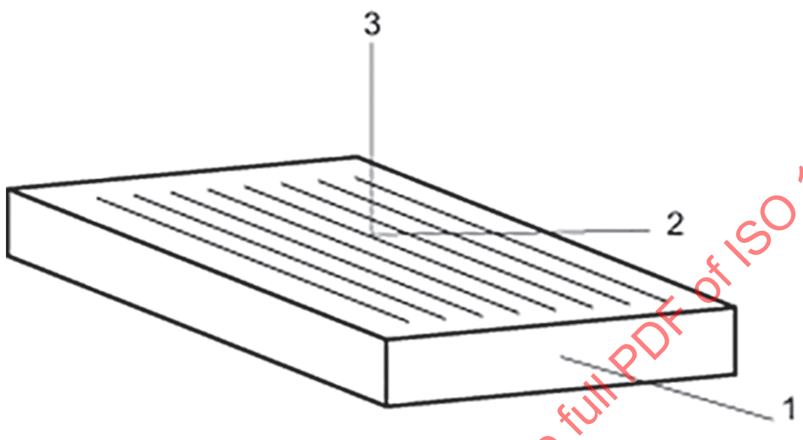
EXAMPLE 1 A ceramic matrix composite composed of a silicon carbide fibre, a carbon interphase and a silicon carbide matrix is denoted by SiC/C/SiC.

Note 1 to entry: More complex symbols can be used to describe the constituents with a greater degree of precision.

EXAMPLE 2 For a composite composed of a carbon fibre, a multi-layered interphase of four alternate layers of carbon and silicon carbide, and a silicon carbide matrix, the symbol is: $C_f/[C/SiC]_4/SiC_m$.

3.3
unidirectional ceramic matrix composite
1D material
ceramic matrix composite (3.1), the reinforcement of which is distributed in one single direction

Note 1 to entry: See Figure 1.



Key

1 direction of reinforcement

2 direction of the greater transverse dimension (width), perpendicular to direction 1

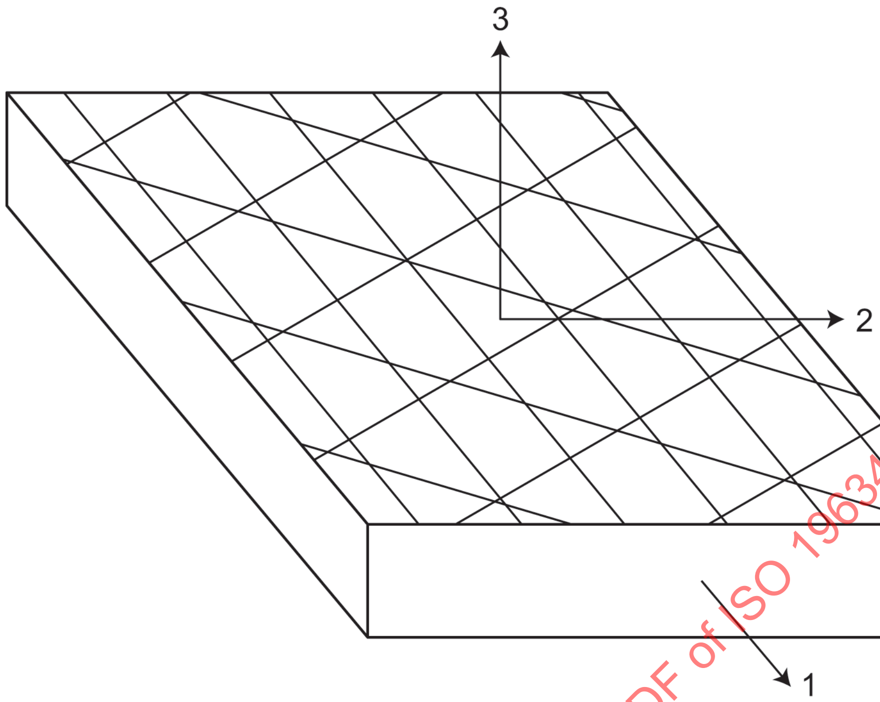
3 direction of the smaller transverse dimension (thickness), perpendicular to direction 1

NOTE When the width and the thickness are equal, then directions 2 and 3 are equivalent and can be chosen freely.

Figure 1 — Schematic diagram of a 1D material

3.4
in-plane reinforced ceramic matrix composite
2D material
ceramic matrix composite (3.1), where the reinforcements are placed along at least two directions in a single plane

Note 1 to entry: See Figure 2.



Key

1 direction of the greater fraction of reinforcement

2 direction perpendicular to direction 1 in the plane of reinforcement (not necessarily a direction of reinforcement)

3 direction perpendicular to the plane of reinforcement

NOTE Strictly more than one direction of fibrous reinforcement, all contained within one plane [in the present case, three directions of reinforcement in plane (1,2)].

When several directions have an equal fraction of reinforcement, it shall be stated which direction is chosen as direction 1 in relation to the reinforcement structure (for example, orthogonal reinforced fabric: warp in direction 1, weft in direction 2).

Figure 2 — Schematic diagram of a 2D material

3.5
multidirectional ceramic matrix composite
xD (2 < × ≤3) material
ceramic matrix composite (3.1), where the reinforcement is spatially distributed in at least three directions not in a single plane

Note 1 to entry: See Figures 3 and 4.

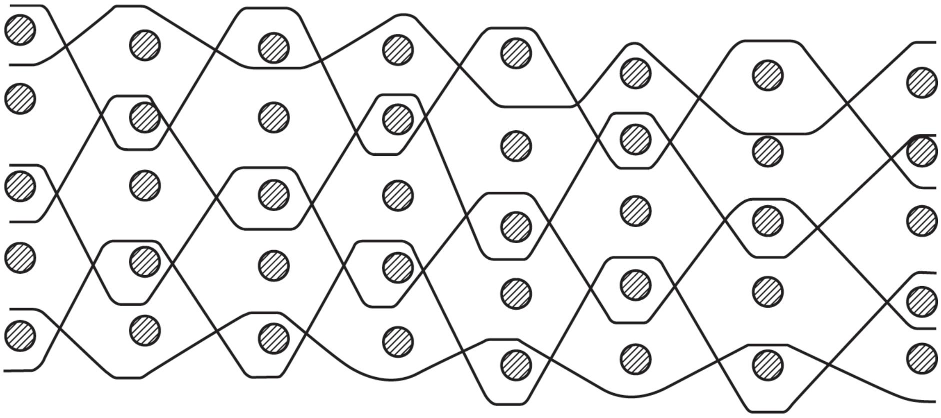
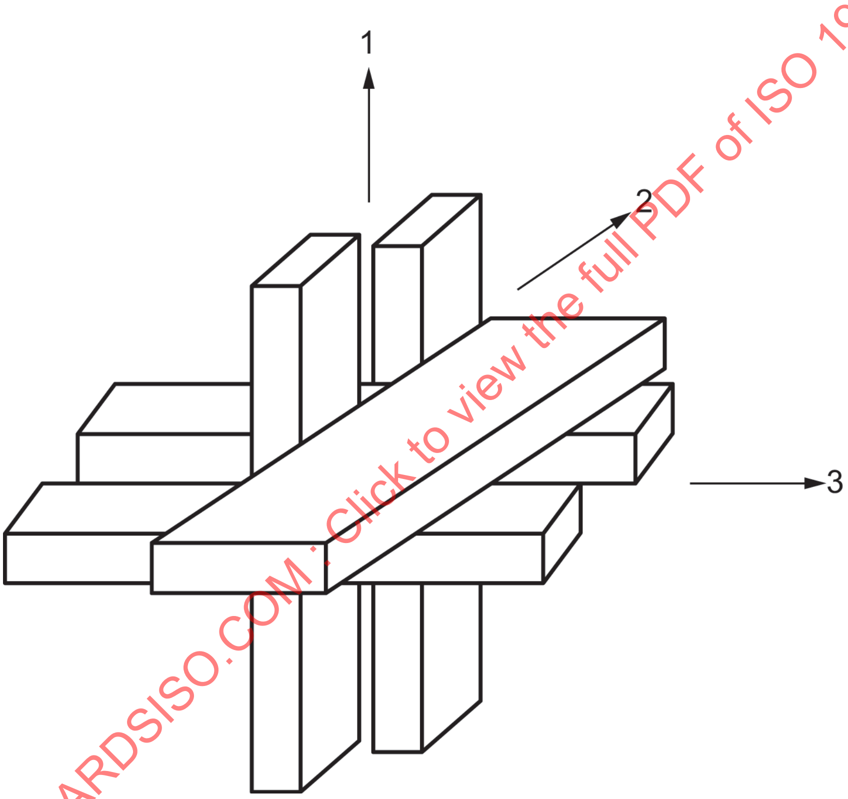


Figure 3 — Schematic diagram of a xD (2 < × ≤ 3) material



Key

1 direction of the greater fraction of reinforcement

2 direction perpendicular to direction 1

3 direction perpendicular to the plane containing directions 1 and 2

When several directions have equal fraction of reinforcement, it shall be stated which direction is chosen as direction 1, in relation to the reinforcement structure. When it is possible to define a plane of reinforcement, direction 2 will be chosen in this plane perpendicular to direction 1 (direction 2 is not necessarily a direction of reinforcement), and direction 3 will be perpendicular to the plane containing directions 1 and 2. When it is not possible to define a plane of reinforcement, direction 2 is chosen arbitrarily, but perpendicular to direction 1 and shall be clearly identified.

Figure 4 — Schematic diagram of a 3D material

4 Symbols

The symbols used for the various mechanical and thermal quantities are given in Tables 1 to 4.

Table 1 — Symbols related to physical quantities

Quantity	Symbol	Definition	Unit	Remark
Density	ρ	Ratio of the mass of a body to its volume	kg/m^3	
Apparent density	ρ_a	Ratio of the mass of the body to its total volume	kg/m^3	
Bulk density	ρ_b	Ratio of the mass of the dry material of a porous body to its volume	kg/m^3	Bulk volume = sum of volumes of solid material, open pores and closed pores
Linear density	t	Ratio of the mass of a multifilament tow to its length	tex	Tex is the mass in grams per 1 000 m
Porosity	P	Ratio of the total volume of pores in a porous body to its total volume	—	
Apparent porosity	P_a	Ratio of the volume of open pores to total volume	—	
Mass	m	Quantity of matter in a body	g	
Phase volume fraction	$V_{f,j}$	Fractional volume of phase of type j determined from micrographs of polished cross-sections	—	

Table 2 — Symbols related to geometrical quantities of test pieces

Quantity	Symbol	Definition	Unit	Remark
Length				
Total length	l, l_t	Total length of the test piece	mm	
Calibrated length	l	Part of the test specimen that has uniform and minimum cross-section area	mm	
Initial length	l_0	Initial length of test piece in thermal expansion measurement	mm	
Gauge length	L_0	Initial distance between reference points on the test piece in the calibrated length	mm	
Distance between outer rollers	L_a	Outer support span in three or four-point bending configuration	mm	In flexural strength and modulus testing
Distance between inner rollers	L_i	Inner loading span in four-point bending configuration	mm	In flexural strength and modulus testing
Cross-section	S	Cross-section area	mm^2	
Initial cross-section area	S_0	Original cross-section area of the test piece within the calibrated length at test temperature	mm^2	
NOTE 1 When the material is protected by a surface treatment, two initial cross-section areas can be defined:				
Apparent cross-section area	$S_{0,a}$	Geometrical area of the cross-section	mm^2	
Effective cross-section area	$S_{0,e}$	Geometrical area corrected by a factor, to account for the presence of a surface treatment	mm^2	
Distance between notches	L	In inter-laminar shear testing, the spacing between opposite notches	mm	
Width and thickness				
Width	b	Width of a test piece	mm	
NOTE 2 When the material is protected by a surface treatment, two widths can be defined:				
Apparent width	b_a	Geometrical width	mm	
Effective width	b_e	Geometrical width corrected by a factor to account for the presence of a surface treatment	mm	
NOTE 3 When width changes along the length, a numerical subscript is added to symbol b; b_1 is the width in the calibrated length, b_2, b_3, ... are the other widths. These subscripts are defined in individual documents.				
Thickness	h	Thickness of a test piece	mm	

Table 2 *(continued)*

Quantity	Symbol	Definition	Unit	Remark
NOTE 4 When the material is protected by a surface treatment, two thicknesses can be defined:				
Apparent thickness	h_a	Geometrical thickness	mm	
Effective thickness	h_e	Geometrical thickness corrected by a factor to account for the presence of a surface treatment	mm	
NOTE 5 When thickness changes along the length, a numerical subscript is added to symbol h; h_1 is the thickness in the calibrated length h_2, h_3, ... are the other thicknesses. These subscripts are defined in individual documents.				
Indentation diagonal length (in hardness testing)	Δ	In hardness testing, the lengths of the diagonals of a Vickers indentation or long axis of a Knoop indentation	mm	
Initial crack or notch depth	a_0	In fracture toughness testing, the length of the initial crack or notch	mm	
Deflection				
Flexural deflection	D	Displacement of the loading points relative to the support points (or any other reference points) in flexure	mm	Used with various subscripts
Representative volume element				
Representative volume element	RVE	Minimum volume which is representative of the material considered		
Diameter				
Diameter	d	Diameter of the test piece in the calibrated length	mm	
NOTE 6 When the material is protected by a surface treatment, two diameters can be defined:				
Apparent diameter	d_a	Geometrical diameter	mm	
Effective diameter	d_e	Geometrical diameter corrected by a factor to account for the presence of a surface treatment	mm	
NOTE 7 When diameter changes along the length, a numerical subscript is added to symbol d; d_1 is the diameter in the calibrated length, d_2, d_3 ... are the other diameters. These subscripts are defined in individual documents.				
Shoulder radius	r	Transition radius of curvature between parts of the specimen with different cross-section	mm	The type of radius can be defined in each document by use of a subscript

Table 3 — Symbols related to mechanical quantities[a]

Quantity	Symbol	Definition	Unit	Remark
Deformation				
Flexural deformation	δ	Variation of the gauge length in the outer surface (in tensile) of flexural specimen	mm	
Longitudinal deformation	A	Variation in the gauge length caused by an applied load. Variation is positive in tensile and negative in compressive test	mm	Tensile/compressive test
Longitudinal tensile deformation at maximum force	$A_{t,m}$	Value of longitudinal tensile deformation corresponding to the maximum force	mm	
Longitudinal compressive deformation at maximum force	$A_{c,m}$	Value of longitudinal compressive deformation corresponding to the maximum force	mm	
Strain				
Strain	ε	Ratio of deformation to initial gauge length defined as the ratio A/L_0	—	Tensile/compressive test
Tensile strain at maximum force	$\varepsilon_{t,m}$	Value of strain corresponding to the maximum tensile force	—	
Compressive strain at maximum force	$\varepsilon_{c,m}$	Value of strain corresponding to the maximum compressive force	—	
Shear strain	γ	The change in angle of an originally orthogonal set of lines as a consequence of a shear load	—	
Force				
Force	F	Force applied to the test piece during the test	N	
Maximum tensile force	F_m	Maximum force during a test or at fracture	N	
Stress and strain				
Stress (tensile/compressive/shear)	σ	Ratio of the force carried by the test piece by the initial cross-section area	MPa	Sign convention — tensile is positive, compression is negative
Flexural stress	σ	The nominal stress on the outer surface of the test piece, calculated at mid span	MPa	
In-plane shear stress	τ	Ratio of the force carried by the test piece by the initial cross-section subjected to shear	MPa	
Effective tensile stress	$\sigma_{t,eff}$	Tensile force supported by the test specimen at any time in the test divided by the effective cross-section area (S_0 *eff*)	MPa	

Table 3 *(continued)*

Quantity	Symbol	Definition	Unit	Remark
Strength				
Strengths correspond to stresses at maximum force during a test carried out to rupture.				
Tensile strength	$\sigma_{t,m}$	Ratio of the maximum tensile force to the initial cross-section area	MPa	
Compressive strength	$\sigma_{c,m}$	Ratio of the maximum compressive force to the initial cross-section area	MPa	
Flexural strength	$\sigma_{f,m}$	Maximum flexural stress or force applied to a test piece that fractures during a flexural test	MPa	The flexural stress can be determined only when the composite does not exhibit a significant non-linear response
Interlaminar shear strength	σ_{ILSS}	Ratio of the maximum force applied to the initial cross-section area	MPa	
In-plane shear strength	τ_m	Ratio of the maximum force to the surface area between the notches	MPa	
Effective tensile strength	$\sigma_{t,m,eff}$	ratio of the maximum tensile force to the effective cross-section area		
NOTE 1 The symbols listed here for mechanical quantities at rupture (strength and strain) have a first subscript indicating the type of test (*t* for tensile, *c* for compressive, *f* for flexure). A second subscript, m, is added to indicate the maximum value. Other subscripts may be added to refer to test conditions (for example, temperature). These additional subscripts are set between brackets. EXAMPLE 1 $\sigma_{t,m}$ (1 500)(vacuum) = tensile strength at 1 500 °C under vacuum				
Elastic properties				
Elastic modulus tensile/compressive (Young Modulus)	E	Slope of the linear part of the stress strain curve when the linear part starts at the origin	GPa	
Shear modulus	G	Slope of the linear part of the shear stress strain curve when the linear part starts at the origin	GPa	
NOTE 2 When the material is protected by a surface treatment, two types of mechanical quantities can be considered. The subscript "a" for apparent is added when the apparent cross-section area is used. The subscript "e" for effective is added when the effective cross-section area is used. EXAMPLE 2 $\sigma_{t,m,eff}$ = effective tensile strength				
Proportionality coefficient or pseudo modulus				
Proportionality ratio or pseudo-elastic modulus	E_p	Slope of a linear portion of the stress-strain curve between two couples of stress-strain values	GPa	The quantity is used for materials which do not have a linear behaviour from the origin
Proportionality coefficient in shear	G_p	Slope of a linear portion of the shear stress shear strain curve between two values (τ_1, τ_2)	GPa	

Table 3 *(continued)*

Quantity	Symbol	Definition	Unit	Remark
Effective proportionality ratio	EP_{eff}	slope of the linear section of the stress-strain curve, if any, when the effective tensile stress is used	GPa	
Poisson ratio	ν	Ratio of lateral strain to axial strain in axially stressed body	—	
Mode of vibration	n	Modal analysis is used to characterize resonant vibration in machinery and structures. A mode of vibration is defined by the three parameters: modal frequency, modal damping value and mode shape	—	
Flexural frequency	f_f	Recorded flexural vibration frequency of struck or resonating test piece	Hz	
Torsional frequency	f_t	Recorded torsional vibration frequency of struck or resonating test piece	Hz	
Longitudinal wave sound velocity	v_l	Velocity of a compression wave transmitted through a material	m/s	Used in computation of moduli in ultrasonic testing
Transverse wave sound velocity	v_t	Velocity of a shear wave transmitted through a material	m/s	

[a] If not summarized to the contrary, the notation is referring to a test made in direction 1 and in plane 1,2.