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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at high temperature — Determination of stress-rupture time diagram under constant tensile loading

Céramiques techniques (céramiques avancées, céramiques techniques avancées) — Propriétés mécaniques des composites à matrice céramique à température élevée sous air et à pression atmosphérique — Détermination du diagramme contrainte temps de rupture sous chargement constant en traction

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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) — Mechanical properties of ceramic composites at high temperature — Determination of stress-rupture time diagram under constant tensile loading

1 Scope

This document specifies the conditions for determination of the stress-rupture time diagram of continuous fibre-reinforced ceramic matrix composites (including carbon fibre-reinforced carbon matrix composite) at high temperature in air, vacuum and inert gas atmospheres under constant tensile loading.

This document applies to all ceramic matrix composites with continuous fibre reinforcement: unidirectional (1D), bidirectional (2D) and tridirectional (xD, with $2 < x \leq 3$), loaded along one principal axis of reinforcement.

NOTE 1 In most cases, ceramic matrix composites to be used at high temperature in air are coated with an antioxidation coating.

NOTE 2 Since the main purpose of the test is to obtain the stress-rupture time data, the deformation measurement is not mandatory.

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

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 17161, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Ceramic composites — Determination of the degree of misalignment in uniaxial mechanical tests*

ISO 20507, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Vocabulary*

IEC 60584-1, *Thermocouples — Part 1: Reference tables*

IEC 60584-2, *Thermocouples — Part 2: Tolerances*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 20507 and the following 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
test temperature
T
temperature measured at the centre of the test specimen gauge section

3.2
calibrated length
l
part of the test specimen that has uniform and minimum cross-sectional area

3.3
gauge length
L_0
initial distance between reference points on the test specimen in the calibrated length

3.4
controlled temperature zone
part of the *calibrated length* (3.2) including the *gauge length* (3.3) where the temperature is within 20 °C for the test temperature of <500 °C, and within 50 °C for the test temperature of ≥ 500 °C

3.5
initial cross-section area
S_0
total area of the cross-section of the test specimen within the *calibrated length* (3.2) at room temperature

3.6
apparent cross-section area
$S_{0\ app}$
total area of the cross-section of the test specimen with an antioxidative protection

3.7
effective cross-section area
$S_{0\ eff}$
total area corrected by a factor, to account for the presence of an antioxidative protection

3.8
applied tensile force
F
constant tensile force loaded to the test specimen

3.9
applied tensile stress
σ
applied tensile force (3.8) supported by the test specimen at any time in the test divided by the initial cross-section area

3.10
apparent tensile stress
σ_{app}
applied tensile force supported by the test specimen at any time in the test divided by the *apparent cross-section area* (3.6)

3.11
effective tensile stress
σ_{eff}
applied tensile force (3.8) supported by the test specimen at any time in the test divided by the *effective cross-section area* (3.7)

3.12
longitudinal deformation
A
increase in the *gauge length* (3.3) between reference points under a constant tensile force

3.13
tensile strain
ε
relative change in the *gauge length* (3.3) defined as the ratio A/L_0 under a constant tensile force

3.14
tensile strain rate
$\dot{\varepsilon}$
change in tensile strain per unit time under a constant tensile force

3.15
rupture time
t_r
time required for the test specimen to fracture under a constant tensile force

3.16
rupture strain
ε_f
accumulated tensile strain to rupture under a constant tensile force

4 Principle

A constant uniaxial tensile force is applied to a test specimen of specified dimensions at high temperature in ambient air, vacuum or inert gas atmospheres. By continuing the test until rupture or a certain period, tensile strains and rupture time are determined.

5 Significance and use

Several mechanisms may be responsible for time-dependent deformation and rupture time of continuous fibre-reinforced ceramic matrix composites at high temperature under a constant tensile force. These may be creep of the fibre and/or the matrix, or may be caused by the composite nature of the material (e.g. matrix micro-cracking, fibre-matrix interface sliding, oxidation-activated slow crack growth, degradation of fibres). Creep behaviour is characterized by the total time-dependent increase of the gauge length and the rupture time, starting from the time when the specified force level is reached, whatever mechanism is responsible.

6 Apparatus

6.1 Test machine

The test machine shall conform to the following requirements.

a) The test machine shall meet the requirements of grade 1 or better of ISO 7500-1.

b) The forces loaded by the tensile testing machines shall be accurate to ±0,5 % at any force within the force capacity range of 5 % to 100 %.

c) The test machine shall be installed so as not to be influenced by external vibration and shock.

d) The test machine shall be equipped with features to maintain alignment and transmit force to a test specimen smoothly. A direct load or lever arm load test machine is desirable.

6.2 Gripping devices

6.2.1 General

Various types of gripping devices may be used to transmit the tensile force applied by the test machine to the test specimen. The gripping design shall prevent the test specimen from slipping.

The gripping devices can be classified generally into two types. One is that employing an active grip interface and the other is that employing a passive one.

In both types of grips, hot and cold grips can be used. The former is the grip where the gripping section is in the hot zone of the furnace and the latter is the grip where the gripping section is outside of the hot zone.

Such load train couplers as universal joints may be used to reduce the bending strains of test specimens.

NOTE The choice of gripping system depends on materials, test specimens and alignment requirements.

6.2.2 Active gripping devices

Active gripping devices transmit the tensile force from test machines to test specimens by a mechanical, hydraulic or pneumatic force. An example of an active gripping device is shown in Figure 1.

The gripping surfaces shall be scored or serrated to prevent slippage between the gripping face and the test specimen. Sufficient pressure shall be applied normal to the gripping face.

6.2.3 Passive gripping devices

Passive gripping devices transmit the tensile force from test machines to test specimens through a direct mechanical link. Examples of the direct mechanical links are an edge loading type for a test specimen with shank shoulders (see Figures 2 and 3) and a pin loading type for a test specimen with pin-holes in gripping sections (see Figure 4).

6.3 Test chamber

For tests in a gas atmosphere or in a vacuum, a gastight chamber shall be used, which allows proper control of the test environment in the vicinity of the test specimen during the test.

The installation shall be such that the variation of load due to the variation of pressure during the test is less than 1 % of the scale of the load cell being used.

For tests in a gas atmosphere, the atmosphere shall be chosen depending on the material to be tested and the test temperature. The level of pressure shall be determined depending on the material to be tested, the temperature, the type of gas and the type of extensometer.

For tests in a vacuum, the degree of vacuum shall not induce chemical and/or physical instabilities of the test material or the extensometer rods.

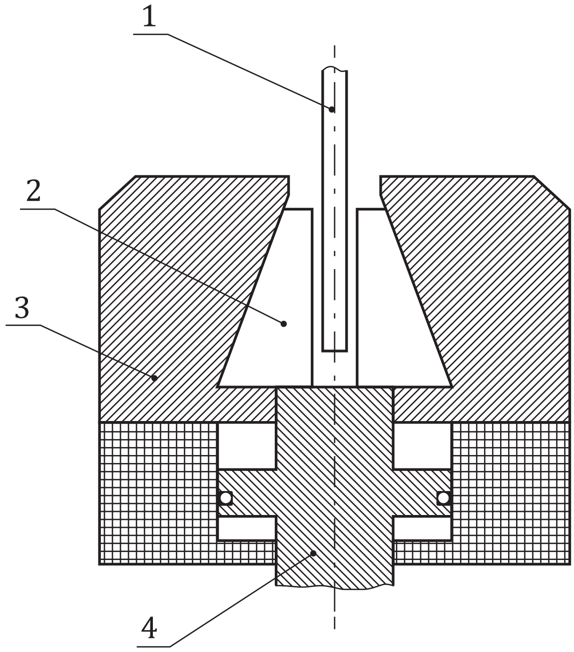
6.4 Load indicator

The load value shown by the load indicator shall be the same as that applied to the test specimen. There are two methods of achieving this:

1. Method to install a load cell in a test chamber (direct method);
2. Method to calibrate chamber pressure and the indication value by the load cell initially installed outside the chamber.

The load variation due to the pressure fluctuations in a chamber shall not exceed the limits specified in 6.1.

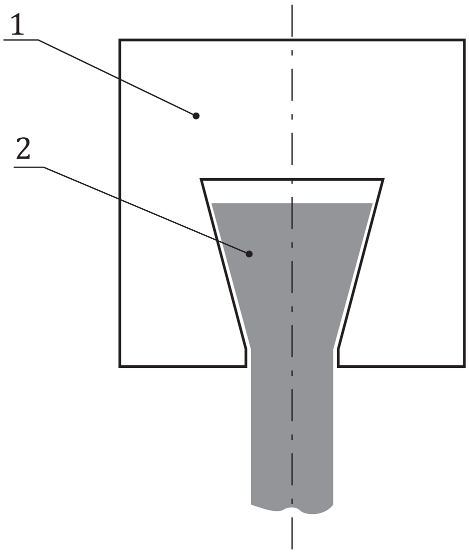
The accuracy of alignment and load train of the test machine shall not be influenced by the heating.



Key

1 test specimen
2 wedge gripe
3 grip body
4 piston

Figure 1 — Example of an active gripping device



Key

1 grip attachment
2 test specimen

Figure 2 — Example of a passive gripping device

