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ISO/DIS 17142

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at high temperature in air at atmospheric pressure — Determination of fatigue properties at constant amplitude

Céramiques techniques — Propriétés mécaniques des céramiques composites à haute température sous air à pression atmosphérique — Détermination des propriétés de fatigue à amplitude constante

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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.

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ISO 17142 was prepared by Technical Committee ISO/TC 206, *Fine ceramics*, Subcommittee SC , .

This second/third/... edition cancels and replaces the first/second/... edition (), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at high temperature in air at atmospheric pressure -- Determination of fatigue properties at constant amplitude

1 Scope

This International Standard specifies the conditions for the determination of constant-amplitude of load or strain in uniaxial tension/tension or in uniaxial tension/compression cyclic fatigue properties of ceramic matrix composite materials (CMCs) with fibre reinforcement for temperature up to 1 700 °C in air at atmospheric pressure.

This International Standard applies to all ceramic matrix composites with fibre reinforcement, unidirectional (1D), bi-directional (2D), and tri-directional (xD, where 2 < x ≤ 3).

The purpose of this International Standard is to determine the behaviour of CMC when subjected to mechanical fatigue and oxidation simultaneously. Tests for the determination of fatigue properties at high temperature in inert atmospheres differ from those in oxidative atmospheres. Contrary to an inert atmosphere, damage in an oxidative atmosphere accumulates due to the influence of purely mechanical fatigue and to chemical effects of the material's oxidation.

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.

ISO 15733, *Fine ceramics (advanced ceramics, advanced technical ceramics) -- Test method for tensile stress-strain behaviour of continuous, fibre- reinforced composites at room temperature*

ISO 14574, *Fine ceramics (advanced ceramics, advanced technical ceramics) - Mechanical properties of ceramic composites at high temperature - Determination of tensile properties*

ISO 14544, *Fine ceramics (advanced ceramics, advanced technical ceramics) -- Mechanical properties of ceramic composites at high temperature -- Determination of compression properties*

CEN/TR 13233 *Advanced technical ceramics — Notations and symbols*

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

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

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 9513, *Metallic materials — Calibration of extensometers used in uniaxial testing*

ISO 3611, *Geometrical product specifications (GPS)-Dimensional measuring equipment: Micrometer callipers for external measurements-Design and metrological characteristics*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in CEN/TR 13233 and the following apply.

3.1
test temperature, T
temperature of the test specimen at the centre of the gauge length

3.2
calibrated length, l
part of the test specimen which has uniform and minimum cross-section area

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

3.4
controlled temperature zone
part of the calibrated length including the gauge length where the temperature is within 50 °C of the test temperature

3.5
initial cross-section area, S_o
initial cross-section area of the test specimen within the calibrated length, at the test temperature

NOTE Two initial cross-section areas of the test specimen can be defined:

- apparent cross-section area: this is the total area of the cross-section $S_{o\ app}$;

- effective cross-section area: this is the total area corrected by a factor, to account for the presence of a coating, $S_{o\ eff}$.

3.6
longitudinal deformation, A
change in the gauge length between reference points under an uniaxial force

3.7
strain, ε
relative change in the gauge length defined as the ratio A/L_o

3.8
stress, σ
force supported by the test specimen at any time in the test, divided by the initial cross-section area

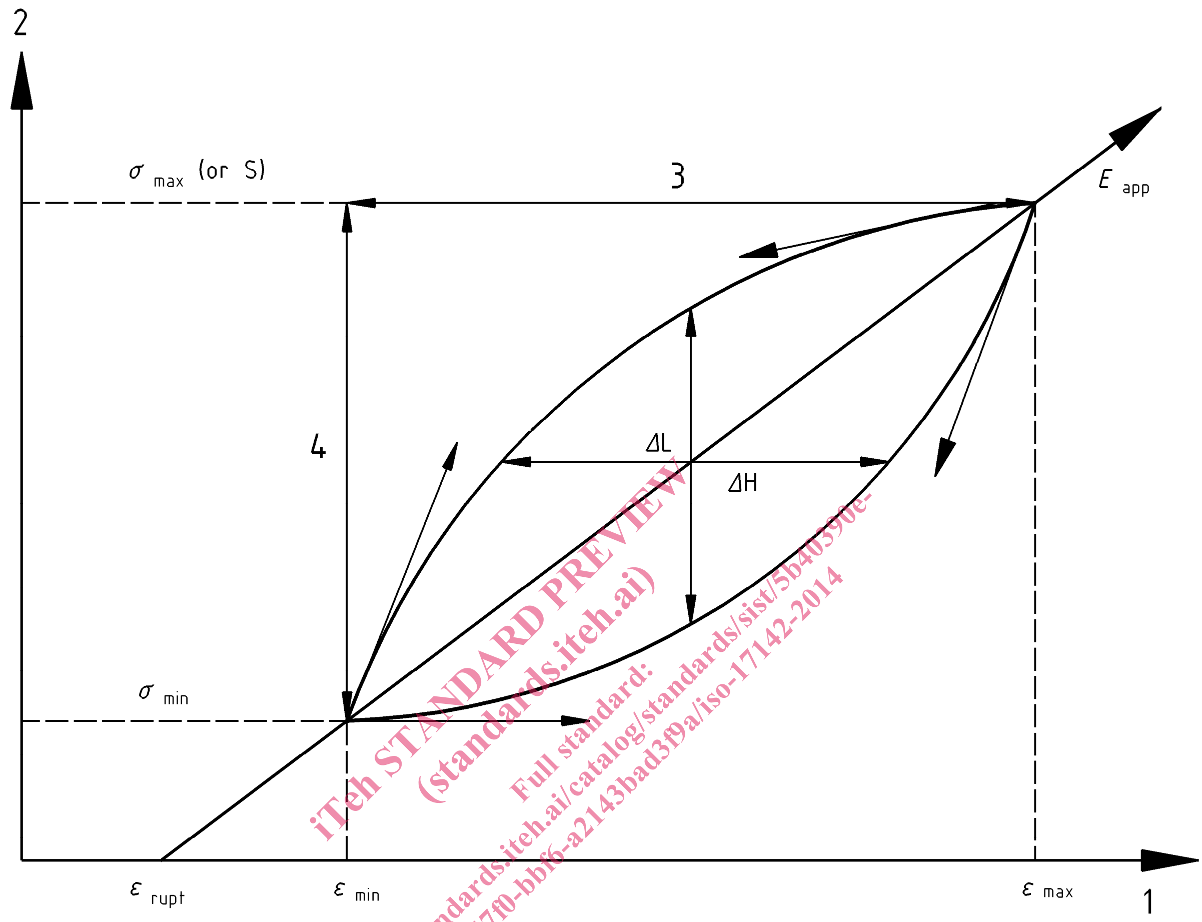
NOTE Two stresses can be distinguished:

- apparent stress, σ_{app}, when the apparent cross-section area (or total cross-section area) is used;

- effective stress, σ_{eff}, when the effective cross-section area is used.

Stress can be either in tension or in compression.

3.9
constant amplitude loading
in cyclic fatigue loading, constant wave form loading in which the peak loads and the valley loads are kept constant during the test (see Figure 1 for nomenclature relevant to cyclic fatigue testing)



Key
1 strain (ε)
2 stress (σ)
3 width (L)
4 height (H)

Figure 1 — Cyclic fatigue nomenclature and wave forms

3.10 Cyclic fatigue phenomena

3.10.1
load ratio, *R*
in cyclic fatigue loading, algebraic ratio of the two loading parameters of a cycle

NOTE The most widely used ratios are:

R = (minimum load/maximum load) or

R = (valley load/peak load).

3.10.2 stress cyclic fatigue

3.10.2.1
maximum stress, σ_{max}
maximum applied stress during cyclic fatigue

3.10.2.2
minimum stress, σ_{min}
minimum applied stress during cyclic fatigue

3.10.2.3
mean stress, σ_m
average applied stress during cyclic fatigue such that:

$$\sigma_m = (\sigma_{max} + \sigma_{min})/2$$

3.10.2.4
stress amplitude, σ_a
difference between the maximum stress and the minimum stress, such that:

$$\sigma_a = (\sigma_{max} - \sigma_{min})/2 = \sigma_{max} - \sigma_m = \sigma_m - \sigma_{min}$$

3.10.3 Strain cyclic fatigue

3.10.3.1
maximum strain, ε_{max}
maximum applied strain during cyclic fatigue

3.10.3.2
minimum strain, ε_{min}
minimum applied strain during cyclic fatigue

3.10.3.3
mean strain, ε_m
average applied strain during cyclic fatigue such that:

$$\varepsilon_m = (\varepsilon_{max} + \varepsilon_{min})/2$$

3.10.3.4
strain amplitude, ε_a
difference between the maximum stress and the minimum stress, such that:

$$\varepsilon_a = (\varepsilon_{max} - \varepsilon_{min})/2 = \varepsilon_{max} - \varepsilon_m = \varepsilon_m - \varepsilon_{min}$$

3.10.4 Fatigue parameters

3.10.4.1
number of cycles, N
total number of loading cycles which is applied to the test specimen during the test

3.10.4.2
cyclic fatigue life, N_f
total number of loading cycles which is applied to the test specimen up to failure

3.10.4.3
time to failure, t_f
time duration required to obtain the number of cycles N_f

3.10.5 Stress-strain curve parameters

Stress-strain curve parameters are defined as given in Figure 2.

4 Principle

A test specimen of specified dimensions is heated to the testing temperature and tested in cyclic fatigue as follows:

- method A: the test specimen is cycled between two constant stress levels at a specified frequency;
- method B: the test specimen is cycled between two constant strain levels at a specified frequency.

The total number of cycles is recorded. If strain is not determined, only the life-time duration or the residual mechanical properties can be determined. If strain is determined, a number of stress-strain cycles are recorded at specified intervals to determine damage parameters, in addition to the life-time duration and residual mechanical properties.

NOTE Residual properties can be determined on the test specimens which have not failed during the test, using the methods described in the appropriate International Standards.

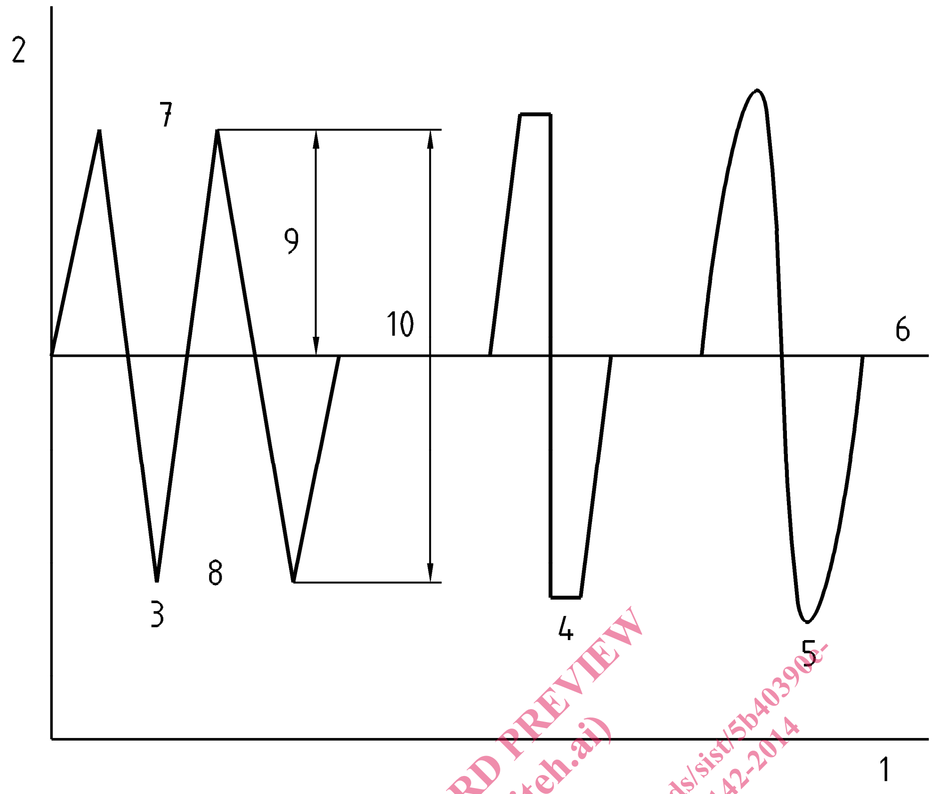
5 Significance and use

This test method enables characterization of the cyclic fatigue behaviour at constant amplitude of CMCs subjected to long duration loading. The simplest way to determine the fatigue properties of a material is to establish life-time diagrams. In these diagrams, the time to failure (or the cyclic fatigue life) is plotted versus stress (or strain) amplitude.

The complete life-time diagram requires the use of a great number of test specimens, which is expensive and time consuming. Hence, it is sufficient to know the cyclic-fatigue under specified stress (or strain) conditions, or to measure the fatigue limit. In any case, the typical fatigue test is defined by cyclic loading, constant amplitude, environment, temperature and frequency.

To better characterize the mechanical behaviour during a fatigue test, it is possible to determine several mechanical parameters from stress-strain curves. These parameters can then be plotted versus time or versus number of cycles. This displays the damage evolution during the cyclic loading. The following parameters can be considered (see Figure 2):

- the residual strain at zero load;
- the secant elastic modulus, or the relative damage parameters;
- the area of the stress-strain hysteresis loop, or the internal friction;
- the maximum strain, the minimum strain, or the difference between them for a selected cycle;
- some specific tangent elastic moduli, for example at the top or at the bottom of the stress-strain loop.



Key

1 time
2 control parameter (test mode)
3 triangular form
4 trapezoidal form
5 sinusoidal form
6 mean
7 peak (maximum)
8 valley (minimum)
9 amplitude
10 range

Figure 2 — Parameters that can be considered to assess the cyclic fatigue behaviour

6 Apparatus

6.1 Fatigue test machine

A hydraulic type or electric actuator driven test machine shall be used. It shall be load or strain control operated.

The system for measuring the force applied to the test specimen shall be specially designed for fatigue tests and shall conform to grade 1 or better in accordance with ISO 7500-1. This shall apply during actual test conditions. The machine shall be equipped with a cycle counter for the chosen test frequency.

6.2 Load train

The load train configuration shall ensure that the load indicated by the load cell and the load experienced by the test specimen are the same.

The load train performance including the alignment system and the force transmitting system, shall not change because of heating.

The attachment fixtures shall align the test specimen axis with that of the applied force.