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Metallic and other inorganic coatings — Measurement of the linear thermal expansion coefficient of thermal barrier coatings

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Foreword

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This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

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Introduction

Thermal barrier coatings are highly advanced material systems, generally applied to surfaces of hot-section components made of nickel or cobalt-based superalloys, such as combustors, blades and vanes of power-generation gas turbines in thermal power plants and aero-engines operated at elevated temperatures.

The function of these coatings is to protect metallic components for extended periods at elevated temperatures by employing thermally insulating materials that can sustain an appreciable temperature difference between load bearing alloys and coating surfaces. These coatings permit the high-temperature operation by shielding these components, thereby extending their lives.

Although the linear thermal expansion coefficient is an important property of thermal barrier coatings, the existing International Standard (e.g. ISO 17562) describes only a method for measuring this parameter for monolithic ceramics.

This document specifies a method for measuring the linear thermal expansion coefficient of the ceramic top coat for thermal barrier coating.

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Metallic and other inorganic coatings — Measurement of the linear thermal expansion coefficient of thermal barrier coatings

1 Scope

This document specifies a method for measuring the reproducible linear thermal expansion coefficient of ceramic top coats (TCs) for thermal barrier coatings (TBCs) up to 1 300 °C.

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 17139, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Thermophysical properties of ceramic composites — Determination of thermal expansion*

ISO 17562, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for linear thermal expansion of monolithic ceramics by push-rod technique*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17139 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
thermal barrier coating
TBC
two-layer coating consisting of a metallic bond coat (BC) and a ceramic top coat (TC), in order to reduce heat transfer from outside the top coat through the coating to the substrate

Note 1 to entry: See Figure 1.

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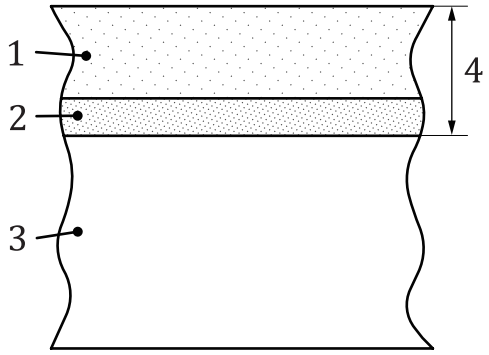

Key

1	top coat (TC)	3	substrate
2	bond coat (BC)	4	thermal barrier coating (TBC)

Figure 1 — Diagrammatic view of a section of a TBC

[SOURCE: ISO 14188:2012, 3.1, modified — "ceramic top coat" has replaced "oxide top coat", "substrate" has replaced "base material", and a different note to entry and figure has been used.]

3.2
mean linear thermal expansion coefficient
$\alpha(T)$
linear thermal expansion between temperatures T_1 and T_2 divided by the temperature increment from T_1 to T_2 and the length at room temperature T_0, as shown by the formula:

$$\alpha(T)=\frac{L(T_2)-L(T_1)}{L(T_0)}\times\frac{1}{(T_2-T_1)}$$

where

$$T=\frac{T_2+T_1}{2};$$

$L(T_0)$ is the initial length of the specimen at room temperature;

$L(T_1)$ is the length of the specimen at temperature T_1;

$L(T_2)$ is the length of the specimen at temperature T_2.

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4 Principle

Ceramic TCs exhibit an unstable linear thermal expansion coefficient during the initial few heating cycles, as shown in Annex A. Therefore, the measurement shall be repeated until the reproducible linear thermal expansion coefficient is obtained. The fundamental procedures are shown in Figure 2. A specimen of a TC, prepared as described in Clause 6, that constitutes a TBC is heated to a specified temperature at a controlled heating rate. During the heating, the linear thermal expansion coefficients of the specimen are measured based on the change of the length and the temperature of the specimen. The measurement shall be repeated until the criterion to finish the measurement mentioned in Clause 7 is satisfied.

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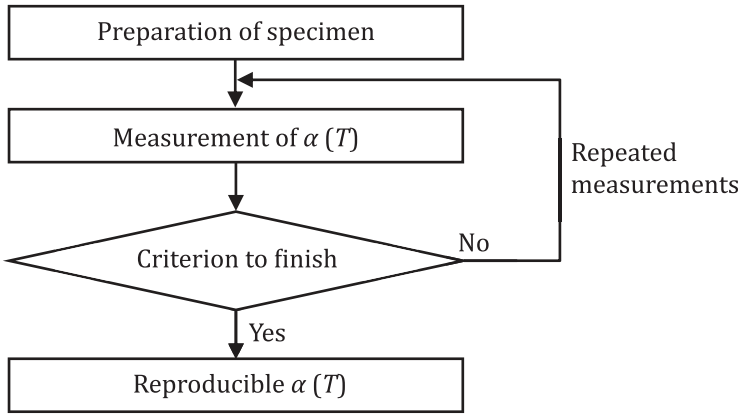

Figure 2 — Fundamental procedures for determining the linear thermal expansion coefficient

5 Apparatus for measuring the linear thermal expansion coefficient

5.1 Apparatus

An example of the apparatus for measuring the linear thermal expansion coefficient is schematically shown in Figure 3. The apparatus shall be specified in accordance with ISO 17139 and shall be calibrated using the reference specimen (see 6.2). Care shall be taken to ensure that the thermocouple tip is in close proximity to the specimen in accordance with ISO 17562.

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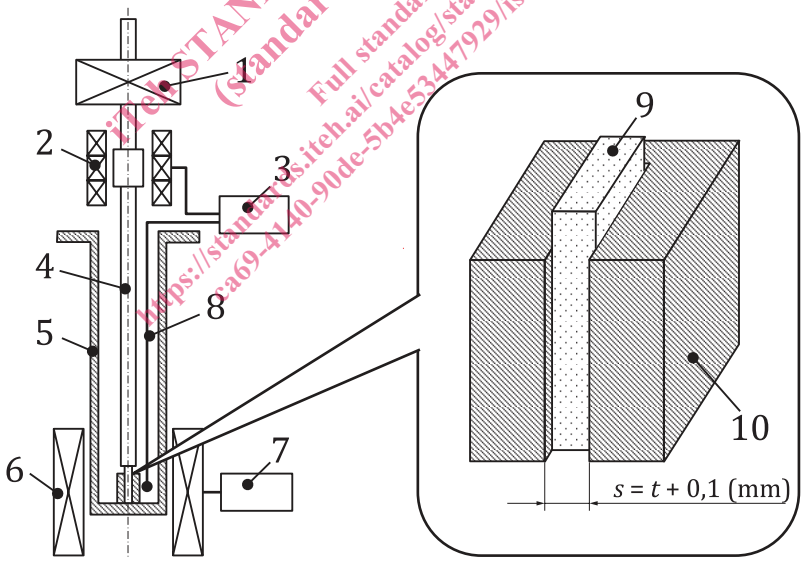

Key

1	load controlling device	7	temperature controller
2	differential transformer	8	thermocouple
3	recorder	9	specimen
4	push rod	10	supporting jig
5	specimen holder	*s*	width of slit
6	furnace	*t*	thickness of specimen

Figure 3 — Typical apparatus for measuring the linear thermal expansion coefficient

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