INTERNATIONAL STANDARD

ISO 23486

First edition
2021-04

Metallic and other inorganic coatings — Measurement of Young's modulus of thermal barrier coatings at elevated temperature by flexural resonance method

Reference number
ISO 23486:2021(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Thermal barrier coatings (TBCs) 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 which 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 Young's modulus is an important property of TBCs, the existing ISO 19477 only describes a method for measuring this parameter at room temperature.

This document specifies a method for measuring the Young's modulus of TBCs that consist of multilayers formed on substrate by thermal spraying, from room temperature up to elevated temperature.

Metallic and other inorganic coatings — Measurement of Young's modulus of thermal barrier coatings at elevated temperature by flexural resonance method

1 Scope

This document specifies a method for measuring the in-plane Young's modulus of thermal barrier coatings (TBCs) formed on substrates, from room temperature up to 1 000 °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 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*

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

ISO 13385 (all parts), *Geometrical product specifications (GPS) — Dimensional measuring equipment*

ISO 14188:2012, *Metallic and other inorganic coatings — Test methods for measuring thermal cycle resistance and thermal shock resistance for thermal barrier coatings*

ISO 17561:2016, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for elastic moduli of monolithic ceramics at room temperature by sonic resonance*

ISO 19477, *Metallic and other inorganic coatings — Measurement of Young's modulus of thermal barrier coatings by beam bending*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14188 and ISO 19477 and the following apply.

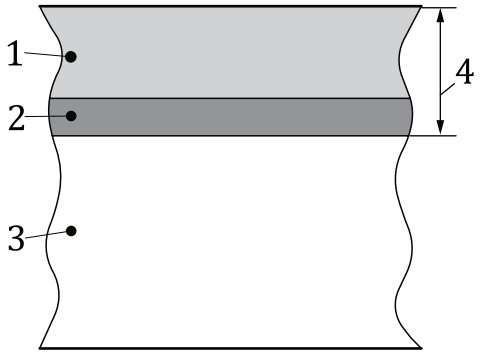
ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— 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 of a heat-resistant metallic material

Note 1 to entry: See Figure 1.



Key

1 TC
2 BC
3 substrate
4 TBC

Figure 1 — Diagrammatic view of a section of a TBC

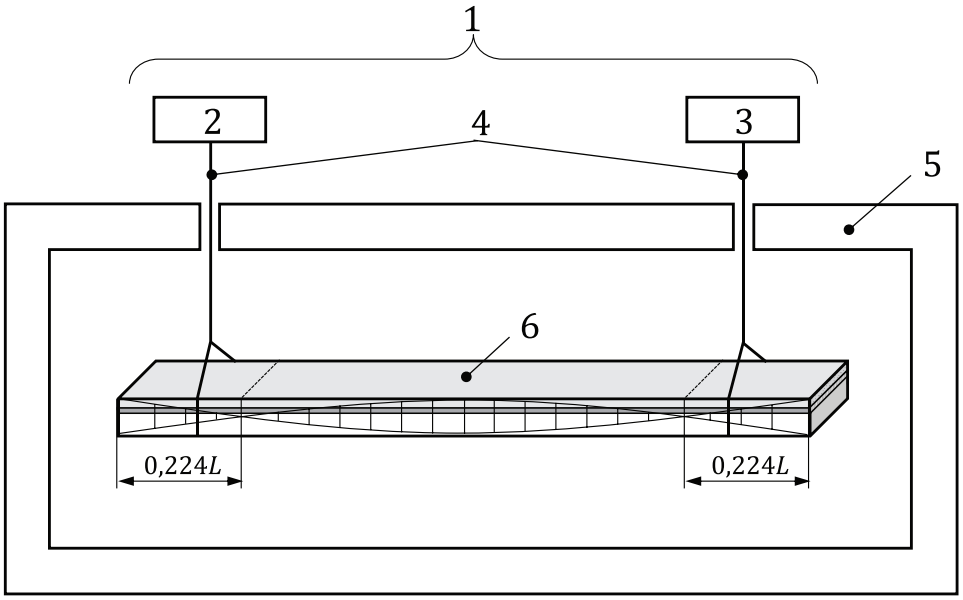
[SOURCE: ISO 14188:2012, 3.1, modified — In the definition, “a ceramic top coat” has replaced “an oxide top coat” and “to the substrate of a heat-resistant metallic material” has replaced “to the base material”. A different note to entry and figure have been used.]

4 Principle

The fundamental procedures for measuring the Young’s moduli of the substrate, BC and TC consist of the measurement of the resonance frequency of three types of specimens (substrate, substrate with BC and substrate with TBC) at an elevated temperature by a flexural resonance method, and of calculations according to the theory of flexural vibration for a composite beam[1][2][3][4].

5 Apparatus for measuring resonance frequency

An example of the apparatus for measuring the resonance frequency is schematically shown in Figure 2. The apparatus consists of a flexural resonance system and a heating device. See Annex A.



Key

1 flexural resonance system
2 driver
3 detector
4 suspending thread
5 heating device
6 specimen

Figure 2 — Typical apparatus for measuring the resonance frequency

5.1 Flexural resonance system, which shall be specified in accordance with ISO 17561.

The suspending thread shall be a heat-resistant material, such as an alumina yarn.

5.2 Heating device, consisting of a furnace with a temperature control system.

6 Specimen

6.1 Shape and dimensions

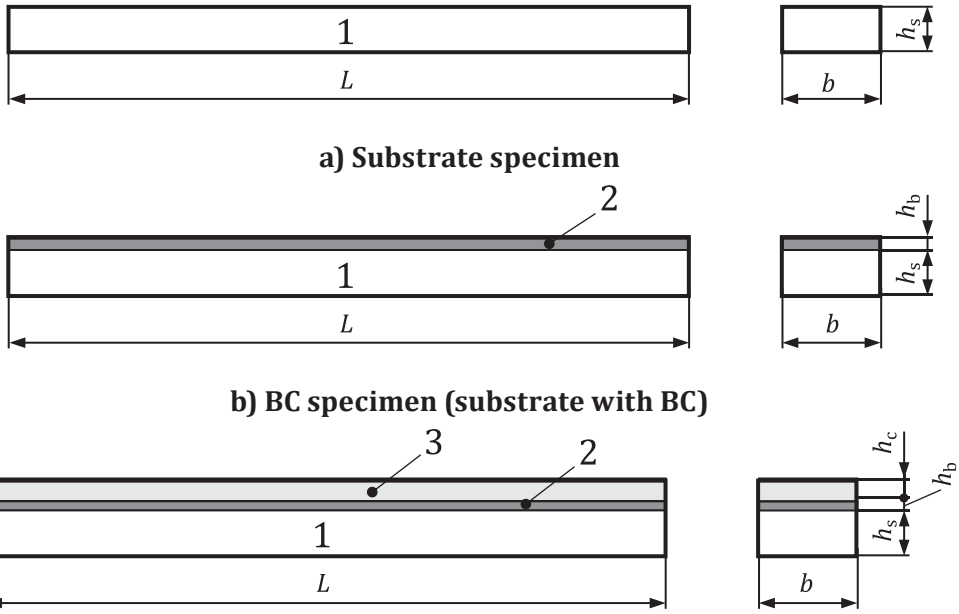
The shape and dimensions of the specimen shall be specified as follows.

a) Three types of specimens (the substrate, BC and TBC) shall be used. The substrate shall be the same as the heat-resistant metallic material to which the TBC is applied.

b) The specimen shape is a beam type (see Figure 3) and the dimensions of the specimen shall be as given in Table 1.

c) The thickness tolerance of the substrate shall be ±0,01 mm.

d) The side surface of the BC and TBC specimens shall be polished to remove the coating deposited on the side surface. The polishing shall be done cautiously so that it does not damage the coating.



a) Substrate specimen

b) BC specimen (substrate with BC)

c) TBC specimen (substrate with both BC and TC)

Key

1	substrate	L	total length
2	BC	b	width
3	TC	h_s	substrate thickness
		h_b	BC thickness
		h_c	TC thickness

Figure 3 — Shape of specimens

Table 1 — Dimensions of specimens

Symbol	Designation	Dimension
L (mm)	total length	$70 \le L$ and $20 \le L/(h_s + h_b + h_c)$
b (mm)	width	$5{,}0 \le b \le (1/6)\ L$
h_s (mm)	substrate thickness	$1{,}5 \le h_s \le 2{,}5$
h_b (mm)	BC thickness	$0{,}20 \le h_b$ and $0{,}10 \le h_b/h_s$ for BC specimen
h_c (mm)	TC thickness	$0{,}40 \le h_c$ and $0{,}20 \le h_c/(h_s + h_b)$ for TBC specimen

6.2 Preheat treatment

Specimens should be heat-treated at the maximum test temperature for about 2 h in air prior to the measurement in order to minimize the change of coating microstructures during the test, since the Young's moduli of as-sprayed BC and TC change remarkably depending on temperature history.

7 Measuring procedure

7.1 Dimension and mass of specimen

The dimensions and the mass of the specimen shall be measured as follows:

a) The total length of the specimen shall be measured in accordance with the ISO 13385 series.