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Metallic and other inorganic coatings — Test method of cyclic heating for thermal-barrier coatings under temperature gradient

Revêtements métalliques et autres revêtements inorganiques — Méthode d'essai de cyclage thermique de systèmes barrière thermique sous gradient de température

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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.

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.

ISO 13123 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

Introduction

Thermal-barrier coatings (TBCs) are refractory coatings which provide thermal insulation for turbine blades and vanes, as well as for combustion chamber liners in power generation, aviation gas turbines and rocket combustors. They allow operation at substantially higher surface temperatures than is possible with bare metal, and thus TBCs have been used to extend the life of components that suffer from severe heat load cyclically during operation.

Conventional isothermal test methods are not suitable for evaluating the TBC under high heat load with a large temperature-gradient condition. Standardization of a cyclic heating test method for determination of their thermal-barrier performance and cyclic heat resistance under a temperature gradient field is required.

Metallic and other inorganic coatings — Test method of cyclic heating for thermal-barrier coatings under temperature gradient

1 Scope

This International Standard applies to the test method of cyclic heating to evaluate the thermal-barrier performance and cyclic heat resistance of the thermal-barrier coatings provided for high-temperature components, such as burners, rotor and stator blades, etc. of power-generation gas turbines used in thermal power plants, aircraft engines and rocket engines.

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 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*

ISO 2063, *Thermal spraying — Metallic and other inorganic coatings — Zinc, aluminium and their alloys*

ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method*

ISO 14917, *Thermal spraying — Terminology, classification*

ISO 80000-1, *Qualities and units — Part 1: General*

IEC 60584-1:1995, *Thermocouples — Part 1: Reference tables*

IEC 60584-2:1982, *Thermocouples — Part 2: Tolerances*

IEC 60584-3:2007, *Thermocouples — Part 3: Extension and compensating cables —Tolerances and identification system*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2063, ISO 14917 and the following apply.

3.1
temperature gradient
temperature gradient caused by heating and cooling of both material surfaces of a test piece with thermal-barrier coatings

3.2
cyclic-heating testing
testing in which a temperature gradient is applied cyclically to the test piece with a thermal-barrier coating

3.3
number of thermal cycles
number of times the cyclic heating test is applied to the test piece with thermal-barrier coatings

3.4
acoustic emission
AE
phenomenon of a test piece provided with a thermal-barrier coating to emit an elastic wave by releasing the energy previously accumulated during damage generation like spalling, cracking, etc.

3.5
spalling area ratio
ratio of the total spalling area of a thermal-barrier coating to the effective area to which the thermal-barrier coating has been applied

4 Principle

The test piece provided with a thermal-barrier coating is subject cyclically to the cyclic heating test, in which the variation in equivalent effective thermal conductivity or acoustic emission occurrence frequency is measured, for the purpose of evaluating the thermal-barrier performance of the thermal-barrier coatings.

The test is also used to evaluate the cyclic heat resistance of thermal-barrier coatings by visually observing spalling and cracking in the test piece, and by determining the number of heating cycles needed to reach the damage tolerance limit.

5 Test piece

The typical shape and dimensions of the test piece are shown in Figure 1.

The shape and dimensions of a typical test piece shall be a disk having a diameter of 15 mm to 30 mm.

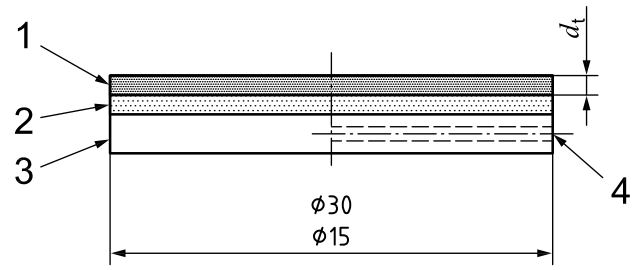
The effect of substrate thickness on the performance should be determined based on the agreement between the parties involved prior to the test. Its thickness should be measured according to ISO 1463 and ISO 2178.

It is recommended that the edge of the heating side of the substrate be rounded to a curvature of about 0,5 mm to 2 mm, or chamfered, in order to prevent cracking at the test-piece edge.

The thermal-barrier coating shall cover the entire heating surface of the substrate. The coating thickness shall be measured at multiple points in the middle and peripheral portions and shall be within ±10 % of the average value.

To measure the temperature in the central portion of the substrate, a hole may be provided for the thermocouple, running from the side of the substrate to the central portion (see 6.1.2.2). The position of the hole shall be such that no adverse effect is exerted on the stress field occurring in the coating layer and on the temperature measurement accuracy. The maximum diameter of the hole for the thermocouple should be close to the outside diameter of the thermocouple isolation. The position and diameter of the hole can be measured and described in the report, if necessary.

Dimensions in millimetres



Key

1 top coat

2 bond coat

3 substrate

4 thermocouple hole

d_t top coat thickness (mm)

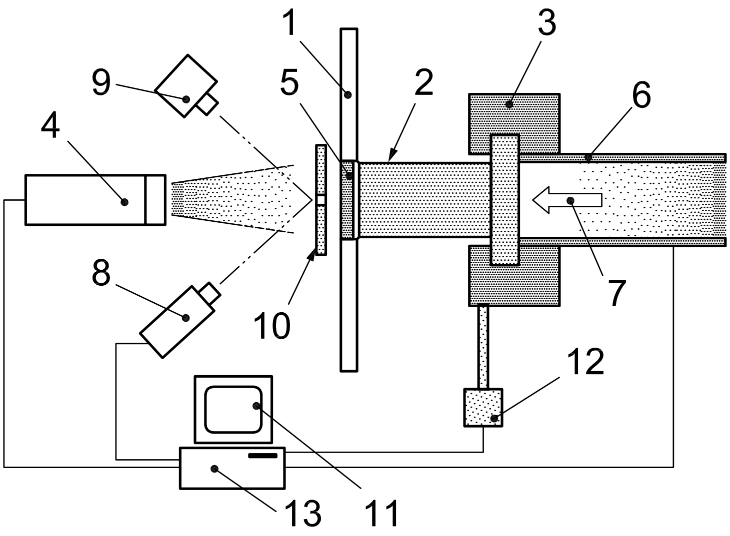
Figure 1 — Typical shape and dimensions of test piece

6 Test method

6.1 Test equipment

6.1.1 General

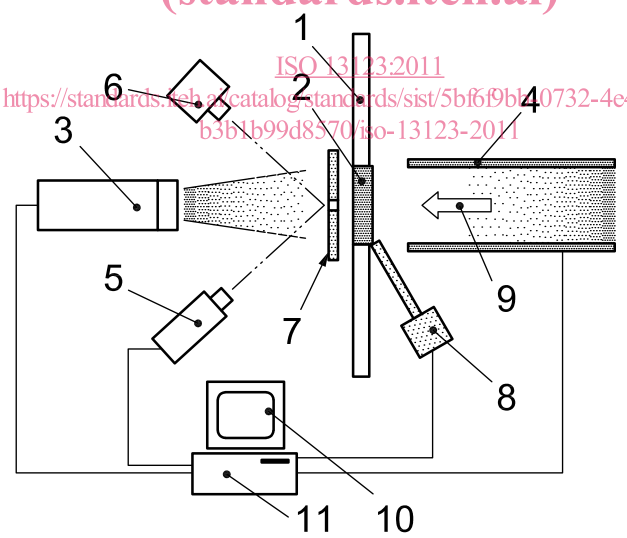
The test equipment shall consist of a heating unit, cooling unit, test block, controller, and detector/measurement instruments. Figure 2 shows a typical test equipment arrangement.



Key

1 heat shield
2 heat flux meter
3 test-piece holder
4 heating unit
5 test piece
6 cooling unit
7 coolant
8 pyrometer
9 camera
10 shutter
11 computer
12 AE sensor
13 control and detector unit

a) Test equipment with heat flux meter



Key

1 heat shield
2 test piece
3 heating unit
4 cooling unit
5 pyrometer
6 camera
7 shutter
8 AE sensor
9 coolant
10 computer
11 control and detector unit

b) Test equipment without heat flux meter

Figure 2 — Schematic diagram of test equipment

6.1.2 Test block

6.1.2.1 General

The test block shall consist of a test piece, heat flux meter and test-piece holder.

6.1.2.2 Heat flux meter

Typical examples of a heat flux meter with a test piece are shown in Figure 3.

The heat flux meter shall be brazed to the test piece as shown in Figure 3 a).

A thermal-barrier coating may be directly coated on the top of a heat flux meter as shown in Figure 3 b), in order to avoid the incomplete bonding or interdiffusion. The effect on the performance of the substrate thickness in the case of direct bonding should be considered and agreed upon between the parties involved.

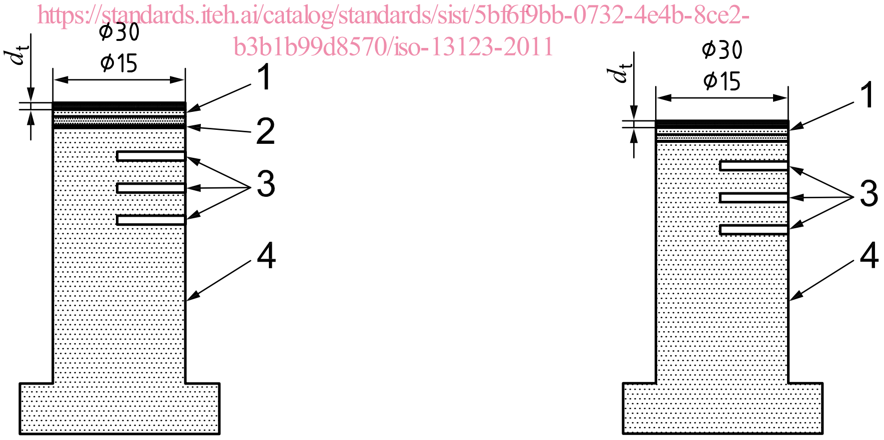
The outside diameter of the heat flux meter shall be the same as that of the test-piece substrate.

The material of the heat flux meter should have a high thermal conductivity and a small temperature dependence, normally such as copper, nickel, etc.

In order to determine the heat flux, multiple-thermocouple holes shall be provided, at regular intervals, running from the heat flux meter's outer surface through to its central axis. The number of holes and the intervals separating them shall be chosen based on the material and dimensions of the heat flux meter, test conditions, etc.

The heat flux meter need not be used when the test is intended only for evaluation of the cyclic heat resistance.

Dimensions in millimetres



a) Brazing method **b) Direct coating method**

Key

1 test piece
2 thermocouple hole
3 brazing layer
4 heat flux meter
d_t top coat thickness (mm)

Figure 3 — Shape and dimensions of heat flux meter

