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Metallic and other inorganic coatings — Test methods for measuring thermal cycle resistance and thermal shock resistance for thermal barrier coatings

Revêtements métalliques et autres revêtements inorganiques — Méthodes d'essai pour mesurer la résistance au cyclage thermique et la résistance au choc thermique des revêtements barrières thermiques

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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 14188 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

Introduction

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

The purpose of these coatings is to insulate metallic components for an extended period at elevated temperatures by employing thermally insulating materials which can sustain an appreciable temperature difference between load bearing alloys and coating surfaces. By shielding these parts, these coatings permit the use of high operating temperatures by restricting exposure of structural parts to these temperatures, thereby extending their lives.

This International Standard specifies test methods, applicable to these thermal barrier coatings, for measuring thermal cycle resistance and thermal shock resistance using appropriate heating and cooling procedures.

Metallic and other inorganic coatings — Test methods for measuring thermal cycle resistance and thermal shock resistance for thermal barrier coatings

1 Scope

This International Standard specifies test methods applicable to thermal barrier coatings for measuring thermal cycle resistance by using steady cyclical heating and cooling procedures, and for measuring thermal shock resistance using a heating and quenching technique.

These measurements are used for the evaluation of durability of thermal barrier coatings to thermal strain.

This International Standard is applicable for screening thermal barrier coating systems including materials and processing, and not for controlling the thermal spraying processes.

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 14232, *Thermal spraying — Powders — Composition and technical supply conditions*

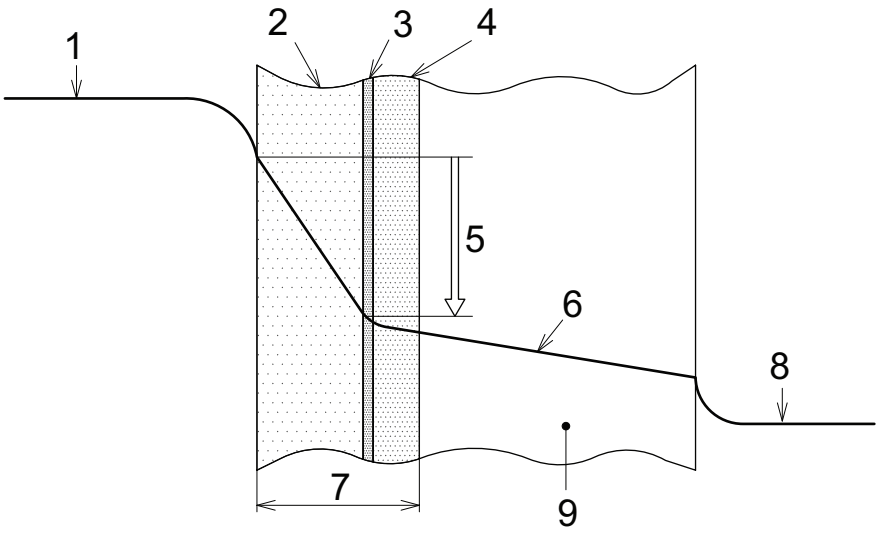
ISO 14916, *Thermal spraying — Determination of tensile adhesive strength*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
thermal barrier coating
TBC
two-layer coating consisting of a metallic bond coat and an oxide top coat, in order to reduce heat transfer from outside the top coat through the coating to the base material

NOTE When a TBC is exposed to operating at a high temperature, thermally grown oxide (TGO) develops on the top of the bond coat. The substrate is a typically heat-resistant high nickel based alloy class, UNS N 06002 type of material. The coatings, illustrated in Figure 1, are applied by using physical or chemical vapour deposition or by thermal spray processes, such as plasma spray and high velocity oxy-fuel (HVOF) spray conforming to ISO 14232.



Key

1 combustion gas temperature
2 top coat
3 TGO
4 bond coat
5 thermal barrier effect
6 temperature
7 TBC
8 cooling air temperature
9 substrate

Figure 1 — Diagrammatic view of the section and effects of TBC

3.2
thermally grown oxide
TGO
oxide grown between top and bond coat when the coating system is heated

3.3
ratio of spalling areas
proportion of the total spalling area relative to the effective area of the TBC

3.4
critical number of cycles to spalling
number of thermal cycles immediately prior to achieving 30 % in ratio of spalling area

NOTE In the assessment of spalling area, areas of delamination or cracking are excluded.

3.5
thermal shock temperature difference
difference in temperatures between heating and cooling water treatments of the test pieces in thermal shock tests

3.6
thermal shock resistance
thermal shock temperature difference that causes a reduction of tensile adhesive strength immediately prior to a decrease of 30 % relative to the tensile adhesive strength in the absence of thermal shock

4 Principle

The test methods include the thermal cycle resistance test by using steady cyclical heating and cooling procedures and consist of measuring ratio of spalling areas, and the thermal shock resistance test by measuring tensile adhesive strength following application of thermal shock. Thermal shock is applied by heating the test pieces in a furnace to the appropriate temperature and quenching in water. The coatings are applied by physical, chemical vapour deposition or by thermal spray processes such as plasma spray and high velocity oxy-fuel (HVOF) spray by using feedstock powders (ISO 14232).

5 Test methods

5.1 General

a) All measurements related to physical quantities, dimensions and quantities and unit systems shall be carried out in accordance with appropriate International Standards (see Bibliography).

b) When ordering testing in accordance with this International Standard, agreement between the contracting parties are needed in writing in contract or purchase order, concerning the following:

   1) handling and sectioning procedures, method of application of coatings, whether the coating surface is to be used as coated;

   2) for the thermal cycle test, selection of test pieces, position and size of piercing on test pieces, number of and any interruption of thermal cycles, and upper limit of high temperature, heating time, holding time at high temperature, cooling time and holding time at low temperature of a thermal cycle.

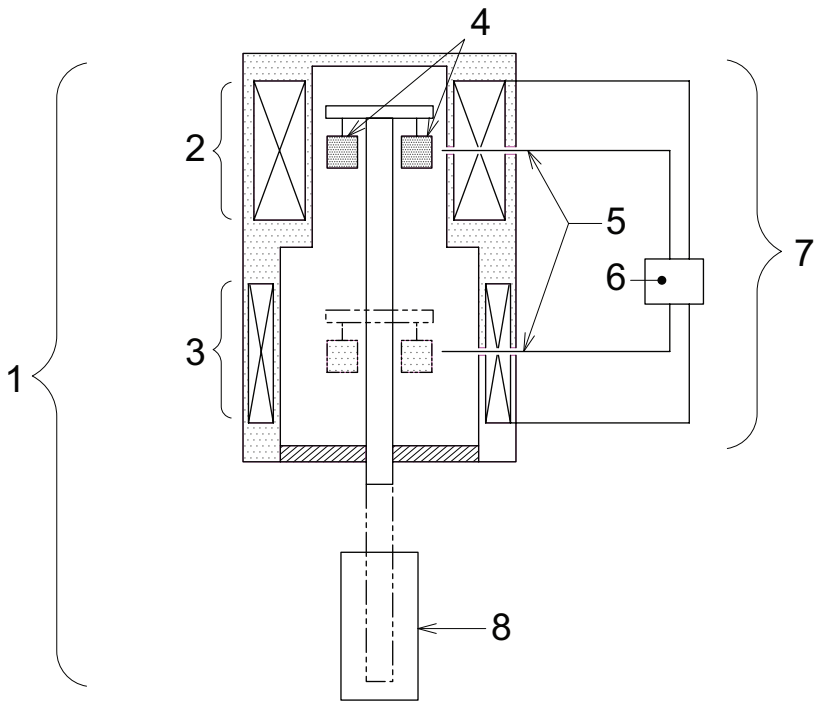
5.2 Thermal cycle resistance method

5.2.1 General

The test method covers a thermal cycle resistance test by using steady cyclical heating and cooling procedures and consists of measuring ratio of spalling areas. This method is useful in the selection of materials, coating processes and process conditions in the TBC system used in gas turbines operating at elevated temperatures.

5.2.2 Apparatus

The apparatus consists of a heating and cooling device and temperature control system, and is shown in Figure 2.

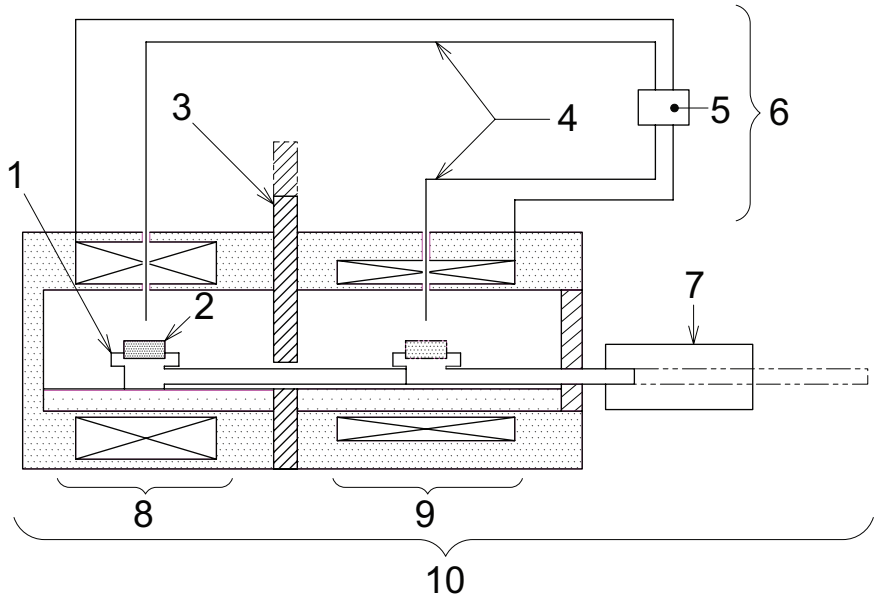


a) Vertical type

Key

1 heating and cooling device
2 high-temperature bath
3 low-temperature bath
4 test piece
5 thermocouple
6 temperature controller
7 temperature control system
8 test-piece-moving device

Figure 2 — Typical device for thermal cycle resistance method (*continued*)



b) Horizontal type

Key

1 test piece support
2 test piece
3 shield plate (up/down possible)
4 thermocouple
5 temperature controller
6 temperature control system
7 test-piece-moving device
8 high-temperature bath
9 low-temperature bath
10 heating and cooling device

Figure 2 — Typical device for thermal cycle resistance method

5.2.2.1 Heating and cooling device

a) The heating and cooling device consists of high- and low-temperature baths respectively. The atmosphere in both baths is air.

b) The test piece is placed alternately in the two baths which are fixed; or alternatively, the test piece is fixed and the baths are alternated.

c) The test pieces may be directly exposed to ambient air instead of using the low-temperature bath.

d) The temperature control system consists of the temperature controller and thermocouples (see Figure 2). The temperature is regulated to ensure that the temperature of the test pieces is within the range given in Table 1.