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**Test method of cyclic heating for
thermal-barrier coatings under
temperature gradient**

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In the event of any doubts arising as to the contents,
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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Osaka Science & Technology Center (OSTEC)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently, **JIS H 7851**:2005 is replaced with this Standard.

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Test method of cyclic heating for thermal-barrier coatings under temperature gradient

Introduction

This Japanese Industrial Standard has been prepared based on the first edition of **ISO 13123** published in 2011 with some modifications of the technical contents.

The portions given sidelines or dotted underlines are the matters in which the contents of the corresponding International Standard have been modified. A list of modifications with the explanations is given in Annex JB.

1 Scope

This Standard specifies the test method of cyclic heating under temperature gradient¹⁾ for evaluating the thermal-barrier performance and the cyclic heat resistance of thermal-barrier coatings provided for high-temperature components such as burners, rotating blades and stationary blades of power-generation gas turbines, aircraft engines and so on.

Also, this Standard is applicable to the evaluation test for the thermal-barrier performance and the cyclic heat resistance of functionally gradient materials.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 13123:2011 *Metallic and other inorganic coatings—Test method of cyclic heating for thermal-barrier coatings under temperature gradient* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

Note ¹⁾ The temperature gradient in this Standard means the temperature field close to the actual environment in which a temperature gradient is intentionally provided by heating the surface of test piece and cooling the back-side thereof, which is different from the test method of cyclic heating under isothermal field specified in **JIS H 8451**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standard (including amendments) indicated below shall be applied.

JIS B 7502 *Micrometer callipers*

JIS B 7507 *Vernier, dial and digital callipers*

JIS C 1602 *Thermocouples*

NOTE : Corresponding International Standards: IEC 60584-1:1995 *Thermocouples—Part 1: Reference tables* and IEC 60584-2:1982 *Thermocouples. Part 2: Tolerances* (overall evaluation: MOD)

JIS C 1612 *Test methods for radiation thermometers*

JIS H 8200 *Thermal spraying terms*

JIS H 8401 *Methods of thickness measurement for sprayed coatings*

JIS H 8451 *Testing methods for thermal cycle and thermal shock resistance of thermal barrier coatings*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions, and those given in JIS H 8200 and JIS H 8451 apply.

3.1 thermal barrier coatings (TBC)

coating applied to the substrate constructing a high-temperature component in order to suppress the temperature rise caused by the combustion gas

It is composed of a bond coat applied to the surface of substrate constructing a high-temperature component and a top coat which is a cladding of high-melting-point and low-thermal-conductivity ceramics (see figure 1).

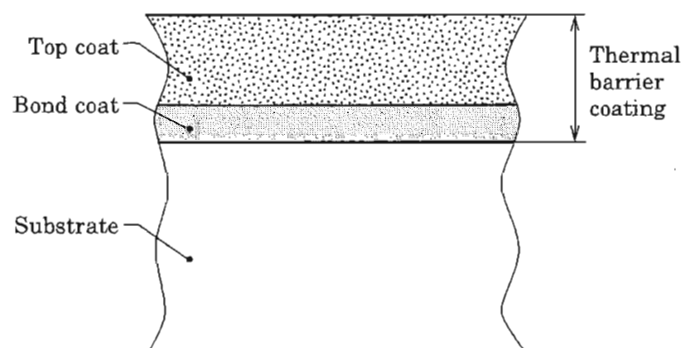


Figure 1 Cross-section of TBC

3.2 top coat surface temperature

surface temperature of top coat of TBC heated by the combustion gas, etc.

3.3 top coat backside temperature

temperature of boundary between the top coat and the bond coat (see Annex A)

3.4 number of thermal cycles

number of times of cyclic heating test

3.5 acoustic emission (AE)

phenomenon of TBC to emit an elastic wave due to the release of the energy which has been accumulated up to the time when it deforms or is damaged due to cracking, peeling-off, etc.

3.6 heat flux

value obtained by multiplying the average gradient of the temperatures measured at multiple points along the central axis of a cylindrical jig to which the test piece is attached by the thermal conductivity of the cylindrical jig [see 8 a)]

3.7 equivalent effective thermal conductivity

value obtained by dividing the product of the heat flux and the top coat thickness by the difference between the top coat surface temperature and the top coat backside temperature [see 8 c)]

3.8 damage tolerance limit

limit up to which the test piece is allowed to be subjected to a cyclic heating test, which is any of the following

- a) when the spalling area ratio becomes 20 % or more by visual observation
- b) when the top coat surface temperature rises drastically
- c) when the temperature difference between the heated surface and the backside increases drastically
- d) when the number of counts of AE increases drastically

4 Principle

The surface of test piece provided with TBC is heated and the backside is cooled to form a specified temperature gradient, and the thermal-barrier performance of TBC is evaluated by measuring the maximum top coat surface temperature attained, the temperature difference between the surface and the backside, and the equivalent effective thermal conductivity.

The cyclic heat resistance of TBC is evaluated by conducting the cyclic heating test in which a predetermined temperature gradient is repeatedly applied to the test piece and by counting the number of thermal cycles necessary for reaching the damage tolerance limit.

Depending on the testing purpose, the test method in Annex JA is also available in the case where the cyclic heat resistance of TBC is evaluated only by the number of cycles necessary for reaching the damage tolerance limit in the cyclic heating test.

5 Test piece and jig

5.1 Test piece

The test pieces shall be as follows.

- a) The shape and dimensions of a test piece shall be a disk having a diameter of 15 mm to 30 mm (see figure 2).

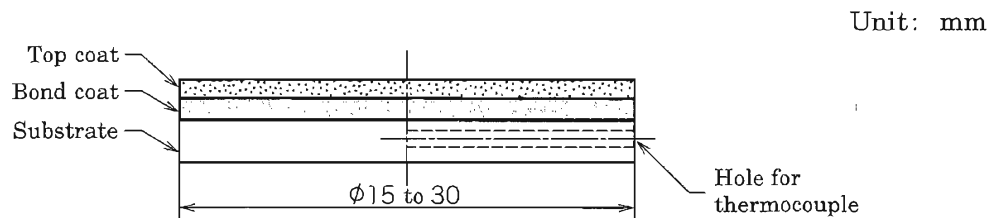


Figure 2 Example of structure of test piece and dimensions thereof

- b) The thickness of substrate shall be upon the agreement between the purchaser and the manufacturer.
- c) The edge of substrate to which the bond coat is applied should be rounded to a curvature of about 0.5 mm to 1 mm.
- d) TBC shall cover the whole heating surface side of the substrate. The thickness of top coat and bond coat shall be measured based on **JIS H 8401** using such as a micrometer specified in **JIS B 7502** and callipers specified in **JIS B 7507**. The dispersion of the top coat and the bond coat thicknesses shall be $\pm 10\%$ of the average value.
- e) A hole running from the side surface of substrate to the central portion may be provided for a thermocouple in order to measure the temperature in the central portion of the substrate on the cooling surface side.
- f) The diameter of the hole for thermocouple shall be such that the sheathed thermocouple to be used does not fall off easily.

5.2 Cylindrical jig

The cylindrical jig shall be as follows.

- a) To the test piece, the cylindrical jig necessary for the calculation of the heat flux to be applied in the test shall be attached.

The cylindrical jig need not be used when the test is intended for the evaluation of the cyclic heat resistance only (see Annex JA).

- b) Examples of typical attachment are shown in figure 3. The cylindrical jig shall be brazed to [see figure 3 a)] or mechanically joined to the test piece shown in figure 2. The test piece shown in figure 2 may be directly prepared on the top of the cylindrical jig in order to avoid the incomplete bonding or interdiffusion. An example is shown in figure 3 b).
- c) The outside diameter of the cylindrical jig shall be the same as that of the substrate of test piece.
- d) The material of the cylindrical jig should have a large thermal conductivity and a small temperature dependence such as copper and nickel. The material whose thermal conductivity is known shall be used.
- e) In order to determine the heat flux applied in the test, adequate number of holes for thermocouple shall be provided at regular intervals, which are running from the cylindrical jig's outer surface through to its central axis. The number of holes and the interval thereof shall be selected based on the material and dimensions of the cylindrical jig, test conditions, etc.