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Thermal spraying — Determination of interfacial toughness of ceramic coatings by indentation

Projection thermique — Détermination de la ténacité interfaciale des revêtements céramiques par indentation

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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.

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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

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

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Introduction

The interfacial toughness of thermal spray ceramic coatings is required for two reasons:

a) to understand quantitatively degradation of adhesion in service;

b) for life assessment of the coated components.

Adhesion strength of thermal spray coatings is usually measured in accordance with the tensile method specified by ISO 14916. However, there is a technical limitation in the application of ISO 14916. It requires preparation of a tensile adhesion test specimen using glue and, as such, coatings with higher adhesion strength than glue cannot be quantitatively evaluated. By virtue of its simplicity and practicality, an indentation method is a promising method to evaluate the adhesion of such coatings. In this method, a Vickers hardness tester is used. An interfacial toughness value is evaluated by measuring a length of the crack formed after pushing the indenter on the coating interface. The application of the method specified in this document can reduce uncertainty over the adhesion strength evaluation of coatings and makes it possible to evaluate the adhesion strength in a simpler way.

The results can be expressed either as a stress intensity factor, in $MN \cdot m^{-3/2}$, or as a fracture surface energy, in $J \cdot m^{-2}$.

"Interfacial toughness" can have several meanings.

a) Interfacial fracture toughness, K_{Ic}, in $MN \cdot m^{-3/2}$, is a material constant that shows how easily the coating may be peeled away from a substrate.

b) Energy release rate (or work done to fracture), G, is an alternative expression for interfacial fracture toughness, often obtained by converting K to G [i.e. $G = K^2(1 - \nu^2)/E$, where E is Young's modulus and ν is Poisson's ratio]. G has units of $J \cdot m^{-2}$.

For the purposes of developing the test method, the term indentation interfacial toughness, K_{IFC}, is defined separately from interfacial fracture toughness, K_{Ic}. The indentation interfacial toughness is a value obtained by using Vickers hardness tester, and is calculated from the total length of cracks induced along the interface by the indentation. Shorter crack lengths indicate that the coating has higher interfacial toughness or adhesion strength than other samples with longer cracks. There is no standard method to determine such interfacial toughness for thermal spray ceramic coatings, and different organizations or groups currently use their own evaluation procedures.

When measurements are carefully performed following the methods defined in this document, the evaluation of crack length, and thus interfacial toughness, will not require much effort and can describe the adhesion characteristics of the system (substrate chemistry, pre-preparation/roughness of substrate surface, coating chemistry and properties). This document recommends good practice to minimize uncertainty in the measurement procedures.

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Thermal spraying — Determination of interfacial toughness of ceramic coatings by indentation

1 Scope

This document specifies a method for measuring the interfacial toughness of thermal spray ceramic coatings at room temperature based on an indentation method. The interfacial toughness is calculated from the mean length of cracks emanating from the corners of the impression induced by a Vickers hardness tester, and it is intended for use with ceramic coatings with a single layer or multilayers. The test procedures proposed in this document are intended for use in an ambient environment.

This document is recommended for thermal spray ceramic coatings such as thermal barrier coatings, wear resistant coatings and electrical insulating coatings.

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 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6507-2, *Metallic materials — Vickers hardness test — Part 2: Verification and calibration of testing machines*

3 Terms and definitions

No terms and definitions are listed in this document.

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

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols and units

For the purposes of this document, the symbols and units given in Table 1 apply (see also Figures 1 and 2).

Table 1 — Symbols and designations

Symbol	Designation	Unit
a	diagonal half-length of impression parallel to interface	m
c	mean value of half crack length: $(c_1 + c_2)/2$	m
c_1, c_2	individual crack lengths at corner of impression (lengths from crack tip to centre of impression, parallel with the macroscopic interface)	m
E_1	Young's modulus of ceramic coating	$GN \cdot m^{-2}$
E_2	Young's modulus of substrate (or bond coat)	$GN \cdot m^{-2}$
F	test force (indentation load)	N
H	mean value of distance from centre of impression to the interface: $(H_1 + H_2)/2$	mm
H_1, H_2	individual distance from centre of impression to interface	mm

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