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Advanced technical ceramics - Methods of test for ceramic coatings - Part 11: Determination of internal stress by the Stoney formula

Céramiques techniques avancées - Méthodes d'essais pour revêtements céramiques - Partie 11 :Détermination de la contrainte interne par la formule de Stoney

Hochleistungskeramik - Verfahren zur Prüfung keramischer Schichten - Teil 11: Bestimmung der inneren Spannung nach der Stoney-Gleichung

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Foreword

This CEN Technical Specification (CEN/TS 1071-11:2005) has been prepared by Technical Committee CEN/TC 184 "Advanced technical ceramics", the secretariat of which is held by BSI.

EN 1071 *Advanced technical ceramics — Methods of test for ceramic coatings* consists of 11 parts:

Part 1: *Determination of coating thickness by contact probe filometer*

Part 2: *Determination of coating thickness by the crater grinding method*

Part 3: *Determination of adhesion and other mechanical failure modes by a scratch test*

Part 4: *Determination of chemical composition by electron probe microanalysis (EPMA)*

Part 5: *Determination of porosity*

Part 6: *Determination of the abrasion resistance of coatings by a micro-abrasion wear test*

Part 7: *Determination of hardness and Young's modulus by instrumented indentation testing*

Part 8: *Rockwell indentation test for evaluation of adhesion*

Part 9: *Determination of fracture strain*

Part 10: *Determination of coating thickness by cross sectioning*

Part 11: *Measurement of internal stress by the Stoney formula*

Parts 5 to 6 are European prestandards.

Parts 7 to 11 are Technical Specifications.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this CEN Technical Specification: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This Technical Specification specifies a method for the determination of the internal stress in thin ceramic coatings by application of the Stoney formula to the results obtained from measurement of the radius of curvature of coated strips or discs.

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.

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2005)*

3 Principle

Coating stress often plays a major role in the performance of coated tools and machine parts. Different techniques have been developed for the determination of coating stress. The technique considered in this document calculates the stress from measurement of the bowing of thin discs or strips of well characterised materials of known thickness that have been coated on one side only. It is assumed that the deformation is elastic, i.e. if the coating were to be removed, the substrate would return to its initial shape.

Provided that the coating is thin compared to the thickness of the substrate (coating thickness < 2 % of substrate thickness); that the curvature has a spherical form; and that the substrate was initially flat or of known curvature, then the stress in the coating can be calculated using the Stoney formula (see 6.6) without the need to know the elastic properties of the coating material.

The technique requires an accurate knowledge of the thickness of the coating, the thickness of the substrate, and the Young's modulus and Poisson's ratio of the substrate material.

NOTE 1 Coating thickness can be determined by techniques such as step height measurement (see EN 1071-1 [1]), crater grinding (see EN 1071-2 [2]) and cross sectioning (see CEN/TS 1071-10 [3]).

As ceramic coatings are normally deposited at elevated temperatures, the stress determined at any other temperature will be a combination of the intrinsic growth stress and stress introduced by virtue of the difference in thermal expansion between the coating and the substrate.

The internal stress σ_o in the coating is deduced from the measured radius of curvature $R_{\exp}$, through the application of the Stoney formula [4]:

$$\sigma_o = -\frac{1}{6}\frac{E_s}{1-\nu_s}\frac{h_s^2}{h_f}\frac{1}{R_{\exp}}$$

where h_f and h_s denote the thickness of the coating and substrate respectively, and where E_s and ν_s denote Young's modulus and Poisson's ratio of the substrate respectively.

NOTE 2 σ_o is the mean value of the local stress through the thickness of the coating ($h_f << h_s$):