



BSI Standards Publication

Metallic materials — Instrumented indentation test for hardness and materials parameters

Part 6: Instrumented indentation test at elevated temperature

National foreword

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A list of organizations represented on this committee can be obtained on request to its committee manager.

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**Metallic materials — Instrumented
indentation test for hardness and
materials parameters —**

**Part 6:
Instrumented indentation test at
elevated temperature**

*Matériaux métalliques — Essai d'indentation instrumenté pour
les paramètres de dureté et de matériaux —*

Partie 6: Essai d'indentation instrumenté à température élevée

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Foreword

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This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

A list of all parts in the ISO 14577 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Hardness has typically been defined as the resistance of a material to permanent penetration by another harder material. The results obtained when performing Rockwell, Vickers, and Brinell tests are determined after the test force has been removed. Therefore, the effect of elastic deformation under the indenter has been ignored.

ISO 14577 (all parts) has been prepared to enable the user to evaluate the indentation of materials by considering both the force and displacement during plastic and elastic deformation. By monitoring the complete cycle of increase and removal of the test force, hardness values equivalent to traditional hardness values can be determined. More significantly, additional properties of the material, such as its indentation modulus and elasto-plastic hardness, can also be determined. All these values can be calculated without the requirement to measure the indent optically. Furthermore, by a variety of techniques, the instrumented indentation test is able to generate hardness and modulus values at different indentation depths within the indentation cycle.

This document has been prepared to enable the user to obtain hardness and other materials parameters using instrumented indentation testing at elevated temperature. The elastic and plastic properties of material components at elevated temperature are critical for determining the performance representative of in-service condition above ambient temperature. Typical applications include hard coatings, nuclear materials, welded materials, fuel cell materials, aerospace materials, etc. In-service properties of wear surfaces, cutting tool, high friction contacts are also significant applications.

This document covers the instrumented indentation testing systems with independent heating of both the indenter and test piece with feedback control and equipped with temperature sensing. This type of instrumented indentation testing system is suitable for testing materials of high or low thermal conductivity in air, in inert or reducing gaseous environment, and also in vacuum, which offers the potential for higher testing temperature. Active heating of the indenter tip allows independent adjustment of energy flow into the tip and test piece so that a condition of iso-thermal contact is achieved rather than just thermal equilibrium with constant (but unknown) thermal gradients. A temperature sensor mounted in an indenter body with a low heat capacity is sensitive to small heat flows and, therefore, can detect small temperature differences between test piece and tip.

The method described in this document can achieve low uncertainty in the temperature assigned to the indentation contact when testing materials with high thermal conductivity (uncertainty increases when testing low thermal conductivity materials). This is achieved by traceable calibration of the indenter tip temperature for a reproducible temperature offset between the contact temperature and indenter temperature sensor reading. A reproducible temperature offset is obtained by using a procedure to minimise (optimally to zero) the heat flow between the test piece and the indenter. This not only makes the temperature offset from indenter temperature sensor to indenter tip a reproducible amount, but also minimises the temperature gradient in the test piece (from the contact to the bulk of the test piece) that occurs when there is a heat flow through the contact. The minimum detectable heat flow of a system depends upon the heat capacity of the indenter and the resolution of the indenter temperature sensor. Any amount of heat flow causes a higher uncertainty in assigned contact temperature that is higher the lower the thermal conductivity of the test material is.

Metallic materials — Instrumented indentation test for hardness and materials parameters —

Part 6: Instrumented indentation test at elevated temperature

1 Scope

This document specifies the instrumented indentation method for testing at elevated temperature for determination of hardness and other materials parameters at temperatures above ambient. Elevated temperature testing is defined in this document to be when the test piece and indenter tip are heated above the ambient conditions of the instrument to a controlled and measured temperature; insulating shielding is used to enclose the hot zone to reduce heating effects so that the majority of the instrumented indentation testing machine is at ambient conditions.

This document is restricted to test machines that have been traceably calibrated and pass an indirect verification according to ISO 14577-2 when operating at elevated temperature to ensure that any effects on ambient sensors caused by the presence of a hot zone are accounted for. This document covers instrumented indentation testing at elevated temperatures in air, in inert or reducing gaseous environments, or in vacuum.

This document provides a method for instrumented indentation testing at elevated temperature with both the indenter tip and test piece actively heated, and with independent feedback control and temperature measurement of both the indenter tip and test piece.

This document provides a method for estimation of the uncertainty of the contact temperature. The uncertainty increases as the thermal conductivity of the test piece decreases. It is left to the user to decide if that uncertainty is fit for their purpose.

The test method in this document is not applicable to:

- instrumented indentation testing where there is no direct measurement of the temperature of the indenter tip body itself;
- instrumented indentation testing where above ambient temperatures are obtained by placing the entire instrument in a hot box to achieve iso-thermal heating of the whole system. These systems typically only achieve limited elevated temperature;
- instrumented indentation testing with active heating of the test piece but only passive heating of the indenter, e.g. by proximity to the hot test piece and thermal conduction through the indentation contact, hot gas, or any combination.

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 14577-1, *Metallic materials — Instrumented indentation test for hardness and materials parameters — Part 1: Test Method*

ISO 14577-2, *Metallic materials — Instrumented indentation test for hardness and materials parameters — Part 2: Verification and calibration of testing machines*