International Standard

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

Part 1: Test method

Matériaux métalliques — Essai de pénétration instrumenté pour la détermination de la dureté et de paramètres des matériaux —

Partie 1: Méthode d'essai

Reference number
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Contents

Page

Foreword ... **iv**
Introduction ... **v**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **2**
4 Symbols and designations ... **2**
5 Principle ... **4**
6 Testing machine ... **5**
7 Test piece ... **5**
8 Procedure ... **6**
9 Uncertainty of the results ... **9**
10 Test report ... **10**
Annex A (normative) **Materials parameters determined from the force/indentation depth data set** ... **12**
Annex B (informative) **Types of control use for the indentation process** ... **25**
Annex C (normative) **Machine compliance and indenter area function** ... **26**
Annex D (informative) **Notes on diamond indenters** ... **28**
Annex E (normative) **Influence of the test piece surface roughness on the accuracy of the results** ... **29**
Annex F (informative) **Correlation of indentation hardness H_{IT} to Vickers hardness** ... **30**
Annex G (normative) **Determination of drift and minimizing creep influence** ... **32**
Annex H (informative) **Estimation of uncertainty of the calculated values of hardness and materials parameters** ... **34**
Annex I (normative) **Calculation of radial displacement correction** ... **39**
Bibliography ... **43**

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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 document 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 of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 459/SC1, *Test methods for steel (other than chemical analysis),* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 14577-1:2015), which has been technically revised.

The main changes are as follows:

— Better specification of the approach speed of the tip.

— Addition of a loading method with constant strain rate.

— Change of order of hardness definitions: first H_{IT} then HM.

— Better proposals for cleaning the tip.

— Differentiation between contact area under load and in unloaded state.

— Complete reformulation of normative Annex I for radial displacement correction.

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.

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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 increasing 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 need to measure the indent optically. Furthermore, by a variety of techniques, the instrumented indentation test allows to record hardness and modulus depth profiles within a, probably complex, indentation cycle.

Although the indentation modulus (E_{IT}) value obtained in this test method is not directly equivalent to Young's modulus or the orientation specific elastic modulus of the material indented, E_{IT} is, however, equivalent to the isotropic Hill average of the elastic plane strain modulus of the material when there is no pile up and no residual stress.

ISO 14577 (all parts) has been written to allow a wide variety of post-test data analysis.

Part 1 of ISO 14577 specifies the method of indentation test for determination of instrumented indentation hardness and material properties.

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

Part 1: Test method

1 Scope

This document specifies the method of instrumented indentation test for determination of hardness and other materials parameters for the following three ranges:

— macro range: 2 $N \leq F \leq 30$ kN;

— micro range: 2 $N > F$; $h > 0{,}2$ µm;

— nano range: $h \leq 0{,}2$ µm.

For the nano range, the mechanical deformation strongly depends on the real shape of indenter tip and the calculated material parameters are significantly influenced by the contact area function of the indenter used in the testing machine. Therefore, careful calibration of both instrument and indenter shape is required in order to achieve an acceptable reproducibility of the materials parameters determined with different machines.

The macro and micro ranges are distinguished by the test forces in relation to the indentation depth.

Attention is drawn to the fact that the micro range has an upper limit given by the test force (2 N) and a lower limit given by the indentation depth of 0,2 µm.

The determination of hardness and other material parameters is given in the normative Annex A.

At high contact pressures, damage to the indenter is possible. For test pieces with very high hardness and modulus of elasticity, permanent indenter deformation can occur and can be detected using suitable reference materials. Indentations that result in damage or permanent deformation of the indenter are excluded from the scope of this test method.

This test method can also be applied to thin metallic and non-metallic coatings and non-metallic materials. In this case, it is recommended that the specifications in the relevant standards be taken into account (see also 7.3 and ISO 14577-4).

The analysis methods of this standard assume that materials behave like ideal materials. Any deviation (internal stress, pile-up, sink-in, densification, phase transitions, cracks) will result in additional uncertainties. This becomes especially important if comparisons shall be done to material parameters, obtained with other methods.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14577-2:2026, *Metallic materials — Instrumented indentation test for hardness and materials parameters — Part 2: Verification and calibration of testing machines*

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ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 Symbols and designations

For the purposes of this document, the symbols and designations in Table 1 shall be applied (see also Figure 1 and Figure 2).

Table 1 — Symbols and designations

Symbol	Designation	Unit
$A_p\ (h_c)$	Projected area of contact under load of the indenter at distance h_c from the tip	mm^2
$A_{p,UL}\ (h_c)$	Projected area of contact in unloaded state of the indenter at distance h_c from the tip	mm^2
$A_s\ (h)$	Surface area of the indenter at distance h from the tip in unloaded state	mm^2
C_{IT}	Indentation creep	%
C_T	Total measured compliance of the contact (dh/dF tangent to the force removal curve at maximum test force)	nm/mN
C_F	Machine compliance	nm/mN
C_S	Compliance of the contact after correction for machine compliance	nm/mN
E_{IT}	Indentation modulus of the test piece	GPa
E_r	Reduced plane strain modulus of the contact (combination of test piece and indenter plane strain moduli)	GPa
F	Test force	N
F_{max}	Maximum test force	N
h	Indentation depth under applied test force	mm
h_c	Contact depth of the indenter with the test piece at F_{max}	mm
h_{max}	Maximum indentation depth at F_{max}	mm
h_p	Permanent indentation depth after removal of the test force	mm
h_r	Point of intersection of the tangent c to curve b at F_{max} with the indentation depth-axis as identified on Figure 1	mm
H_{IT}	Indentation hardness	GPa
HM	Martens hardness	GPa
HM_s	Martens hardness, determined from the slope of the increasing force/indentation depth curve	GPa
HM_{diff}	Martens hardness, determined from the first derivative of h vs $\sqrt{F}$	GPa
ν_s	Poisson's ratio of the test piece	
r	Radius of spherical indenter	mm
R_{IT}	Indentation relaxation	%

NOTE 1 To avoid very long numbers, the use of multiples or sub-multiples of the units can be used.

NOTE 2 The continued use of the unit N/mm^2 is allowed. 1 MPa = 1 N/mm^2.

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