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Metallic materials — Leeb hardness test —

Part 1: Test method

Matériaux métalliques — Essai de dureté Leeb —

Partie 1: Méthode d'essai

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Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
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Foreword

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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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The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

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ISO 16859 consists of the following parts, under the general title *Metallic materials — Leeb hardness test*:

— *Part 1: Test method*

— *Part 2: Verification and calibration of the testing devices*

— *Part 3: Calibration of reference test blocks*

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Metallic materials — Leeb hardness test —

Part 1:
Test method

1 Scope

This part of ISO 16859 covers the determination of a dynamic hardness of metallic materials using seven different Leeb scales (HLD, HLS, HLE, HLDL, HLD+15, HLC, HLG).

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 16859-2, *Metallic materials — Leeb hardness test — Part 2: Verification and calibration of the testing devices*

ISO 16859-3, *Metallic materials — Leeb hardness test — Part 3: Calibration of reference test blocks*

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3 Principle

When testing hardness according to Leeb, a moving impact body collides at normal incidence with a surface and rebounds. The velocity of the impact body is measured before (v_A) and after impact (v_R). The energy amount absorbed by the test piece respectively dissipated in the test measures the dynamic Leeb hardness of the test piece. It is assumed that the impact body does not permanently deform.

The ratio of the impact and rebound velocity values gives the coefficient of restitution for the impact configuration and energy used. This coefficient represents the proportion of initial kinetic energy returned to the impact body within the contact time of the impact.

The hardness number according to Leeb, HL, is calculated as given in Formula (1)

$$\mathrm{HL} = \frac{v_R}{v_A} \cdot 1\,000 \qquad (1)$$

where

v_R is rebound velocity;

v_A is impact velocity.

By definition, the Leeb hardness is a ratio and thus becomes a quantity without dimensions.

4 Symbols, abbreviated terms, and designations

4.1 For most common Leeb scale and type of impact devices, see Table 1.

NOTE Other parameter values can be used based on the specific agreement between the parties.

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Table 1 — Symbols, dimensions, designations, and parameters of Leeb scales according to type of impact devices

Symbol	Unit	Designation	Parameters of types of impact devices						
			D[a]	S	E	DL	D+15	C	G
E_A	mJ	Kinetic impact energy[b]	11,5	11,4	11,5	11,95	11,2	3,0	90,0
v_A	m/s	Impact velocity	2,05	2,05	2,05	1,82	1,7	1,4	3,0
v_R	m/s	Rebound velocity	0,615 - 1,824 5	0,82 - 1,886	0,615 - 1,886	1,1092 - 1,729	0,561 - 1,513	0,49 - 1,344	0,9 - 2,25
	mm	Maximum distance of ball indenter from test piece surface at velocity measurement	2,00	2,00	2,00	2,00	2,00	2,00	3,00
M	g	Mass of impact body incl. ball indenter	5,45	5,40	5,45	7,25	7,75	3,1	20,0
R	mm	Spherical radius of indenter ball	1,5	1,5	1,5	1,39	1,5	1,5	2,5
		Material of indenter	WC-Co[c]	C[d]	PCD[e]	WC-Co[c]	WC-Co[c]	WC-Co[c]	WC-Co[c]
HL		Leeb hardness	HLD	HLS	HLE	HLDL	HLD+15	HLC	HLG
		Field of application	300 HLD - 890 HLD	400 HLS - 920 HLS	300 HLE - 920 HLE	560 HLDL - 950 HLDL	330 HLD+15 - 890 HLD+15	350 HLC - 960 HLC	300 HLG - 750 HLG

[a] Alternative common designation “DC”.

[b] Impact vertically down, in direction of gravity, rounded.

[c] Tungsten-carbide cobalt.

[d] Ceramics.

[e] Polycrystalline diamond.

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4.2 The Leeb hardness number is followed by the symbol “HL” with one or more subsequent characters representing the type of impact device.

EXAMPLE 570 HLD

Leeb hardness, HL, is measured using impact device type D in direction of gravity. Measurements using a different impact device type will deliver a different hardness number, as the result from Formula (1) depends on the parameters of each impact device type.

For testing in other directions, the measured hardness number will be biased. In such cases, a correction shall be applied in accordance with Annex A. If the test is not conducted in direction of gravity, the testing direction and correction shall be recorded, and the adjusted hardness number shall be given as the Leeb hardness result.

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5 Testing instrument

5.1 The instrument used for Leeb hardness testing consists of an impact device (for an example, see Annex D) and an electronic measuring and indicating unit to determine the impact and rebound velocity of the impact body.

5.2 The impact body consists of a spherical indenter and the holder of the indenter, see Table 1.

5.3 The support ring shall be mounted tightly to the bottom of the impact device. Except for impact device type DL, the support surface shall be designed to prevent movement of the impact device during the test.

The support ring should be checked regularly, as wear can affect the readings. Specifically, the bottom surface of the support ring should be visually inspected. Deposits and dirt should be removed.

5.4 The instrument shall meet the requirements of ISO 16859-2.

6 Test piece

6.1 Shape

6.1.1 Leeb hardness testing can be done on test pieces of diverse shapes as long as the impact velocity vector is normal to the local surface region to be tested, and the support ring is stably placed on the test piece surface.

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6.1.2 Test pieces with curved surfaces (concave or convex) can be tested providing that the radius of curvature at the test location is not less than 50 mm for the impact device type G, or 30 mm for other impact devices, respectively.

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6.1.3 In all other cases, special support rings shall be used for a stable seating of the instrument on the test surface.

6.2 Thickness and mass

The stiffness of the test piece, which is often determined by the local thickness and the mass of the test piece, shall be considered when selecting the impact device to be employed (see Table 2).

NOTE 1 Failure to provide adequate support will produce incorrect test results.

NOTE 2 Test pieces of mass less than the minimum indicated mass or pieces of sufficient mass with sections less than the minimum thickness require rigid support and/or coupling to a solid supporting body. Coupling refers to a method where the test piece is firmly connected to a much heavier support without straining or stressing the test piece. For example, an adhesive film can be applied between the test piece surface and the heavy support. This combination presents a larger combined mass to resist the impinging impact body. The coupling method can be used after comparison of the results with an uncoupled reference test piece of sufficient mass and thickness.

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Table 2 — Mass and thickness requirements of test piece

Type of impact devices	Minimum mass (no rigid support) kg	Minimum mass (rigid support) kg	Minimum thickness (uncoupled) mm	Minimum thickness (coupled) mm
D, DL, D+15, S, E	5	2	25	3
G	15	5	70	10
C	1,5	0,5	10	1

NOTE 3 Special geometries of the test piece, e.g. thin slabs or tube surfaces, can require additional support of the test location to also permit testing where the thickness of the test piece can be smaller than the minimum thickness given in Table 2. For example on tubes, the support requirement can be expressed in terms of the ratio of the tube diameter, *D,* to its wall thickness, *s,* (see References [2] to [4]), which is a measure of the sample stiffness. If no support can be applied, correction factors to the measured values can be determined in dependence of *D/s* (see Reference [4]).

6.3 Surface preparation

The test surface shall be carefully prepared to avoid any alterations in hardness caused by heating during grinding or by work hardening during machining. It is recommended that the test surface be machined and polished to the surface finish as defined in Table 3. Any coatings, scale, contaminants, or other surface irregularities shall be completely removed. The surface shall be free from lubricants. The surface locations to be tested should not exceed the arithmetical mean roughness values, R_a, (also "centre line average") (see Reference [5]) given in Table 3 for each impact device (see References [2] or [4]).

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Table 3 — Recommended surface finish R_a

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Type of impact device	Maximum arithmetical mean surface roughness R_a µm
D, DL, D+15, S, E	2,0
G	7,0
C	0,4

7 Procedure

7.1 The daily verification defined in Annex B shall be performed before the first test of each day for each scale used.

7.2 In general, the test should be carried out at ambient temperature within the limits of 10 °C to 35 °C. However, because temperature variation can affect the results, users of the Leeb test can choose to control the temperature within a tighter range, such as 23 °C ± 5 °C.

NOTE The temperature of the test material and the temperature of the hardness testing instrument can affect the test results. The test temperature can adversely affect the hardness measurement.

7.3 Magnetic fields at the test location can affect the results of Leeb tests and must be avoided. Leeb hardness tests can be found particularly susceptible to ambient electromagnetic fields in the frequency range of a few kHz.

7.4 The test piece and impact device shall not be moved during a test. The supporting surface shall be clean and free from contaminants (scale, lubricants, dirt, etc.).

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7.5 Vibration and relative motion of the test piece or the impact device during a Leeb test can affect the test result and must be avoided.

7.6 An impact is best carried out when the distance between the centre of an indentation and the edge of the test piece permits placement of the entire support ring on the test piece. In no case shall the distance between impact point and edge of the test piece be less than 10 mm for impact device G, and 5 mm for impact devices D, DL, D+15, C, S, and E.

7.7 The distance between any two adjacent indentations centre-to-centre shall be at least three times the diameter of the indentation. Table 4 gives the typical indentation diameters at various hardness levels for the different types of impact devices.

NOTE As a practical estimation, this requirement will be met if the edge-to-edge distance between any two adjacent indentations is at least two times the diameter of the larger indentation.

Table 4 — Examples of typical indentation sizes on steel of various hardness

Type of impact devices	Approximate diameters		
	low hardness	mid hardness	high hardness
D	0,54 mm at ~ 570 HLD	0,45 mm at ~ 760 HLD	0,35 mm at ~ 840 HLD
DL	0,54 mm at ~ 760 HLDL	0,45 mm at ~ 880 HLDL	0,35 mm at ~ 925 HLDL
D+15	0,54 mm at ~ 585 HLD+15	0,45 mm at ~ 765 HLD+15	0,35 mm at ~ 845 HLD+15
S	0,54 mm at ~ 610 HLS	0,45 mm at ~ 800 HLS	0,35 mm at ~ 875 HLS
E	0,54 mm at ~ 540 HLE	0,45 mm at ~ 725 HLE	0,35 mm at ~ 805 HLE
G	1,03 mm at ~ 535 HLG	0,9 mm at ~ 710 HLG	—[a]
C	0,38 mm at ~ 635 HLC	0,32 mm at ~ 820 HLC	0,3 mm at ~ 900 HLC

[a] Out of typical application range.

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7.8 The impact device shall be held perpendicular to the surface of the test piece.

Prior to a test, the correct instrument set-up and settings in accordance with the manufacturer instructions shall be verified. Any deviations exceeding 5° from the direction of gravity entail measurement errors. For impact directions not in the direction of gravity, the test values shall be adjusted (see 4.2 and Annex A).

7.9 In its loaded state, the impact device shall be snugly placed on the prepared test surface, and the impact triggered. Impact and rebound velocity are determined by the measuring and indicating unit and a Leeb hardness number HL be generated.

7.10 To determine the Leeb hardness, the arithmetic mean value from at least three readings shall be calculated. If the span of three readings exceeds 5 % of the arithmetic mean value, then additional measurements shall be made to provide an average of at least 10 readings.

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8 Uncertainty of the results

The uncertainty of the results depends on the various sources of uncertainty. These can be divided into two categories:

— sources dependent on the Leeb hardness testing instrument (including the measurement uncertainty from the direct calibration of the instrument) as well as the calibration of the reference test block;

— sources dependent on the test method and varying testing conditions.

The permissible error of the testing instrument from ISO 16859-2:2015, Table 3 can be used to estimate the expanded measurement uncertainty.

NOTE 1 A thorough evaluation of the uncertainty of measurement can be performed following Reference [6].

NOTE 2 Sometimes it is not possible to quantify each aspect contributing to the uncertainty of measurement. However, an estimate of the uncertainty of measurement can be derived from the statistical analysis of multiple measurements on the test piece.

An example for the estimation of the uncertainty of Leeb hardness measurements is given in Annex C.

9 Test report

At minimum, the test report shall contain the following information:

a) a reference to this part of ISO 16859, i.e. ISO 16859-1;

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b) the essential details to identify the test piece;

c) specification of the testing instrument (type of impact device);

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d) measurement result and number of underlying single readings;

e) any significant details of the test that are not determined by this part of ISO 16859 or that have been applied by reasoning, e.g. way of coupling, test location on the test piece, impact direction with reference to gravity;

f) any events or peculiarities that could have had an impact on the measurement;

g) test temperature if it is not within the limits of 10 °C to 35 °C.

10 Conversions to other hardness scales or tensile strength values

There is no general process for accurately converting Leeb hardness into other Leeb hardness scales or non-Leeb hardness scales, respectively, or Leeb hardness into tensile strength. Such conversions, therefore, should be avoided, unless a reliable basis for conversion can be obtained by comparison tests.

If it is necessary to check a given Leeb hardness value against a value gained by a different test method, conversion from one hardness value to another or from a hardness value to a tensile strength value can be obtained through a reliable basis of data from comparison tests. Conversions involve uncertainties which must be taken into account. This situation is described in ISO 18265 (see Reference [7]).

ASTM-International E140 (see Reference [8]) includes conversions from Leeb hardness to other hardness scales for a group of steels. There is also a study of the relationship between Leeb hardness and Vickers hardness (see Reference [9]).

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Annex A
(normative)

Tables of correction factors for use in tests not conducted in direction of gravity

Tables A.1 to A.7 (see Reference [10]) give the correction values when tests are not made in direction of gravity. The correction values are tabulated in terms of the angle θ. The correction depends on cos θ, where θ is the angle between the impact direction and the direction of gravity, and the measured hardness value.

NOTE For any given angles not shown in the table, the user can interpolate to obtain the correction value.

EXAMPLE Impact direction upwards, at an angle of θ = 135° to the direction of gravity.

Impact device, type D

Measurement value, 725 HLD

Correction value (from Table A.1), −12 HLD

Hardness of test piece = 725 HLD − 12 HLD = 713 HLD

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Table A.1 — Impact direction corrections, impact device type D

Measured hardness HLD	**Correction** HLD			
	Impact direction θ = 45°	**Impact direction** θ = 90°	**Impact direction** θ = 135°	**Impact direction** θ = 180°
300 ≤ HLD < 350	−6	−12	−20	−29
350 ≤ HLD < 400	−6	−12	−19	−27
400 ≤ HLD < 450	−5	−11	−18	−25
450 ≤ HLD < 500	−5	−10	−17	−24
500 ≤ HLD < 550	−5	−10	−16	−22
550 ≤ HLD < 600	−4	−9	−15	−20
600 ≤ HLD < 650	−4	−8	−14	−19
650 ≤ HLD < 700	−4	−8	−13	−18
700 ≤ HLD < 750	−3	−7	−12	−17
750 ≤ HLD < 800	−3	−6	−11	−16
800 ≤ HLD < 850	−3	−6	−10	−15
850 ≤ HLD < 890	−2	−5	−9	−14

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