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Metallic materials — Knoop hardness test —

Part 1: Test method

Matériaux métalliques — Essai de dureté Knoop —

Partie 1: Méthode d'essai

Reference number
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Contents

Page

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

This second edition cancels and replaces the first edition (ISO 4545-1:2005), which has been technically revised.

The main changes compared to the previous edition are as follows:

— all references have been removed of indentation diagonals <0,020 mm;

— the resolution requirements have been defined for the measuring system;

— the lower test force limit of the Knoop hardness test has been expanded to 0,009 807 N;

— the requirements for the periodic (weekly or daily) verifications of the testing machine have been defined as normative, the maximum permissible bias value has been revised, and the requirements for the maximum permissible error in measuring a reference indentation have been revised;

— the recommendations for inspection and monitoring of the indenter have been added (moved from ISO 4545-2);

— the requirements have been revised for the approach velocity of the indenter prior to contact with the sample surface;

— the timing requirements for the test force application and the duration at maximum test force are revised to indicate target time values;

— Figure 3 has been added illustrating the requirements for the minimum distance between indentations; the distances have been stated with respect to the indentation centres rather than the indentation limits, but the requirements have not changed;

— the requirements have been added to the test report for reporting the test date and any hardness conversion method used;

— Annexes C, D and E have been added concerning Knoop hardness measurement traceability, the CCM — Working group on hardness and adjustment of Köhler illumination systems, respectively.

A list of all parts in the ISO 4545 series can be found on the ISO website.

Metallic materials — Knoop hardness test —

Part 1:
Test method

1 Scope

This document specifies the Knoop hardness test method for metallic materials for test forces from 0,009 807 N to 19,613 N.

The Knoop hardness test is specified in this document for lengths of indentation diagonals ≥0,020 mm. Using this method to determine Knoop hardness from smaller indentations is outside the scope of this document as results would suffer from large uncertainties due to the limitations of optical measurement and imperfections in tip geometry. ISO 14577-1 allows the determination of hardness from smaller indentations.

A periodic verification method is specified for routine checking of the testing machine in service by the user.

Special considerations for Knoop testing of metallic coatings can be found in ISO 4516.

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 4545-2, *Metallic materials — Knoop hardness test — Part 2: Verification and calibration of testing machines*

ISO 4545-3, *Metallic materials — Knoop hardness test — Part 3: Calibration of reference blocks*

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:

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

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

4 Principle

A diamond indenter, in the form of a rhombic-based pyramid with angles, α and β, between opposite edges respectively equal to 172,5° and 130° at the vertex, is forced into the surface of a test piece followed by measurement of the long diagonal, d, of the indentation remaining in the surface after removal of the test force, F (see Figures 1 and 2).

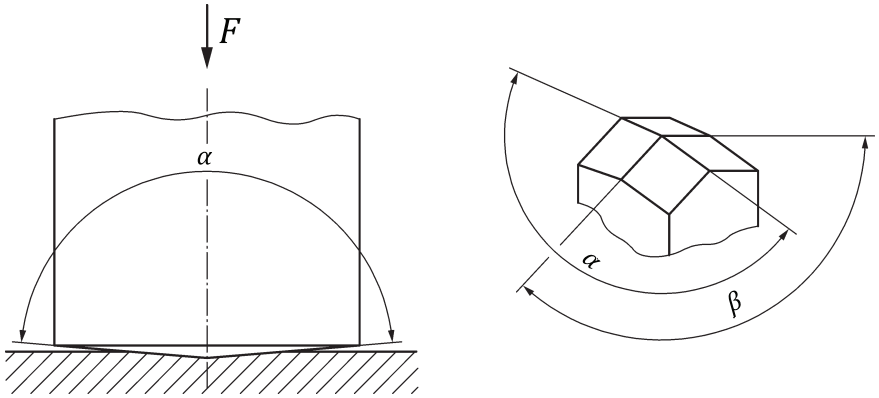

Figure 1 — Principle of the test and indenter geometry

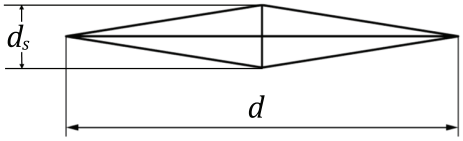

Figure 2 — Knoop indentation

The Knoop hardness is proportional to the quotient obtained by dividing the test force by the projected area of the indentation, which is assumed to be a rhombic-based pyramid, and having at the vertex the same angles as the indenter.

NOTE As applicable, this test document has adopted hardness test parameters as defined by the working group on hardness (CCM-WGH) under the framework of the International Committee of Weights and Measures (CIPM) Consultative Committee for Mass and Related Quantities (CCM) (see Annex D).

5 Symbols and designations

5.1 Symbols and designations used in this document

See Table 1 and Figures 1 and 2.

Table 1 — Symbols and designations

Symbol	Designation
F	Test force, in newtons (N)
d	Length of the long diagonal, in millimetres
d_S	Length of the short diagonal, in millimetres
α	Angle between the opposite edges of the long diagonal at the vertex of the diamond pyramid indenter (nominally 172,5°) (see Figure 1)
β	Angle between the opposite edges of the short diagonal at the vertex of the diamond pyramid (nominally 130°) (see Figure 1)
NOTE Standard acceleration due to gravity, g_n = 9,806 65 m/s^2, which is the conversion factor from kgf to N. To reduce uncertainty, the Knoop hardness can be calculated using the actual indenter angles α and β.	

Table 1 *(continued)*

Symbol	Designation
V	Magnification of the measuring system
c	Indenter constant, relating projected area of the indentation to the square of the length of the long diagonal Indenter constant, $c = \dfrac{\tan\frac{\beta}{2}}{2\tan\frac{\alpha}{2}}$, for nominal angles α and β, c is approximately 0,070 28
HK	Knoop hardness $= \dfrac{\text{Test force (kgf)}}{\text{Projected area of indentation (mm}^2\text{)}}$ $= \dfrac{1}{g_n} \times \dfrac{\text{Test force (N)}}{\text{Projected area of indentation (mm}^2\text{)}}$ $= \dfrac{1}{g_n} \times \dfrac{F}{cd^2}$ For the nominal indenter constant $c \approx 0{,}070\ 28$, Knoop hardness $\approx 1{,}451 \times \dfrac{F}{d^2}$
NOTE Standard acceleration due to gravity, $g_n = 9{,}806\ 65\ \text{m/s}^2$, which is the conversion factor from kgf to N. To reduce uncertainty, the Knoop hardness can be calculated using the actual indenter angles α and β.	

5.2 Designation of hardness number

Knoop hardness, HK, is designated as shown in the following example.

640 HK 0,1 /20

- /20 — Duration of test force (20 s) if not within the specified range (10 s to 15 s)
- 0,1 — Approximate kgf equivalent value of applied test force where (0,1 kgf = 0,980 7 N)
- HK — Hardness symbol
- 640 — Knoop hardness value

6 Testing machine

6.1 Testing machine

The testing machine shall be capable of applying a predetermined force or forces within the desired range of test forces, in accordance with ISO 4545-2.

6.2 Indenter

The indenter shall be a diamond in the shape of a rhombic-based pyramid, as specified in ISO 4545-2.

6.3 Diagonal measuring system

The diagonal measuring system shall satisfy the requirements in ISO 4545-2.

Magnifications should be provided so that the diagonal can be enlarged to greater than 25 % but less than 75 % of the maximum possible optical field of view. Many objective lenses are non-linear towards the edge of the field of view.

NOTE A diagonal measuring system using a camera for measurement can use 100 % of the camera's field of view, provided it is designed to consider field of view limitations of the optical system.

The resolution required of the diagonal measuring system depends on the size of the smallest indentation to be measured, and shall be in accordance with Table 2. In determining the resolution of the measuring system, the resolution of the microscope optics, the digital resolution of the measuring scale and the step-size of any stage movement, where applicable, should be taken into account.

Table 2 — Resolution of the measuring system

Diagonal length *d* mm	**Resolution of the measuring system**
$0,020 \le d < 0,080$	0,000 4 mm
$0,080 \le d$	0,5 % of *d*

7 Test piece

7.1 Test Surface

The test shall be carried out on a polished surface, which is smooth and even, free from oxide scale and foreign matter and, in particular, free from lubricants, unless otherwise specified in product standards. The finish of the surface shall permit accurate determination of the diagonal length of the indentation.

7.2 Preparation

Surface preparation shall be carried out in such a way as to prevent surface damage, or alteration of the surface hardness due to excessive heating or cold-working.

Due to the small depth of Knoop hardness indentations, it is essential that special precautions be taken during preparation. It is recommended to use a polishing/electropolishing technique that is adapted to the material to be measured.

7.3 Thickness

The thickness of the test piece, or of the layer under test, shall be at least 1/3 times the length of the diagonal length of the indentation. No deformation shall be visible at the back of the test piece after the test.

NOTE The depth of the indentation is approximately 1/30 of the diagonal length (0,033 *d*).

7.4 Support of unstable test pieces

For a test piece of small cross-section or of irregular shape, either a dedicated support should be used or it should be mounted in a similar manner to a metallographic micro-section in appropriate material so that it is adequately supported and does not move during the force application.

8 Procedure

8.1 Test temperature

The test is normally carried out at ambient temperature within the limits of 10 °C to 35 °C. If the test is carried out at a temperature outside this range, it shall be noted in the test report. Tests carried out under controlled conditions shall be made at a temperature of (23 ± 5) °C.

8.2 Test force

The test forces given in Table 3 are typical. Other test forces may be used. Test forces shall be chosen that result in indentations with a long diagonal greater than 0,020 mm.

Table 3 — Typical test forces

Hardness scale	Test force value, F	
	N	Approximate kgf[a] equivalent
HK 0,001	0,009 807	0,001
HK 0,002	0,019 61	0,002
HK 0,005	0,049 03	0,005
HK 0,01	0,098 07	0,010
HK 0,02	0,196 1	0,020
HK 0,025	0,245 2	0,025
HK 0,05	0,490 3	0,050
HK 0,1	0,980 7	0,100
HK 0,2	1,961	0,200
HK 0,3	2,942	0,300
HK 0,5	4,903	0,500
HK 1	9,807	1,000
HK 2	19,613	2,000

[a] Not an SI unit.

8.3 Periodic verification

The periodic verification defined in Annex A shall be performed within a week prior to use for each test force used but is recommended on the day of use. The periodic verification is recommended whenever the test force is changed. The periodic verification shall be done whenever the indenter is changed.

8.4 Test piece support

The test piece shall be placed on a rigid support. The support surfaces shall be clean and free from foreign matter (scales, oil, dirt, etc.). It is important that the test piece lies firmly on the support so that any displacement that affects the test result cannot occur during the test.

8.5 Focus on test surface

The diagonal measuring system microscope shall be focused so that the specimen surface and the desired test location can be observed.

NOTE Some testing machines do not require that the microscope be focused on the specimen surface.

8.6 Test force application

The indenter shall be brought into contact with the test surface and the test force shall be applied in a direction perpendicular to the surface, without shock, vibration or overload, until the applied force attains the specified value. The time from the initial application of the force until the full test force is reached shall be 7^{+1}_{-5} s.

NOTE 1 The requirements for the time durations are given with asymmetric limits. For example, 7^{+1}_{-5} s indicates that 7 s is the nominal time duration, with an acceptable range of not less than 2 s (calculated as 7 s – 5 s) to not more than 8 s (calculated as 7 s + 1 s).

The indenter shall contact the test piece at a velocity of ≤0,070 mm/s.

The duration of the test force shall be 14^{+1}_{-4} s, except for tests on materials whose time-dependent properties would make this an unsuitable range. For these tests, this duration shall be specified as part of the hardness designation (see 5.2).

NOTE 2 There is evidence that some materials are sensitive to the rate of straining which causes changes in the value of the yield strength. The corresponding effect on the termination of the formation of an indentation can make alterations in the hardness value.

8.7 Prevention of the effect of shock or vibration

Throughout the test, the testing machine shall be protected from shock or vibration[6].

8.8 Minimum distance between adjacent indentations

The minimum distance between adjacent indentations and the minimum distance between an indentation and the edge of the test piece are shown in Figure 3.

The minimum distance between the edge of the test piece and the centre of any indentation oriented parallel to the edge of the test piece shall be at least 3,5 times the length of the short diagonal of the indentation. The minimum distance between the edge of the test piece and the centre of any indentation oriented perpendicular to the edge of the test piece shall be at least equal to the length of the long diagonal of the indentation.

The minimum distance between the centres of two adjacent indentations, oriented side-by-side, shall be at least 3,5 times the length of the short diagonal. For indentations oriented end-to-end, the minimum distance between the centres of two adjacent indents shall be at least twice the length of the long diagonal. If two indentations differ in size, the minimum spacing shall be based on the diagonal of the larger indentation.

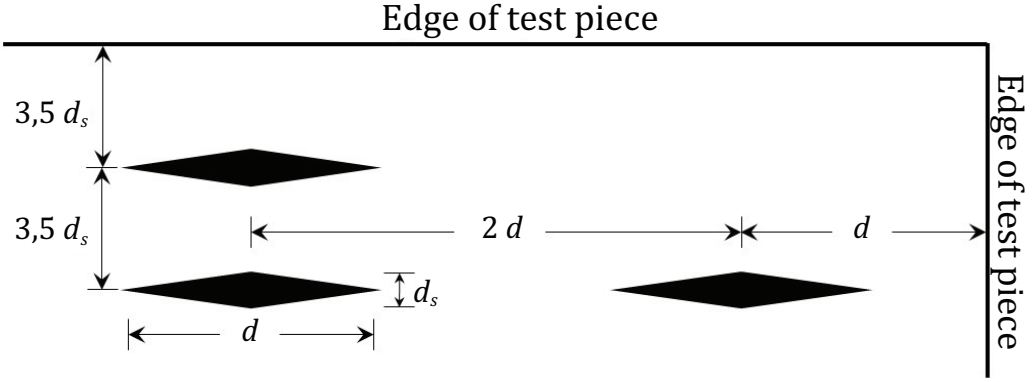

Figure 3 — Minimum distance for Knoop indentations