

RESULTS OF THE REVISION OF THE ISO STANDARDS FOR BRINELL, VICKERS, ROCKWELL AND KNOOP HARDNESS TESTS

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Abstract: With the aim to achieve worldwide valid ISO-Standards the International standards committee ISO/TC 164/SC 3 "Hardness testing of metallic materials" published in 1997-1999 the hardness testing standards for the Brinell, Vickers and Rockwell methods according to the parallel voting in CEN. This contribution contains the results of the first revision of these standards carried out in 2004/2005 and presents for the users the most important amendments.

Keywords: Hardness, ISO-Standards, Revision, Results.

1. INTRODUCTION

The methods for hardness testing are the most frequently used methods to determine in a relatively easy way a material parameter characterizing the mechanical properties. In order to be able to work with comparable measurement results, standardization already started in the thirties of the past century at the different levels (see Table 1).

National, European and ISO standards partly contain different specifications. Meanwhile it is generally accepted to strive for a complete alignment of hardness standards at all standardization levels. With the application of parallel voting within ISO and CEN according to the Vienna Agreement double work will be avoided.

With this target in mind the department of Materials Testing of DIN took over the secretariat of the responsible ISO-Committee ISO/TC 164/SC 3 "Hardness testing of metallic materials" in 1994, aiming to achieve the identity of world-wide ISO-Standards with European and other national standards [1,2]. Another purpose of standardization work is to decrease the uncertainty of test methods [3,4,5].

Hardness testing, in general mechanical testing is carried out on materials for three different reasons:

- For quality control purposes to ensure that a material conforms to a technical specification or that it has been correctly processed.
- To provide information which can be used in the design of a component or structure.
- As part of investigations into the reasons for failures in service.

Hence the results achieved from the mechanical testing of products that are made of/or from materials are used to help guarantee the safety and reliability of materials which in turn ensures the safety of those products.

An actual overview about the existing ISO hardness testing standards is given in Table 2.

2. RESULTS OF THE REVISION OF THE ISO HARDNESS TESTING STANDARDS

2.1 General amendments for all parts of the standards

- **For all Parts 1:**

- uniform presentation of the hardness designation, see Fig.1.
- Clause 8 "measurement uncertainty" has been changed .
- New annex for the periodic inspection of the testing machine by the user.
- New annex for the estimation of measurement uncertainty of the measured hardness values.

- **For all Parts 2:**

- the clause which refers to the intervals between the direct verifications is now clearly revised as a table, see Table 3.
- Editorial revision of the subclauses 5.6 "Repeatability" and 5.7 "Error".
- New annex for the estimation of measurement uncertainty of the calibration results of hardness testing machines

- **For all Parts 3:**

- New note in clause 6 "number of indentations" which allows to apply more than 5 indentations due to minimize the measurement uncertainty .
- Editorial revision of clause 7 "uniformity".
- New annex for the estimation of the measurement uncertainty of the hardness reference blocks.

2.2 Specific amendments to the Brinell method

- **Part 1**

- Since 1999 the only use of the carbide ball as a indenter is specified. Attention is drawn to different results determined with different ball materials. Fig.2 contains empirical determined relation of the difference HBW- HBS depending on the hardness of the tests pieces for unalloyed and low alloyed steels.
- new note in 7.2 for the possibility of using other test forces and force-diameter ratio than specified in the standard.

-tables for the calculation of the Brinell hardness values are now a new part 4 of this standard.

- **Part 2**

-new note in 4.4 for the calibration of the measurement system for portable hardness testing machines.

-new subclause 5.4 for the use of a reference indentation on hardness reference block for the indirect verification of testing machines.

- **Part 3**

-amendment in 8.3 about an information about the location of the reference indentation.

2.3 Specific amendments to the Vickers method

- **Part 1**

-New note in 7.2 for the possibility of using other test forces than specified in table 3 of the standard.

-New note in 7.7 for the choice of magnification of the indentation diagonal with respect to the field of view (25%-75%).

-The tables for the calculation of the Vickers hardness are now a new part 4 of this standard.

- **Part 2**

-New note in 4.4 for the calibration of the measurement device for portable hardness testing machines.

-New subclause 5.5 for the use of a reference indentation on the hardness reference block for the indirect verification of testing machines.

- **Part 3**

Amendment in 8.3 about an information about the location of the reference indentation.

2.4 Specific amendments to the Rockwell method

- **Part 1**

Expansion of the field of application, see footnotes a, b and c in table 1 of the standard.

a The application range of the HRA-Scale can be expanded up to 88 HRA for testing of carbide.

b The application range of the HRB-Scale can be expanded up to 10 HRBW when it is defined in a product specification or separately agreed.

c The application range of the HRC-Scale can be expanded up to 10 HRC when the indenter has the necessary dimensions.

-Permission of ball diameters 6,350 mm and 12,70 mm if it is required in a product specification or separately agreed.

-The HRC-indenter which is common in trade has a machined conical surface with a length of 400µm. For realisation of the test condition 10 HRC according to the standard the machined length must be at least 500 µm, see Fig.3 and 4.

-The use of carbide ball is defined as a standard-indenter. Steel balls are only allowed to be used when it is defined in a product specification or separately agreed. One has to take notice that the hardness values which were determined with different ball materials can be different, see Fig.5.

-Amendment in 6.1, that a grease is allowed when testing reactive metals, such as titanium.

-Amendment of the possibility in 7.3 to reduce the testing temperature range for special application.

-New note in 7.3

NOTE The times for the application of the test force T_a and the duration of the preliminary test force T_{pm} for testing machines with an electronic controller can be calculated with the following equation:

$$T_p = T_a / 2 + T_{pm} \leq 3s$$

whereas

T_p whole duration time of the test force

T_a application time of the test force

T_{pm} duration time of preliminary test force

-New note in 7.4, which allows it to reduce the time period from F_0 to F

Note: It is the common practice that the time from F_0 to F is between 2s and 3s for a test of about 60 HRC. For the Rockwell scales N and T is a time between 1s and 1,5s for a test of around 78 HR 30 N suggested.

-Amendment of the scale HR 15 Tm in annex A.

- **Part 2**

-New note in 4.4 for the calibration of the measuring device
Note: If it is not possible to verify the depth-measuring system directly, its performance can be derived from the results of an indirect verification, using reference blocks and a certified indenter, and making corrections for known errors.

- **Part 3**

New note in 5.3 with the advice for the calculation of different times of the testing cycle for testing machines with an electronic adjustment setting (see part 1)

3. INFORMATION ABOUT THE INSTRUMENTED INDENTATION TEST

According to the mutual agreement between the users of this test method and the testing machine producers the standardization work for this new test method was started in 1988. The essential steps are in given in Table 4.

In October 2003 the International Standard ISO 14577 "Metallic materials - Instrumented indentation test for Hardness and other materials parameters" was published. It consists of the following three parts:

- Part 1: Test method

- Part 2: Verification and calibration of the testing machine

- Part 3: Calibration of reference test pieces.

The new International Standard ISO 14577 has been prepared to enable the user to evaluate the indentation response of material with the maximum reproducibility between different laboratories using different equipments. By monitoring and recording the complete cycle of application and removal of the test force, selected hardness values can be determined as well as additional properties of the material, such as indentation modulus, creep, relaxation, elastic and plastic indentation work. Moreover, as this standard mainly describes the procedure and requirements of the indentation test, it is open for definition and calculation

of additional parameters suitable for the tested material. A detailed explanation is given in [6] and [7].

A raising further requirement was to standardize a test method specific for testing of thin metallic and non-metallic coatings including the nano-range. The relating ISO-Draft-Standard was published as ISO/DIS 14577-4 in 2005-08. The Final-Draft-Standard is expected for the middle of 2006.

REFERENCES

- [1] A. Wehrstedt: "Situation of Standardization in the field of hardness testing of metals", Proceedings of International Symposium on Advances in Hardness measurement, IMEKO, Standards Press of China 1998
- [2] A. Wehrstedt, "Situation of standardization in the field of mechanical testing and measurement", VDI Berichte 1685, Joint International Conference IMEKO 2002, Celle, S. 209-220, ISBN 3-18-091685-0
- [3] A. Wehrstedt, I. Patkovszky, "News in the field of standardization about verification and calibration of materials testing machines", Proceedings of the EUROLAB international SS workshop at EMPA Dübendorf, S. 7 – 18, Switzerland 17/18 May 2001, printed by EMPA
- [4] K. Herrmann, "Fortschritte bei der Bestimmung der Unsicherheit von Härtemessungen", Tagungsband der Tagung „Werkstoffprüfung 2004“, DGM, Neu-Ulm, Tagungsband, WILEY-VCH Verlag Weinheim
- [5] Th. Polzin, "Aktueller Stand der praktischen Anwendung der Bestimmung der Messunsicherheit bei der Härteprüfung", Tagungsband der Tagung „Werkstoffprüfung 2004“, DGM, Neu-Ulm, WILEY-VCH Verlag Weinheim
- [6] Ch. Ullner, A. Wehrstedt, Martenshärte, Eindringhärte oder Eindringmodul ermitteln – Instrumentierte Eindringprüfung nach ISO/DIS 14577, Härtereitechnische Mitteilungen, 56, S. 242 bis 248 (4/2001) Carl Hanser Verlag, München ISSN 0341-101X
- [7] A. Wehrstedt, Ch. Ullner, Erfolgreicher Abschluss der Normungsarbeit "Instrumentierte Eindringprüfung" – ISO 14577 ist veröffentlicht, DIN-Mitt. 81. 2002, Nr. 10, S. 684-689, Beuth-Verlag, ISSN 0722-2912
- [8] H. R. Wilde, A. Wehrstedt, Martens Hardness HM – An international accepted designation for "Hardness under test force", DIN-Mitteilungen 79. 2000 Nr. 11, S. 810-812. Also in English in: Z. Materialprüfung 42 (2000)11-12, S.468-470, Carl Hanser Verlag München ISSN 0025-5300; and Z. Materialwissenschaft und Werkstofftechnik 31 (2000) S. 937-940, WILEY-VCH Verlag Weinheim ISSN 0933-5137

Table 1. First publications of hardness testing standards in different countries

Method	Germany	UK	USA	France	ISO	Europe
Brinell (1900)	1942	1937	1927	1946	1981	1955
Vickers (1920)	1940	1931	1950	1946	1982	1955
Rockwell (1920)	1942	1940	1942/43	1946	1986	1955
Knoop (1939)			1946		1993	

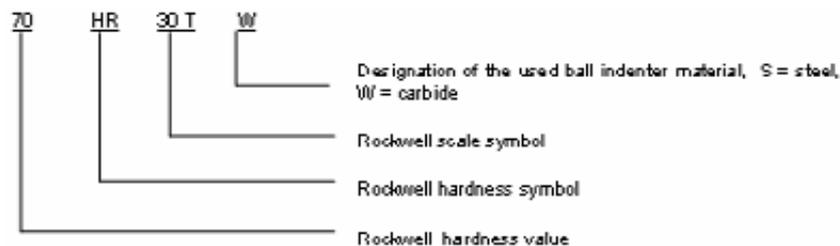


Fig.1 Uniform presentation of the hardness designation

Table 2. Overview about the ISO standards for hardness testing of metallic materials

Method	First		Title	Current		Current working stage
	Stand. N°	edition		Stand.N°	edition	
Brinell	6506	1981	Test method (TM)	6506-1	ISO 2005-12	Revision finished 2005
	156	1982	Testing machines (TMa)	6506-2		
	726	1982	Reference blocks (RB)	6506-3		
	410	1982	Tables	6506-4		
Vickers	6507-1	1982	TM HV 5 to 100	6507-1	ISO 2005-12	Revision finished 2005
	6507-2	1983	TM HV 0,2 to < 5			
	6507-3	1989	TM HV 0,2			
	146	1989	TMa < HV 0,2 to	6507-2		
	146-2	1993	100 < HV 0,2			
	640	1984	RB HV 0,2 to 100	6507-3		
	640-2	1993	RB < HV 0,2			
409-1	1992	Table HV 5 to 100	6507-4			
409-2	1983	Table HV 0,2 to < 0,5				
409-3		Table HV < 0,2				
Rockwell	6508	1986	TM scales A-K	6508-1	ISO 2005-12	Revision finished 2005
	1024	1989	TM scales N/T			
	716	1986	TMa scales A-K	6508-2		
	1079	1989	TMa scales N/T			
674	1988	RB scales A-K	6508-3			
1355	1989	RB scales N/T				
Knoop	4545	1993	TM	4545-1	ISO 2005-12	Revision finished 2005
	4546	1993	TMa	4545-2		
	4547	1993	RB	4545-3		
	10250	1993	Tables	4545-4		
Instrumented indentation test (IIT) (former designation: Universal hardness)	TR	1995	TM	14577-1	ISO 2002-10	
	14577		TMa	14577-2		
			RB	14577-3		
			Test method for thin coatings	14577-4	ISO/FDIS 2006	
			Indentation tensile properties	14577-5		Technical Report in Preparation
	18265	2003	Hardness conversion	18265	2003-07	

Table 3. Requirement for direct verifications of hardness testing machines

Requirments of verification	Force	Measuring system	Test cycle	Indenter
before setting to work first time	X	X	X	X
after dismantling and reassembling, if force, measuring system or test cycle are affected	X	X	X	
failure of indirect verification	X	X	X	
indirect verification >14 months ago	X	X	X	
a In addition it is recommended that the indenter be directly verified after 2 years of use. b Direct verification of these parameters may be carried out sequentially (until the machine passes indirect verification) and is not required if it can be demonstrated (e.g. by tests with a calibrated indenter) that the indenter was the cause of the failure.				

Table 4. Chronology of the standardization work for ISO 14577

1988	First proposal for a draft "Universal-Hardness" in the German standards committee (Initiator R. Meyer)
1990	Proposal for an ISO-New Work Item "Universal-Hardness" in ISO/TC 164/SC 3 (Initiator W. Weiler)
1992	Decision of ISO/TC 164/SC 3 for the publication of a Technical Report (TR) "Universal-Hadness"
1994	Installation of the ad-hoc-group "Universal-Hardness" in the German standards committee
1995	Publication of ISO/TR 14577 "Universal hardness" by ISO/TC 164/SC 3
1997	— Resolution in ISO/TC 164/SC 3 for the transformation of ISO/TR 14577 into an International Standard based on DIN 50359, but not only for Universal-Hardness, as well general for the determination of the force-indentation depth-curve, for the derivation of other materials parameters. — Installation of an international working group ISO/TC 164/SC 3/WG 1 "Instrumented indentation testing" under the convenor K.-H. Behncke and with participation of experts of : ISO/TC 107/SC 2/WG 1 "Microhardness" und CEN/TC 184/WG 5 "Testing of ceramic coatings"
1999-03	Publication of ISO/CD 14577-1, -2, -3
2000-04	Publication of ISO/DIS 14577-1, -2, -3
2000-06	Resolution in ISO/TC 164/SC 3 for the change of the designation "Universal-Hardness" into "Martens-Hardness" [8];
2001-06	Publication of a second DIS
2002-10	Publication of ISO 14577 -1, -2, -3
2002-12	First proposal for a part 4 of ISO 14577 prepared by the international working group ISO/TC 164/SC 3/WG "Instrumented indentation testing for coatings" under the convenor N. Jennett

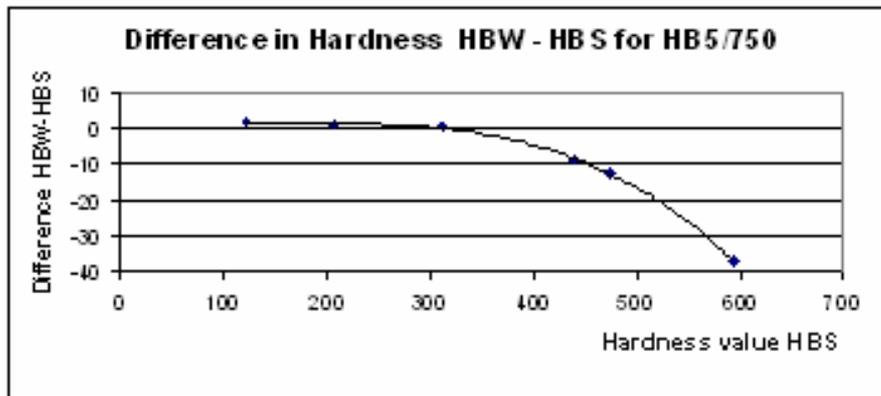


Fig 2. Empirical determined relation of the difference HBW- HBS depending on the hardness of the tests pieces for unalloyed and low alloyed steels

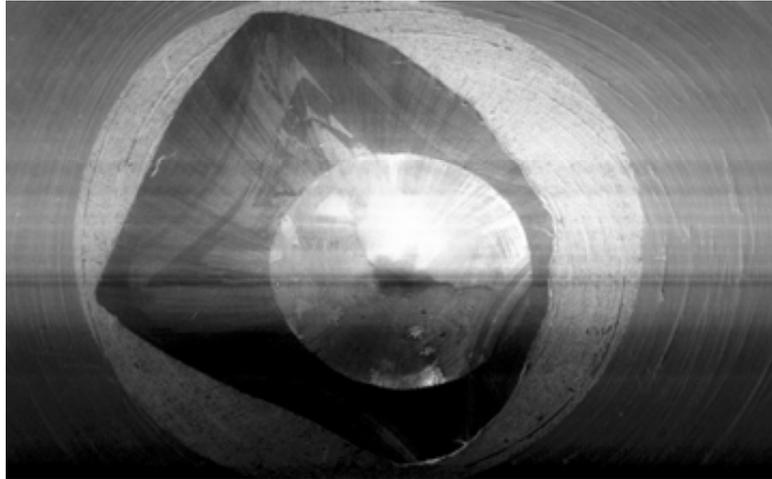


Fig. 3 Machined conical surface of a Rockwell-diamond-indenter

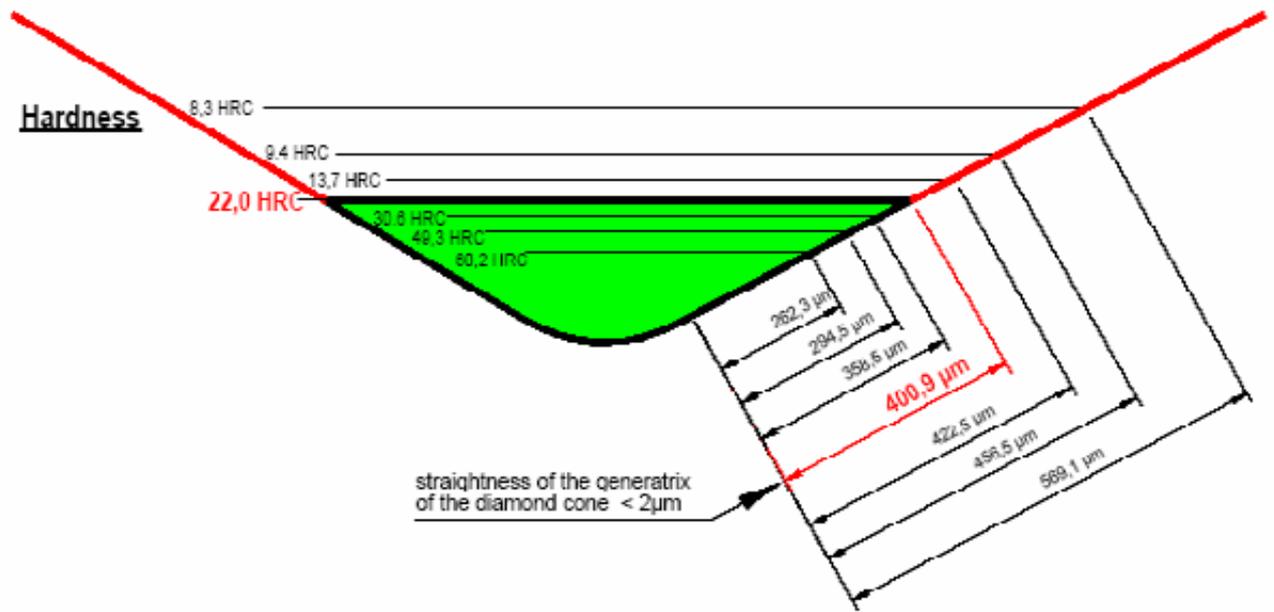


Fig. 4 Necessary machined conical surface of a Rockwell-diamond-indenter in dependence of the penetration

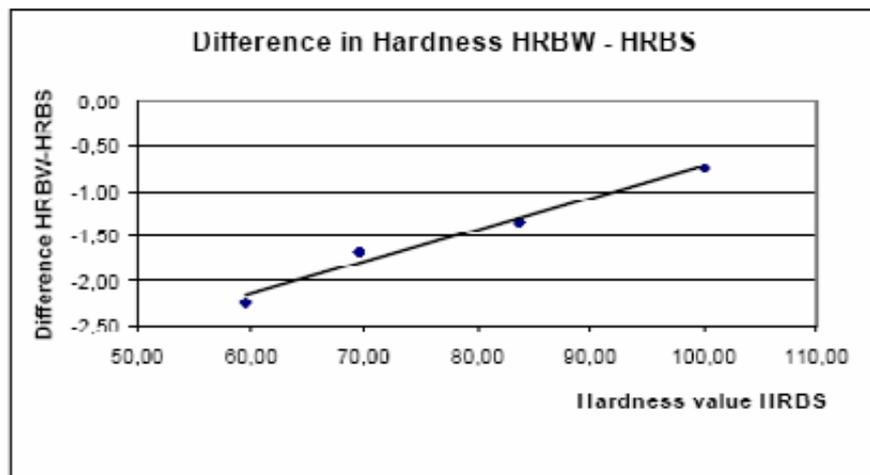


Fig. 5 Empirical determined relation of the difference HRBW-HRBS in dependence of the hardness values concerning unalloyed and low alloyed steels