World-wide Unified Scales for the Rockwell Hardness Test with Conical Indenters

Possibilities to achieve a world wide scale

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Abstract

The aim of this round robin test was to discover what needs to be done to achieve the world-wide unification of Rockwell hardness scales using diamond indenters (HRC, HRA, HRD, HR15N, HR30N and HR45N) [1] - [5]. These scales are the most commonly used and their unification is of high industrial importance. The current degree of unification at an international level was assessed by conducting a round robin test. Seventy four specially developed hardness test blocks were all calibrated by twelve laboratories in eleven countries and the results were compared. Test parameters were specified that were more precise than those required by the standards [1]. The indenters used to make hardness measurements have a significant effect on the measured result. To separate these indenter effects, measurements were made using common indenters as well as the indenters normally used by the laboratories.

Partners for the round robin test

The following institutions took part as Partner of the round robin test:

a) P.R. China: NIM National Institute of Metrology, (Beijing),
b) Denmark: Force Institute, (Copenhagen),
c) Germany PTB, Physikalisch-Technische Bundesanstalt, (Braunschweig und Berlin),
d) Italy: Polytechnic of Turin, (Turin),
e) Italy: IMGC Istituto di Metrologia G. Colonetti, (Turin),
f) Japan: NRLM, National Research Laboratory of Metrology, (Ibaraki),
g) Republic of Korea: Korea Research Institute of Standards and Science, (Taejon)
h) Poland: GUM, Central Office of Measures, (Warsaw),
i) Switzerland: OFMET, Eidgenössisches Amt für Meßwesen, (Wabern),
j) Czech Republic: CMI, Dept. of Hardness, (Prague),
k) UK: NPL, National Physical Laboratory (Teddington),
l) USA: NIST, National Institute of Standards and Technology, (Gaithersburg)

Test cycles

In 1999 the former European Standard EN 10109 was replaced by EN ISO 6508 as agreed by the parallel voting of International Standard Organization (ISO) and of European Committee for Standardization (CEN) . The calibration of hardness reference blocks (in Part 3) is the same in both standards. They both specify 4 $\pm$ 2 seconds for the duration of total test force.

The cycles for this round robin test should be the same as those for:

- all reference blocks to be used in industry
- the calibration of primary blocks
- industrial use.

The cycles for the round robin test with the Common indenter 1 (COM1) in the list and the tables and the indenter of the laboratory (INST) was defined according to the standards but with lower tolerances:

- Duration of preliminary test force T_1=3s.
- The speed of the indenter when increasing from preliminary test force to total test force should be 0,040 mm/s.

Duration of the application of total test force T_2= 5,5 s ± 0,2 s with a repeatability of 0,1 s.

Results of the round robin test

The round robin test was performed in the different laboratories within a period of one year. Data derived from the individual measurements are given in figures 1 and 2 for HRC. The numbers ascribed to the laboratories are not in alphabetical order. The predicted parameters for the measurement with COM1 and INST are given before. In the figures in this report, no corrections are made based on variance analyses.

Values measured with Common Indenter 1 (COM1)

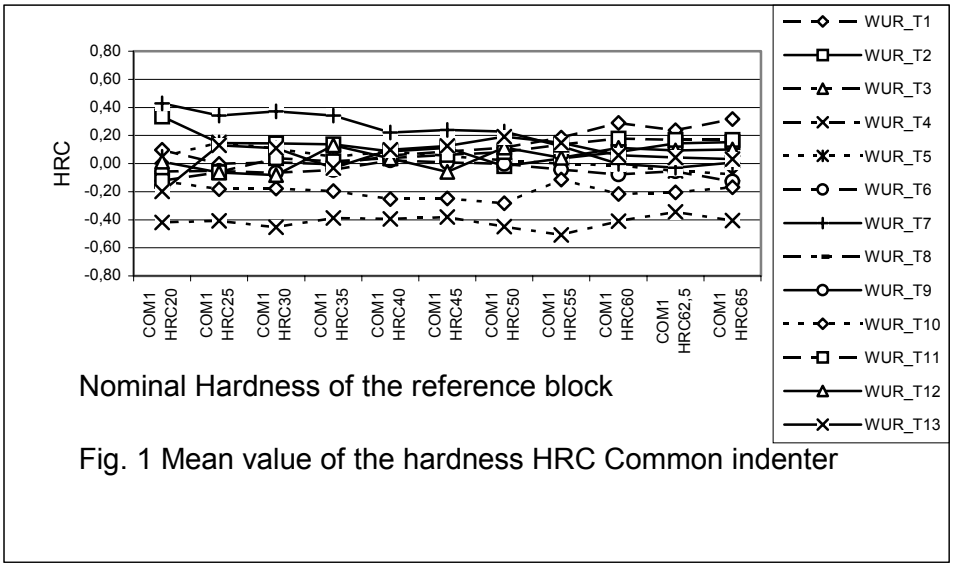

Fig. 1 Mean value of the hardness HRC Common indenter

The measurements were carried out in all the laboratories using the same indenter (COM1) following the procedure described before. The number of blocks and their nominal hardness are the same as those used for the measurements with the INST indenter. Fig. 1 presents the deviation of the mean values from each laboratory from their total mean for the different blocks. The values given are not separated by the fields and/or places on the blocks. Because the measurements were carried out in all the laboratories with the same indenter (COM1), it is possible to compare the mean values of the standardizing machines without the influences of the indenters normally used in the laboratories. Because the test parameters (time and velocity) and the indenter are the same, the differences are expected to be less than those where every Laboratory had a different indenter.

For HRC all the values lie between - 0,75 and + 0,47 HRC. If the differences between the fields are less than 0.1 HR units the differences can be explained as random (e.g. 62.5 HRC). Blocks with higher differences are affected by the non-uniformity of the material.

As with the laboratories own indenters several laboratories achieved a standard deviation for the best blocks of less than 0,1 HR, this confirms that the standard deviation is not influenced by the indenter but only by the machines.

As expected, the standard deviations of the measurements with INST indenter and COM1

indenter agree within the limits of the non-uniformity of the blocks.

Unification requires the laboratories to have a good repeatability expressed by the standard deviations of these measurements. In addition, the values of the realized hardness scales, expressed by the calibration of the blocks, must agree.
For the most important Rockwell scale, HRC, six laboratories achieved an adequate repeatability. For this scale, the measurements from seven laboratories agreed within ±0,3 HRC when using a common indenter but only four laboratories agreed when using their own indenters [4].

Values measured with the laboratories own Indenters (INST)

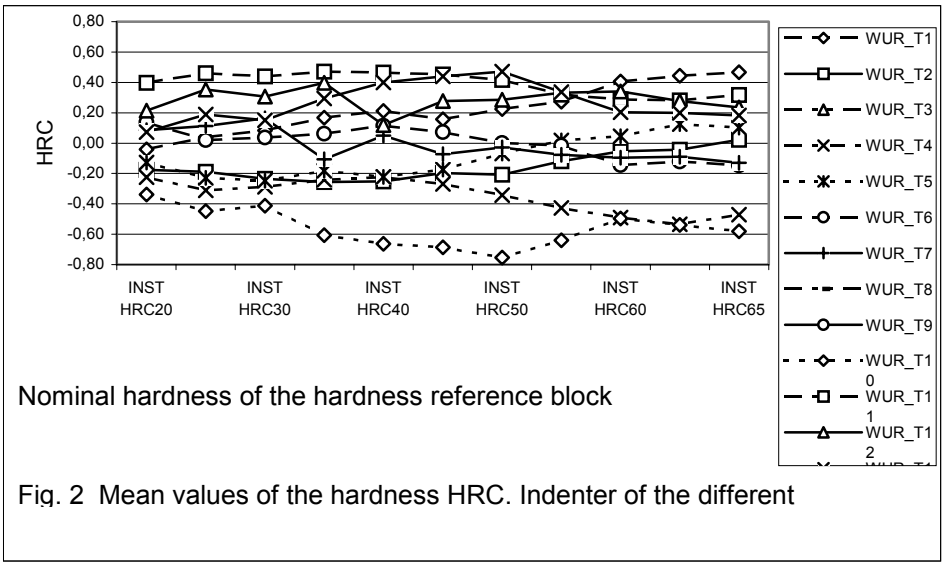

Fig. 2 Mean values of the hardness HRC. Indenter of the different

The measurements were carried out with the indenter/indenters belonging to the laboratories following the procedure described before. The results for the different scales are given in the following figures:

Fig. 2 presents the deviation of the mean values from each laboratory from their total mean for the different blocks. Because the measurements were carried out in all the laboratories with different indenters (INST), it is possible to compare the mean values of the standardizing machines with the influences of their indenters. These differences correlate with the differences of the calibration values of the hardness reference blocks calibrated in the different laboratories.

For HRC, all the values lie between -0,51 and + 0,43 HRC.
Seven laboratories achieved a standard deviation for the best hardness blocks of less than 0,1 HRC.

Possibilities to achieve a unification

In the following text there are explained five possibilities to achieve the world-wide unification of Rockwell hardness scales

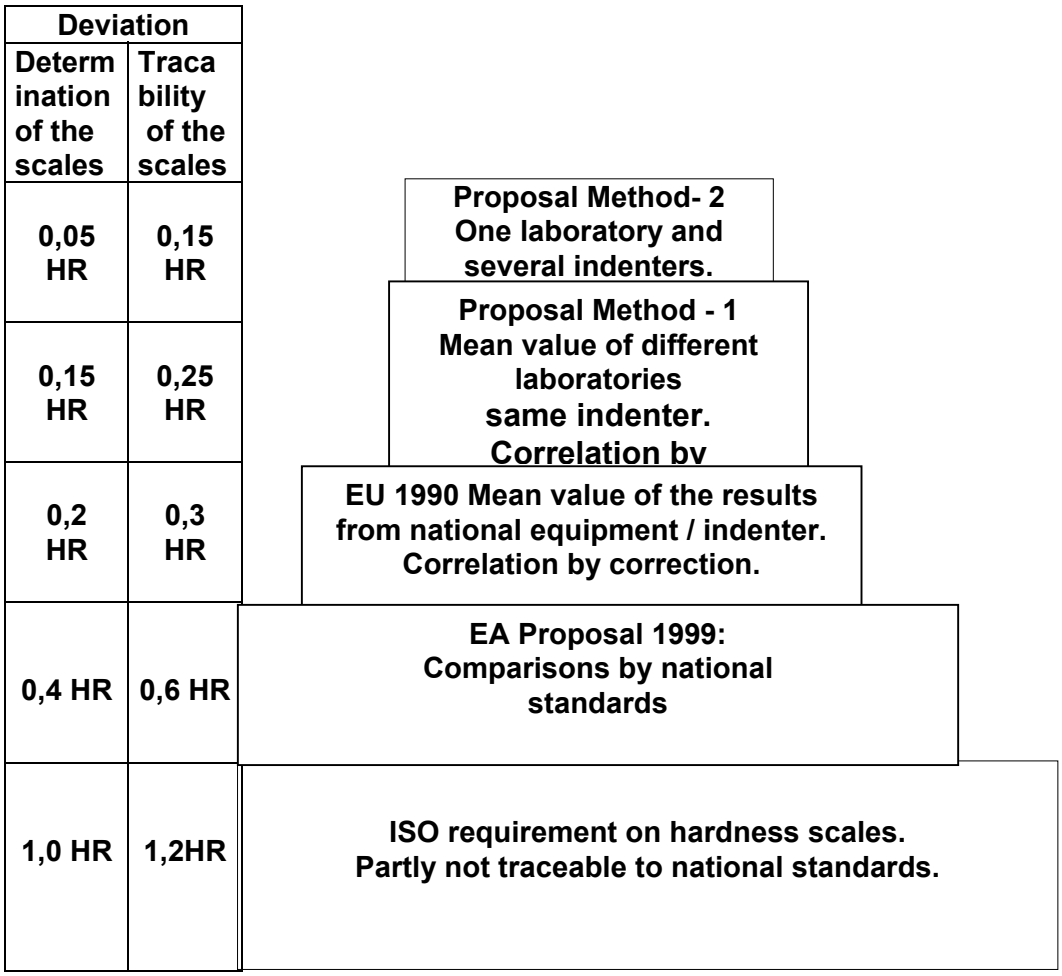

Fig. 3 Possibilities for the Determination of the Rockwell hardness scale

ISO – Proposal

The ISO Standards as ISO 6508 only mention a traceability of hardness scales by using the parameter required in the standards. The uncertainty can be estimated by 1,0 Rockwell unit. This leads under optimized conditions the delivery of the scale can be verified by at least 1,2 Rockwell units. Even this value is not verified in many countries because the scales delivered by the calibration labs are not traced to national scales and/or even there are no existing national scales.

Proposal of EA

In 1999 EA (European Cooperation for Accreditation) proposed a possibility of unification basing only on the comparison of the national scales.
The scale should be comparable to the scale of the clause describing the measurement with the INST indenters. Because there is no determination of a mean value there is no correction to that mean value or a predicted value. When comparing the scales of the INST measurement the deviations are in a range of 0,4 Rockwell units, which leads to an uncertainty of delivery of the scale of 0,6 HR units. A comparable deviation can be expected from the EA Proposal.

Harmonized Scale from 1990 (BCR)

A harmonized scale for Rockwell HRC, which was based on the results of an round robin test supported by EU under the former BCR (Community Bureau of Reference), was introduced in 1990 [12]. There was a mean value between several labs and the harmonized scale was introduced as a fictive scale, which is valid till nowadays. The results led at that time to a determination of the scale with a range of 0,2 HR units which leads under optimized condition to a delivery of the scale of 0,3 HR units. The unification was done by a correction of hardness values in the different ranges of the scale. A correction was only established for the most important scale HRC. The round robin test can be seen as the forgoing test of the test described in this article.

New Proposal Method 1

On the basis of the round robin test described in the first part of this article two new proposals were developed. The first proposal is of same type as in the forgoing clause. All labs shall make the verification of their scale with one or several common indenter. The scales can be verified with an uncertainty of 0,15 Rockwell units, which leads under optimized condition to a delivery of the scale of 0,25 HR units. The verification of all different national scales can be done by correction as done for the BCR scale [12].

New Proposal Method 2

A determination of the hardness scales with a lower value of uncertainty could be reached if a lab holds the scale with several indenters. This lab should in specified time correlate its values by round robin test with several other labs or in one lab there should be more than one equipment to determine if there is no drift. Under this assumption the hardness scales can be determined within 0,05 HR units, which leads under optimized condition to a delivery of the scale of 0,15 HR units

Hardness scale for the user

The verification of the national scales as described in the two forgoing clauses would be achieved by a correction. To pass this correction to the user it would be necessary to correct all hardness values on the reference blocks with a value valid for a scale or of a range of a scale. For the verification and the use of these scales the standards have to be changed [1] and a method for the verification of the scale should be specified.
For the user the following hints can be seen:

⇒ On national level the Rockwell scales are verified in the moment with a deviation up to 0,4 HR units.

⇒ On the level of the calibration labs, correlated to these national scales the deviation could reach 0,6 to 1 HR unit in global comparison.

⇒ A harmonization of the scales would be possible. Two models are proposed: In Method 1 a harmonization could be done as in the BCR project from 1990 with a deviation of 0,25 HR units between national scales and 0,25 on the level of calibration lab. In Method 2 there is a determination as in former time the original meter in Paris with a deviation of 0,05 HR units between national scales and 0,15 on the level of calibration lab.

As to the opinion of the authors of this article the last method would have the highest precision of determination of the scales and the lowest values for the deviation between the measuring labs.

Literature

[1] ISO 6508-3 Metallic materials - Rockwell hardness test - test (scales A, B, C, D, E, F, G, H, K,N,T) Part 3: Calibration of reference blocks (published as well as EN ISO 6508-3 in 1999)

[2] Song, J., Low, S., Pitchure, D., Germak, A., DeSogus, S., Polzin, T., Hui-Qi,Y., Ishida , H., Barbato, G.: Establishing a Common Rockwell Hardness Scale using Geometrical Standard Diamond Indenters, XIV Imeko World Congress, Vol III, P. 258- 263, 1997

[3] Barbato, G., Desogus, S. Germak, A., Herrmann, K., Polzin, T.: How to reach the World-Wide Unified Scales for Rockwell Hardness with Conical Indenter, XIV Imeko World Congress, Vol III, P. 264 - 269, 1997

[4] Polzin, T., Schwenk, D. contributions from He Li, Hansen, V., Herrmann K., Barbato, G., Germak, A., Ishida, H., Onsinska-Karczmarek, A., Scartazzini, W., Borovsky, J., Elkington, D., Low, S. Song, J., Bahng, G. W., World-Wide Unified Scales for the Rockwell Hardness Test with Conical Indenters, Results of the round robin test, differences between the laboratories, Materialprüfung, (42), 2000, S. 460-467

[5] Polzin, T., Schwenk, D., Mögliche Umsetzungen des weltweiten Ringversuches Rockwell, (56) HTM 2001, S. 395-402

[6] Song, J., Low, S., Pitchure, D., Germak, A., Desogus, S., Polzin, T. , Yang, H.-Q., Ishida, H., Barbato, G.: Establishing a World-Wide unified Rockwell hardness scale with metrological traceability, metrologia ,1997, 34 , P.331-342

[7] Song, J., Low, S., Pitchure, D., Germak, A., DeSogus, S., Polzin, T., Hui-Qi, Y., Ishida , H., : Establishing a World-Wide Unified Rockwell Hardness Scale using Standard Diamond Indenters, Measurement 24 (1998) 197-205

[8] Polzin, T.: World-Wide Unified Scales for the Rockwell Hardness Test with Conical Indenters, Aim, works to be done, blocks and indenters to be used, Materialprüfung, 1999, 4, P141-143

[9] Barbato G., Petik F.: Metrological involvement in the definition and dissemination of hardness scales, XIII IMEKO World Congress, Torino, 761-766, 1994

[10] Barbato G., Desogus S., Levi, R.: Design Studies and Characteristics Description of the Standard Deadweight Hardness Tester of Istituto di Metrologia G Colonnetti" (IMGC), VDI Berichte. 97-103, 1978

[11] Marriner, R- S., Wood J. G.: Comparisons of international Rockwell C and Vickers HV 30 Hardness Scales during 1970 and 1971. NPL report MC8, (1972)

[12] Barbato G., Desogus S., Germak A.: Hardness measurement from empiricism to metrology - An application to Rockwell C scale, In "Basic metrology and applications", Editrice Levrotto & Bella, 112117?, 1994

[13] Barbato G., Desogus S., Germak A.: Comments on the results obtained in the comparison of the HRC scales maintained at ETCA. IMGC and MPA NPW, VDI Symposium on Hardness Testing in Theory and Practice, Düsseldorf, 1 1- 17, 1995

[14] Weiler W.: Ein Beitrag zur Abhängigkeit der Rockwell Härte von der Zeit der Lastaufbringung. VDI Berichte n. 100 (1967)

[15] Hild K.: Der Einfluß der Toleranzen des Meßverfahrens nach Rockwell C auf die Härtewerte, Zeitschrift für Instrumentenkunde 66 (1958), S. 202

[16] Yano H., Ishida H., Kamoshita T.: Characteristics of Standard Rockwell Diamond Indenters and Method of establishing Standard Indenters, proceedings of the round table discussion on Hardness testing, 7h Dv1F?-KO Congress, London, 1976

[17] Bochmann G., Hild K.: Der Einfluß von Abweichungen des Eindringkörpers von der Sollform auf die Härtewerte bei dem Meßverfahren nach Rockwell C, Zeitschrift für Instrumentenkunde 68 (1960), S. 155

[18] Barbato G., Desogus S.: The meaning of the geometry of Rockwell indenters, IMGC Technical report n. R128, 1978

[19] Polzin T., Schwenk D.: Vermessung von Rockwell Eindringkörpern mittels Laserinterferenz (Measurement of Rockwell indenters by Laser Interferometric System), VDI Berichte 1194 (1995), S. 265-273

[20] Song, J. F., Rudder, F.F. jr., Vorburger, T. V. Smith, J. H.: Stylus technique for direct verification of Rockwell diamond indenters, VDI Berichte 1194, 1995, P. 129-138.

[21] Polzin, T.; Wehrstedt, A.: Übersicht über den Stand der Normung auf dem Gebiet der Härteprüfung metallischer Werkstoffe, Härtereitechnische Mitteilungen, 48 (1993) 5, S. 330-335

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