

COMPARATIVE MEASUREMENTS OF SLOVENIAN AND USA ROCKWELL C HARDNESS SCALES

Anton Štibler, Samuel Low, Robert Ellis

ZAG, Laboratory for Metrology, Ljubljana, Slovenia
NIST, Gaithersburg, USA
DAVID L: ELLIS, Acton, USA

Abstract – A national scale is set up for each hardness scale representing the reference hardness values in each country. From metrological and international trade aspects agreement between the national scales is very important. Good agreement makes possible good industrial cooperation. Therefore comparison between national scales is necessary. Comparison between national hardness scales and hardness scales set up by the producers of the reference blocks is necessary as well.

The Rockwell measurement method is the most widely used hardness measurement method throughout the world. The measurement is practical, relatively easy to carry out and the measurement result is quickly and simply indicated on the indicator. Among the different Rockwell scales, the C scale is very useful. It satisfies demands for accurate hardness measurement especially during hardening process of steel, which is often applied in industry.

In this paper comparative measurements between the Rockwell C national scales of Slovenia as measured by Zavod za gradbeništvo Slovenije (ZAG) and USA as measured by the National Institute of Standards and Technology (NIST) and the scale set up by a producer of reference blocks, David L. Ellis Co., Inc., are presented.

Keywords: Hardness, comparison, reference blocks

1. INTRODUCTION

Hardness of a material is generally defined as a material's resistance to the introduction of foreign bodies into its surface.

For a practical realization of this definition, a well defined measurement process is necessary. Different hardness measurement processes are defined and written in standards. For the Rockwell C hardness scale, which is the subject of the comparative measurement described in this paper, the standard ISO 6508 (parts 1, 2 and 3) is valid. Deviations between Rockwell C national scales and the reference scale set up by the Ellis Company are investigated by comparative measurement. Slovenian and USA national scales are compared twice: firstly with the use of Slovenian reference blocks specially prepared for comparison of national scales and secondly using blocks made by David L. Ellis Co., Inc.. Results obtained using Slovenian reference blocks are

presented graphically with previously obtained comparison results using these blocks with Italian national institute Istituto di Metrologia "G. Colonnetti" (IMGC) and the German Institute Materialprüfungsamt Nordrhein-Westfalen (MPA NRW). Two separate measurements using a Common Indenter (CI) and the Institute's Indenter (II) are carried out. This allows the influence of the indenter on the uncertainty of measurement to be separated from the measuring results.

2. COMPARATIVE MEASUREMENTS

Measurements were carried out on the machines which represent:

- USA national standard of NIST (fig. 1),
- Slovenian reference standard of ZAG (fig. 2) and
- Ellis reference standard of the David L. Ellis (fig. 3).



Fig. 1: USA national hardness standard machine

The force, time and pattern of the measurement were in accordance with EN ISO 6508-3 and EN ISO 6508-1.



Fig. 2: Slovenian reference hardness standard machine



Fig. 3 Reference hardness standard machine at David L. Ellis

2.1. Comparison of national scales

Three blocks of different hardness levels made by Buderus¹ from Germany were used. The blocks had an engraved grid on its surface so that the exact place for indentation was easily found. Each indentation place was defined by coordinates marked on the surface of the block.

Two separate measurements using the common (CI) and the institute's indenters (II) were conducted.

Seven indentations were carried out on each block with each indenter.

¹ Commercial equipment and materials are identified in order to adequately describe historical events. In no case does such identification imply recommendation or endorsement by the authors, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

2.1.1. Results

In the following figures the results of the comparative measurements using the institute's indenters and the common indenter are depicted. Deviation of the mean values of measured hardness from nominal hardness values of the blocks are shown on diagrams in Figs. 4 and 5².

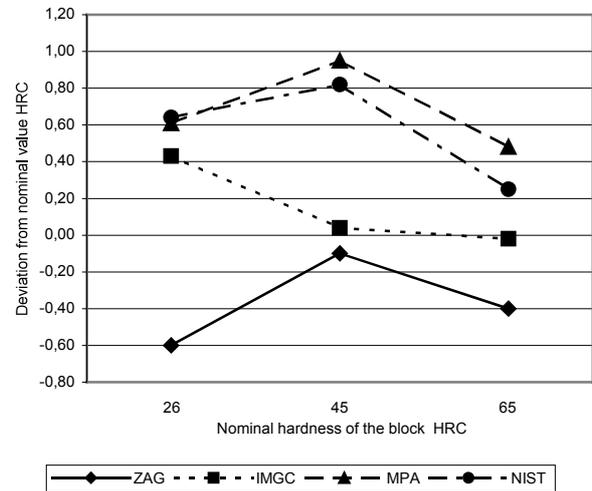


Fig. 4: Mean value of hardness using the institute's indenter

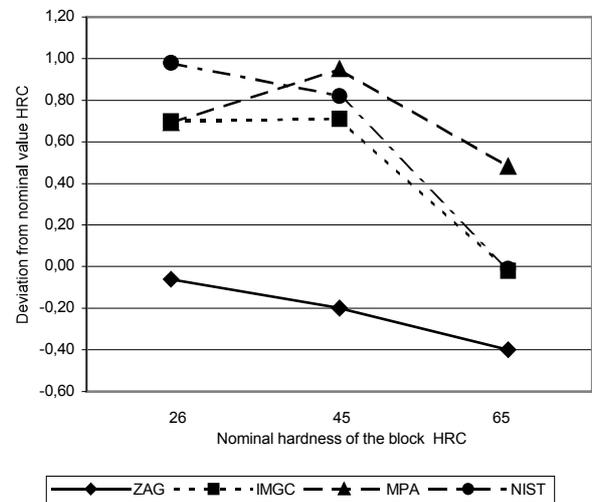


Fig. 5: Mean value of hardness using the common indenter

In Figs. 6 and 7, the repeatability of the measured hardness values of each participant using the institute's indenters and the common indenter are shown.

² The presented NIST measured Rockwell hardness data are estimated to have an expanded uncertainty no larger than $\pm 0,1$ Rockwell units without incorporating biases due to the indenters used and is calculated as $U=k \cdot u_c$ where u_c is the combined standard uncertainty and k , the coverage factor, is taken as 2.

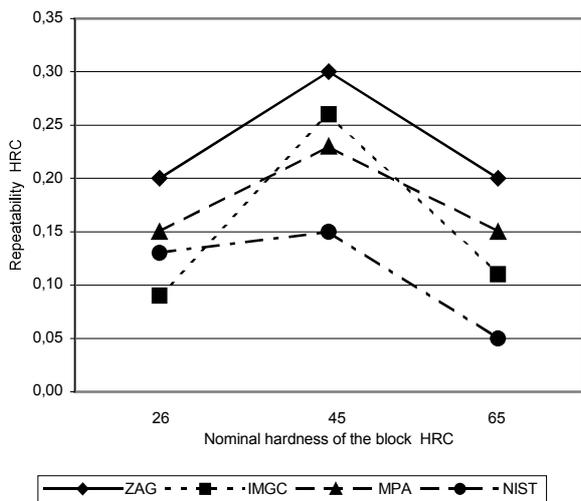


Fig. 6: Repeatability of hardness using the institute's indenter

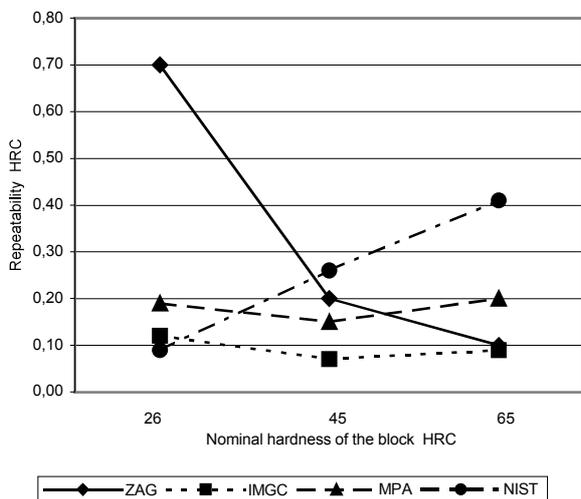


Fig. 7: Repeatability of hardness using the common indenter

2.2. Comparison of national and reference scales using Ellis reference blocks

Three blocks of different hardness levels made by David L. Ellis Co.¹ from the USA were used. The blocks were chosen by chance from the normal production series. Each block was engraved with a grid on its surface so that the exact place for indentation was easily found. Each indentation place was defined by coordinates marked on the surface of the block.

Two separate measurements using a common (CI) and the institute's indenters (II) were conducted in a similar way as described in section 2.1. Five or six indentations were carried out.

The influence of the indenter geometry on the measurement results is shown on the diagram as well.

2.2.1. Results

In the following figures the results of the comparative measurements using the institute's indenters and the common indenter are depicted. The deviations of the mean values of measured hardness for each laboratory with respect to the nominal hardness values of the blocks are shown in diagrams in Figs. 8 and 9.

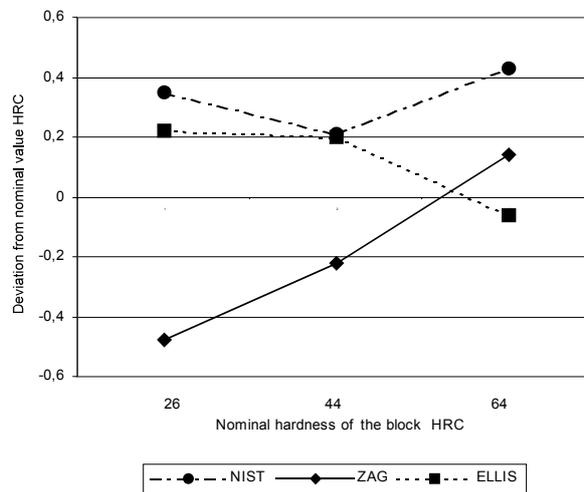


Fig. 8: Deviation of hardness using the institute's indenter

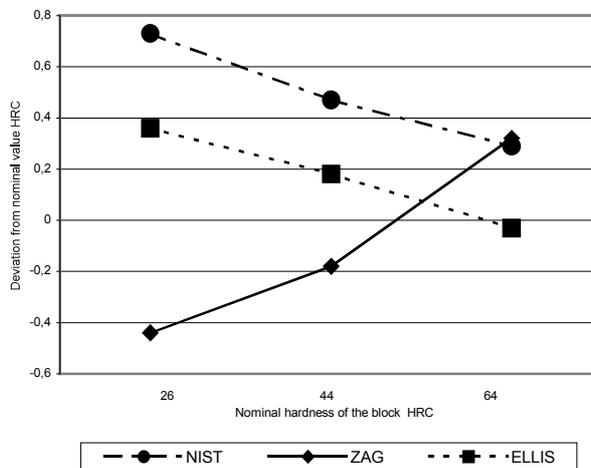


Fig. 9: Deviation of hardness using the common indenter

In figures 10 and 11, the repeatability of the measured hardness values of each participant using the institute's and the common indenters are shown.

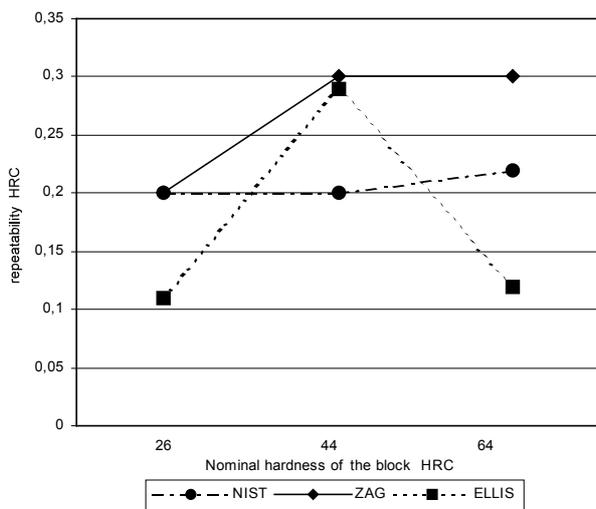


Fig. 10: Repeatability of hardness using the institute's indenter

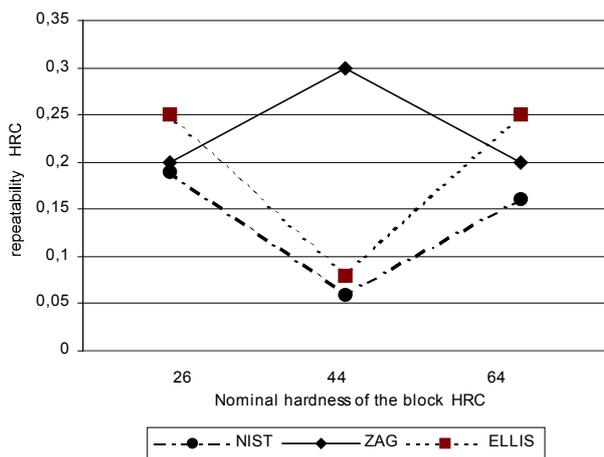


Fig. 11: Repeatability of hardness using the common indenter

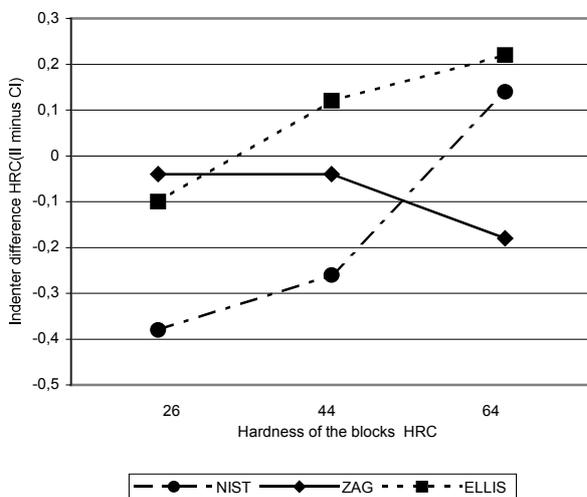


Fig. 12: Measurement differences between Institute's indenters

In figure 12, the measurement difference between each institute's indenter and the common indenter is presented for each laboratory. From this data, the relative measurement difference between the institute's indenters can be seen.

3. CONCLUSIONS

The results of the National hardness scales comparison show that values obtained at the ZAG reference machine are lower by approximately 0,4 to 1 HRC than the values obtained at NIST. Almost the same difference is obtained between ZAG and Italian national standard at IMG C and the reference standard at MPA NRW Germany. This difference is of a systematic type and therefore can be reduced by correction of the measurement result. In such a way good agreement between the USA and Slovenian Rockwell C national scales can be achieved.

The repeatability of hardness at the 45 and 65 HRC levels is within the expected limits. The error of 0,70 HRC at the hardness value of 26 HRC obtained by the ZAG machine using the common indenter is too high and needs further investigation.

The comparison results using the Ellis hardness blocks show good agreement between NIST and the Ellis scale. Values below 45 HRC obtained with the ZAG reference machine are lower by approximately 0,4 HRC to 1,2 HRC than the values obtained at NIST. This deviation is close to the deviation between national scales therefore it can be minimized by correction of the measurement result. Repeatability is within the expected limits.

The indenter differences in figure 12 show that there is a maximum difference of 0,4 HRC for the three HRC hardness values. This difference is in accordance with the differences established with international comparisons.

The results of this comparative measurement of hardness scales support cooperation between USA and Slovenia in the field of metrology and industry as well.

REFERENCES

- [1] ISO 6508-1/2/3: Metallic Materials – Rockwell hardness test, Geneva 1999.
- [2] T.Polzin, D.Schwenk, Mogliche Umsetzung des weltweiten Ringversuches Rockwell; Harterei-Technische Mitteilungen, 56 (2001) 6, 395-402
- [3] A. Štibler, K. Herrmann, T. Polzin, A. Germak; Comparative Measurements of Hardness Scales for Establishing the Hardness Standard of Slovenia; IMEKO TC3/TC5/TC20, Celle, 2002

Authors:

- Mr. A.Stibler ZAG Ljubljana, Dimiceva 12, 1000 Ljubljana, Slovenija, E-mail: anton.stibler@zag.si
- Mr. S. Low NIST, 100 Bureau Drive, Stop 8553., Gaithersburg, MD 20899-8553 USA; E-mail: Samuel.low@nist.gov
- Mr. R. Ellis, David L. Ellis Company Inc. Box 592,310 Old high Street, Acton, MA 01720 USA, E-mail: dlellisco@aol.com.