Comparative measurements of hardness scales for establishing the hardness standard of Slovenia

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Abstract:

A commercial hardness testing machine was provided to represent a hardness reference standard in Slovenia.
In order to evaluate how accurate the hardness scales realised with this machine could be, the main influence factors contributing to the uncertainties were verified and comparative measurements carried out, the results of which were compared with several laboratories owning primary hardness standard machines.

1. Introduction

We have no real need and sources to realize highly precise and costly primary hardness standards in Slovenia. Our goal is to realize a standard with which we can

- satisfy the needs of Slovenian industry for arbitrary measurement and
- raise the calibration service to a higher level.

For this reason the comercial testing machine made by Instron – Wolpert Co. was purchased where hardness scales for Brinell, Vickers and Rockwell measurement methods could be realized. On this machine most commonly used hardness scales should be realized within uncertainties which assure sufficiently accurate measurement in our industry.

The influence parameters such as force, length and time stipulated in standards EN ISO 6506, EN ISO 6507 and EN ISO 6508 were verified with direct calibration method. [1)]
Indirect calibration method was realized in the frame of international comparative measurements in four laboratories.

2. Hardness reference machine

The hardness reference machine of the type 930 (see fig.1) is manufactured by Instron – Wolpert Co.. Forces from 0,9807 N up to 2451,8 N can be applied on this machine so that all Brinell, Vickers and Rockwell measurement scales in this force range can be realized. The test force is applied by a controlled motor (closed loop) drive system during the measurement.

The measuring units comprise an incremental penetration depth measurement system (Rockwell) and an incremental scale for the optical measurement of hardness indentations (Brinell, Vickers). Both measurement systems are directly connected to the Testor panel on the machine and to a PC.
Brinell and Vickers indentations are measured directly on the screen through Zeiss projection optics.

[1)]…Calibration of indentation depth measuring system is going on at this time. The results will be reported later.

Figure 1. Hardness reference machine

3. Metrological caracteristics

3.1. Force

For force calibration the amplifier DK 38 and the force transducer U1, 5 kN, both made by HBM Co. were used. The force transducer was placed in the machine under a hardness reference block. Ten measurements of each force were carried out in accordance with the requirements in standards.
During the calibration we recognized that force application by means of a controlled motor drive system had three main sources of error:

- error of the applied force
- error of the repeatability of the applied force
- error of the maintenance of force.

Force deviation during the maintenance of the required value was detected with the naked eye. This was possible because the frequency of force cycles was relatively low.

Table 1. Main errors in the forces applied for Vickers and Brinell method

Procedure	Force, N	Relative errors (%)		
		Applied force q	Repeatability b	Maintenance of force δ
HV 30	294,2	0,32	0,25	1,73
HBW 2,5/31,25	306,5	0,04	0,43	1,25
HBW 2,5/62,5	612,9	0,04	0,09	0,32
HBW 2,5/187,5	1839	0,06	0,08	0,09

Table 2. Main errors in the forces applied for Rockwell method

Procedure	Force, N	Relative errors (%)		
		Applied force q	Repeatability b	Maintenance of force δ
HRC	F_0 = 98,07	1,29	0,48	
	F = 1471	0,02	0,01	0,03
	F'_0 = 98, 07	1,05	0,28	

3.2. Length measuring systems

The optical length measuring system for Brinell and Vickers hardness testing was calibrated and compared to the Zeiss stage micrometer. Calibration was carried out at a magnification of 70x and 140x in accordance with the standards [1].
Maximum deviation amounted to 0,48% was found during the calibration of the optical length measuring system.

3.3. Indenters

To assure a good reference hardness standard, as perfect as possible indenters are very important. As ZAG is not able to verify the indenters in his laboratory in an exact way, we bought them as high class indenters together with the calibration certificates.
In such a way we assured that the imperfection of indenters and its effects on uncertainties were minimum.

3.4. Test cycles

All phases of the hardness test cycle can be adjusted on the panel of the machine.
The calibration of duration of each phase of the test cycle was carried out by a stop watch. A calibration uncertainty of less than 0,5 s was realized.
We found out that the whole test cycle is within the tolerances given in the standards [1].

4. Comparative measurements

To find out how close the results obtained by measurement on our reference hardness machine are to the hardness scales realized in other countries, a comparative measurement was carried out. The laboratories at PTB, Braunschweig; IMGC, Torino; MPA NRW, Dortmund and our laboratory at ZAG Ljubljana participated in the comparative measurements.
Measurements were carried out for the following scales: Rockwell HRC, Vickers HV 30 and Brinell HBW 2,5/187,5; HBW 2,5/65,5; HBW 2,5/31,25.
For Rockwell and Vickers test method each three blocks, and for Brinell test method two blocks of different hardness levels were used. The blocks for Rockwell and Vickers had engraved grid on it, so that the exact place for indentation was easily found. Each indentation place was defined by coordinates marked on the surface of the block.
For Vickers and Rockwell measurements, two separate measurements using common (CI) and institute´s (II) indenters were conducted. This allows to separate the influence of the indenter geometry on the uncertainty of measurement from the measuring results.
The force-, time- and pattern of the measurements were in accordance with EN ISO 6506-3, EN ISO 6507-3 and EN ISO 6508-3 for laboratories owning the primary hardness standards,

while for the laboratory at ZAG these parameters were evaluated by the calibration of the machine presented in section 3.
Seven indentations for Rockwell and five for Vickers and Brinell were carried out on each block. Each diameter resp. diagonal of the indentation was measured three times in vertical and horizontal position.
For HV 30, each participant also measured the indentations made by PTB with a common indenter. For the Brinell method, each participant also measured the original indentations made by MPA.

4.1. Results

In the following fig. 2 to 11 the results of the comparative measurements using selected Rockwell, Vickers and Brinell are depicted.

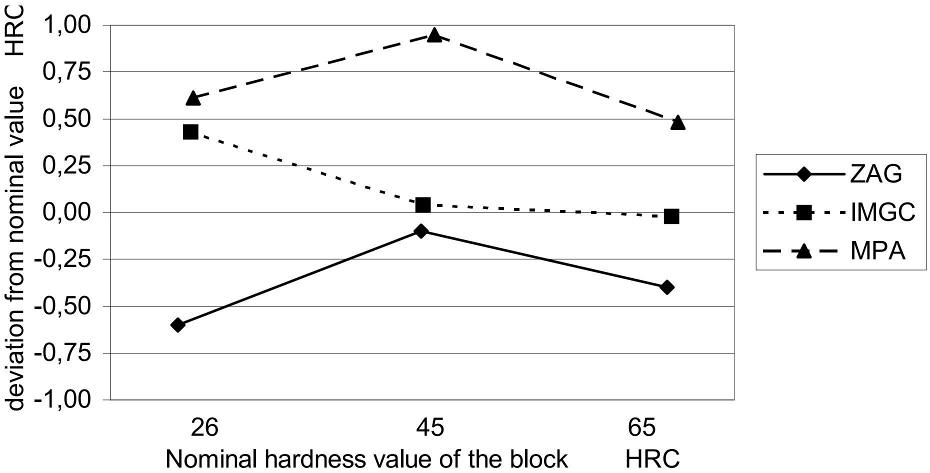

Figure 2. Mean value of hardness for Rockwell HRC using the institute´s indenter

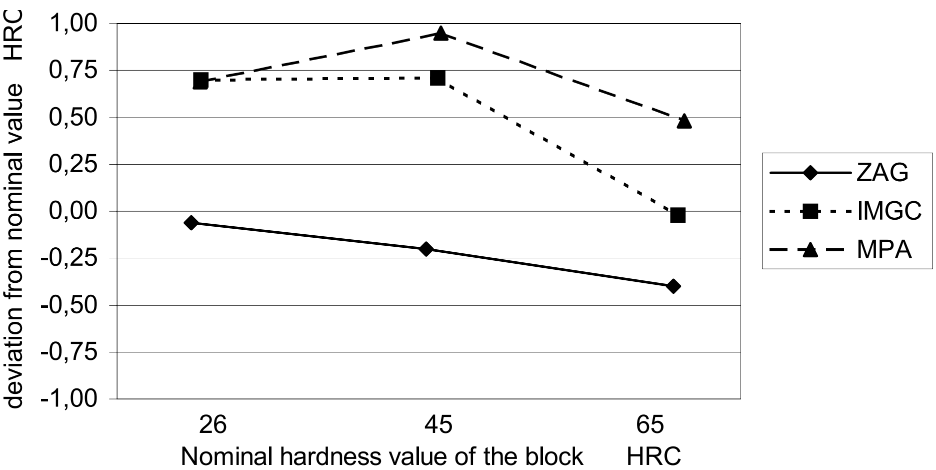

Figure 3. Mean value of hardness for Rockwell HRC using the common indenter.

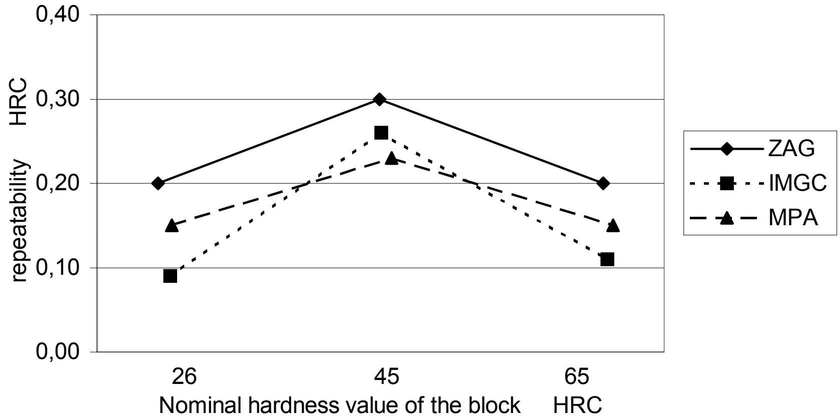

Figure 4. Repeatability of hardness for Rockwell HRC using the institute´s indenter

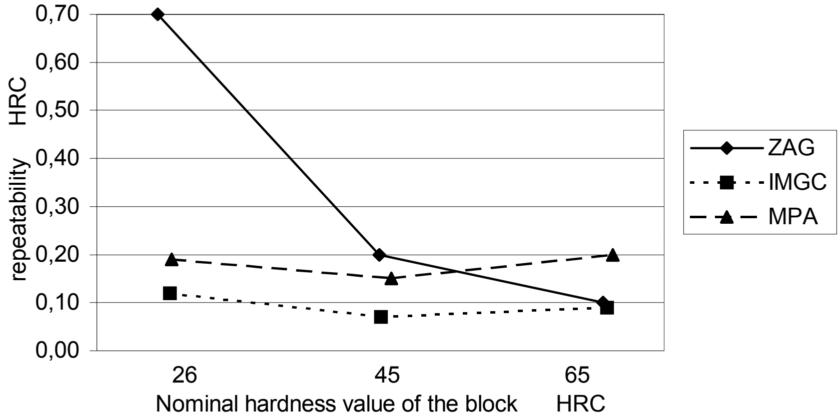

Figure 5. Repeatability of hardness for Rockwell HRC using the common indenter

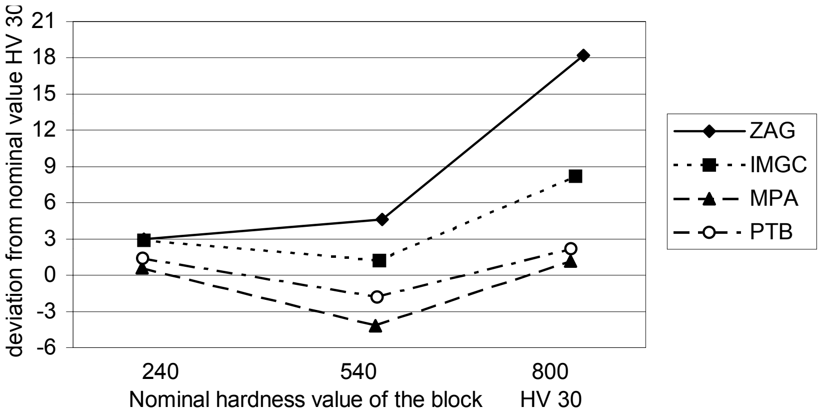

Figure 6. Mean value of hardness for Vickers HV 30 using the institute´s indenter

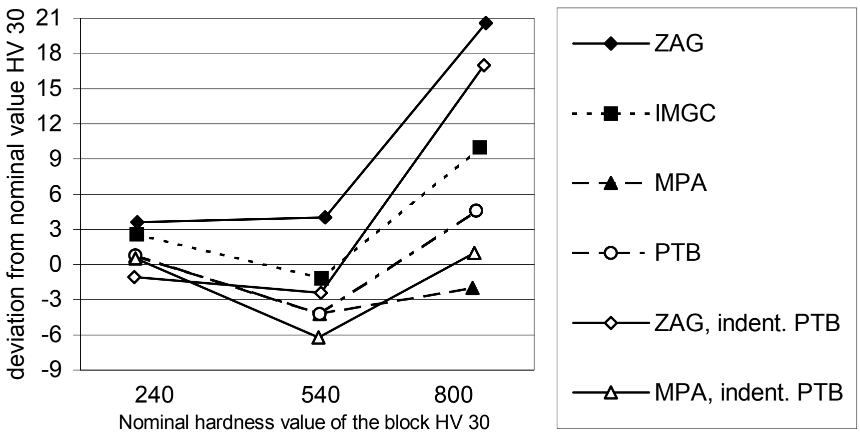

Figure 7. Mean value of hardness for Vickers HV 30 using the common indenter

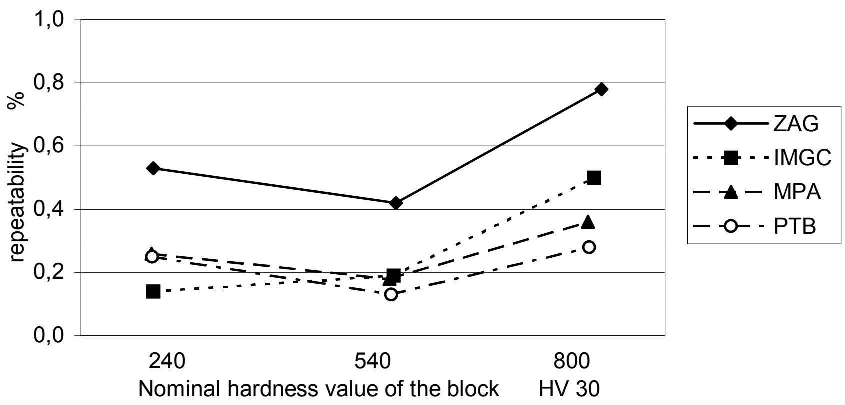

Figure 8. Repeatability of hardness for Vickers HV 30 using the institute´s indenter

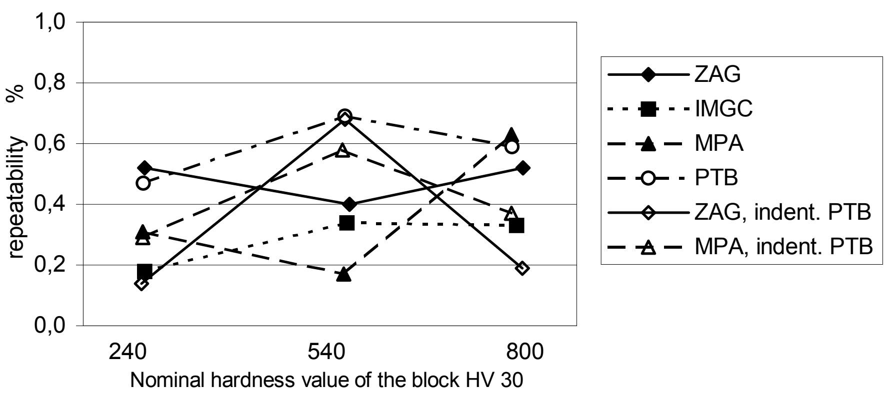

Figure 9. Repeatability of hardness for Vickers HV 30 using the common indenter

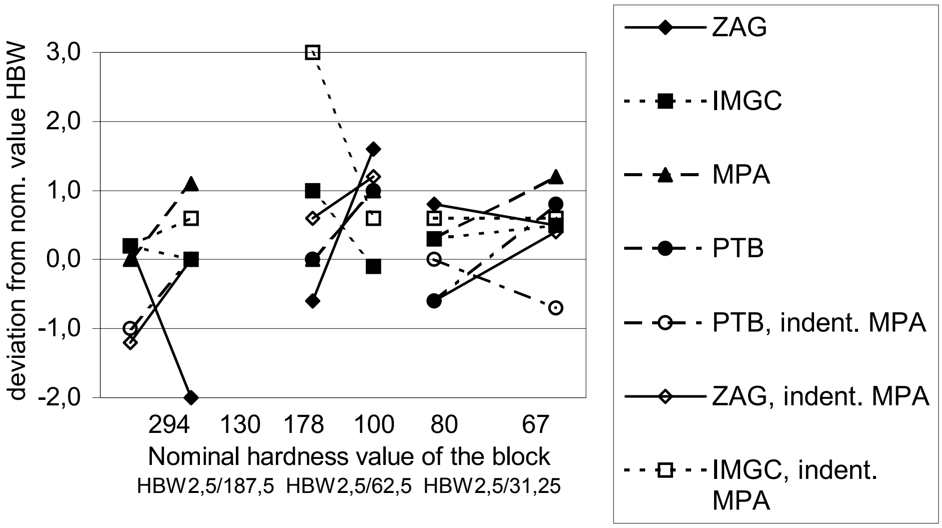

Figure 10. Mean values of hardness for three different Brinell scales

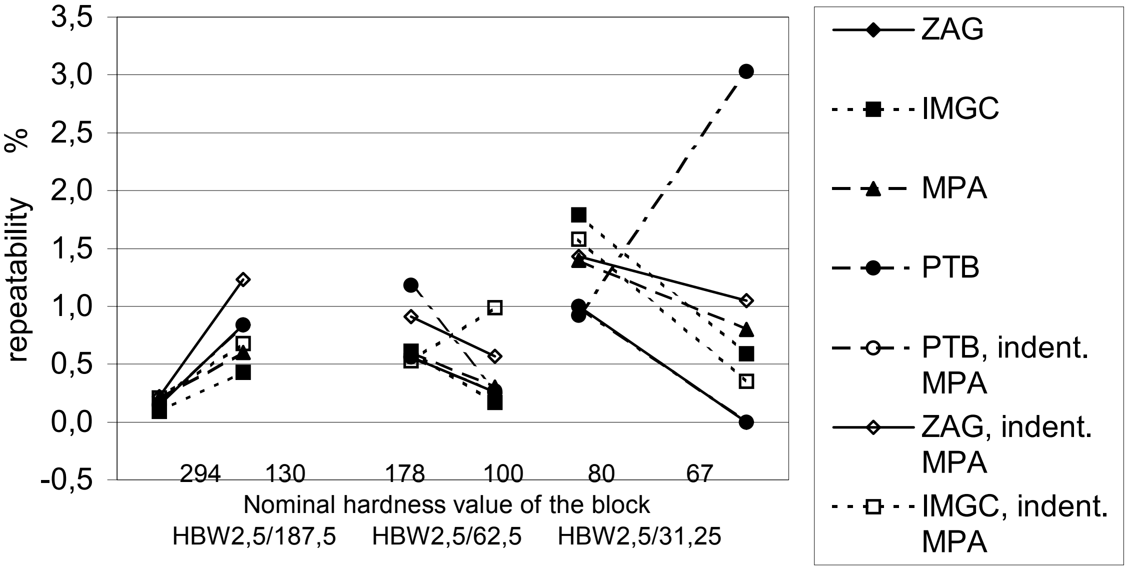

Figure 11. Repeatability of hardness for three different Brinell scales

6. Conclusion

The results of Rockwell HRC hardness measurements show that the values obtained at the ZAG reference hardness machine are lower by approximately 0,5 HRC to 1 HRC than the values obtained at IMGC and MPA NRW. This systematic deviation could be reduced, but before we do this, the calibration of the indentation depth measuring system has to be carried out to find out whether this deviation arises from the depth measuring system or from any other source.
Repeatability for hardness 45 and 65 is in the expected limits. The error of 0,70 HRC at the hardness value of 26 HRC obtained by using a common indenter is too high and needs further investigation.

The Vickers hardness measurement results indicate that the values obtained at the ZAG reference hardness machine are higher than the values obtained in the other three laboratories. The deviation increases with the increasing hardness. On the basis of the compared measurement results obtained by ZAG and MPA NRW, of indentations made by PTB (common indenter- indent.PTB), we found out that the main part of deviation arises from the optical measurement system (including the operator). Further investigations are necessary to take the decision in which way the systematic deviation will be reduced. Repeatability is satisfactory and in accordance with our expectations.

The Brinell hardness measurement results show that the values obtained on the ZAG reference hardness machine are quite good, therefore it is not necessary to apply any correction here. Measurement results obtained at ZAG, PTB and IMGC of indentations made by MPA NRW (indent.MPA) indicate good agreement.

The next step in our investigation work is to find the reasons for the deviation in Rockwell and Vickers measurement results. Then we are going to reduce deviations either by adjusting the machine or by applying the correction of the measurement values. Finally we will evaluate the measurement uncertainties.

References

[1] EN ISO 6506-1/2/3; EN ISO 6507-1/2/3; EN ISO 6508-1/2/3: Metallic Materials – Brinell/Vickers/Rockwell hardness test

[2] G.C. Stanbury and F.A. Davis, The uncertainty evaluation of NPL's hardness facility. XVI IMEKO World Congress, Vienna, Austria, Sept.2000.

[3] G.C. Stanbury and F.A.Davis, UK's provision of primary hardness standards, XVI IMEKO World Congress, Vienna, Austria, Sept.2000.

[4] T. Polzin, D. Schwenk, Mogliche Umsetzung des weltweiten Ringversuches Rockwell; Harterei-Technische Mitteilungen, 56 (2001) 6, 395-402.

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