XVII IMEKO World Congress
Metrology in the 3rd Millennium
June 22 – 27, 2003, Dubrovnik, Croatia

INVESTIGATION OF A CALIBRATION DEVICE FOR THE DEPTH MEASURING SYSTEM IN ROCKWELL HARDNESS TESTING MACHINES

Konrad Herrmann [1], *Anton Stibler* [2], *Imre Patkovszky* [3], *Peter Strobel* [4], *Febo Menelao* [1]

1) Physikalisch-Technische Bundesanstalt Braunschweig, Germany
2) ZAG Ljubljana, Slovenia
3) MPA Hannover, Germany
4) Bareiss Prüfgerätebau GmbH, Oberdischingen, Germany

Abstract − The paper describes investigations on the metrological properties of a newly developed calibration device for the depth measuring system in Rockwell hardness testing machines. The special feature of this calibration device is the inductive measuring system and that it is used under acting test force. The investigation of the calibration device is carried out with two different reference devices. As main result of the investigation an uncertainty of measurement U ≈ 0,24 µm of the calibration device was proven.

Key words: depth measuring system, Rockwell hardness testing machine, calibration device, measurement uncertainty

1. MOTIVATION

Up to now, Rockwell hardness tests due to their simple, automated realisation gain the widest application in hardness testing of metals. In order to guarantee the accuracy of the hardness testing machines, a direct calibration of the test force, the depth measuring system, the indenter and the test cycle and an indirect calibration with hardness reference blocks is prescribed in ISO 6508-2.[1] Among these parameters for the direct calibration, apart from the geometrical deviations of the indenter, the measuring deviations of the depth measuring system are of high significance.

Due to the lack of suited calibration devices for the depth measuring system ISO 6508-2 prescribes as a substitute a calibration method using a set of hardness reference blocks and a reference indenter. But this method has the main drawback that reference indenters are difficult to obtain. Because an economical and sufficiently precise calibration device is missing, the depth measuring system in Rockwell hardness testing machines is often not calibrated. This fact leads to considerable difficulties in the adjustment and calibration of these testing machines.

2. DEVELOPMENT OF A CALIBRATION DEVICE

Therefore, in co-operation between PTB and Bareiss Co. a calibration device for the depth measuring system was recently developed [2], which measures the depth under acting preliminary test force (F_0 = 98,06 N) with an inductive measuring system. This compact calibration device is convenient to operate. The resolution of the inductive measuring system is 0,1 µm. The depth calibration device is mounted axial symmetrically on the measuring table of the hardness testing machine by a cylinder which fits into the mounting hole on the measuring table. Under these circumstances a special hard metal ball indenter acts centrally on the pressure plate on top of the depth calibration device. The vertical movement of the depth calibration device, which causes the displacement of the indenter, is realised by manual rotation of a thread ring on the depth calibration device. Two radially directed bars serve for securing against rotation of the depth calibration device. The measuring values of the inductive system are displayed on a separate digital display device.

Fig. 1 delivers a view of this depth calibration device mounted on a Rockwell hardness testing machine.

Fig. 1 View of the depth calibration device

3. INVESTIGATION OF THE CALIBRATION DEVICE

In order to investigate the performance of this calibration device, two different reference devices were used, which enable length measurements under acting test force. One reference device relies on a laser interferometer and the other on a line scale as reference measuring system. In the following the results of the investigation of the depth calibration device with these two reference devices are reported.

3.1 Laserinterferometric reference device

As laserinterferometric reference device PTB's Rockwell standard measuring device RNG 10 was used. The laser interferometer of the Michelson type which belongs to the depth measuring system has a resolution of 2 nm, and its uncertainty is estimated as U = 20 nm (k = 2). A further important feature is the stiff frame design of the machine, which guarantees very small deformations of the frame under acting test force.

Fig. 2 illustrates the calibration of the depth calibration device with the help of the Rockwell hardness standard machine.

Fig. 2 Calibration of the depth calibration device with the help of the Rockwell hardness standard machine

In Fig. 3 the calibration results for the depth calibration device with this laserinterferometric reference device are depicted.

Summarising, the result was achieved that for upward movement of the depth calibration device the measurement deviation is –0,07 µm, whereas for downward movement it is +0,10 µm. The standard deviation of three measurement series is 0,16 µm.

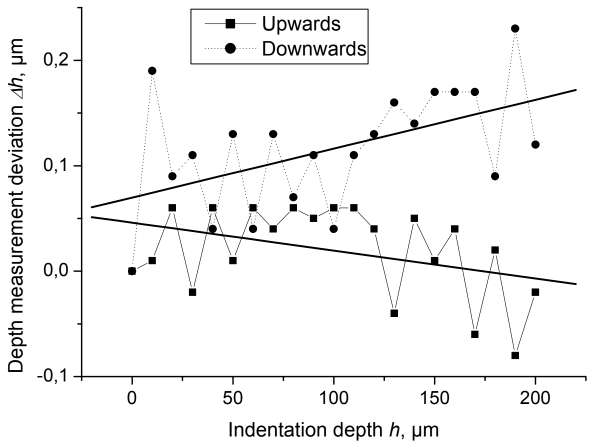

Fig. 3 Calibration results for the up- and downward movement of the depth calibration device with the laserinterferometric reference device RNG 10

Furthermore, in Fig. 4 the difference between up- and downward movement of the depth calibration device is analysed.

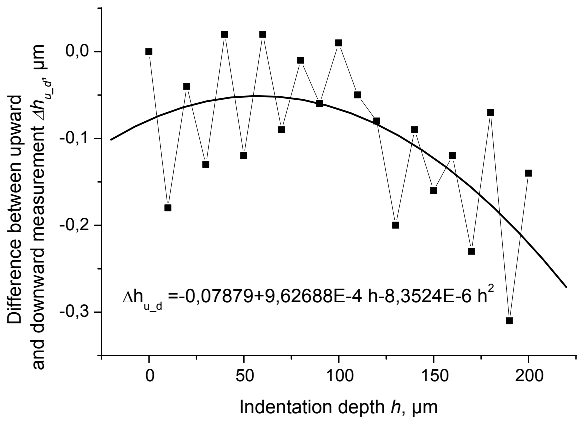

Fig. 4 Difference between up- and downward movement of the depth calibration device

The difference between up- and downward movement of the depth calibration device shows a second order nonlinear course which can be attributed to a small cosine error of the depth calibration device. The mean difference is 0,18 µm and the maximum difference 0,31 µm.

Another measurement is used at the MPA Hannover (see fig. 5). They tested the different between the calibration with and without the test force. Fig. 6 shows the results. The maximum different between the two measurements is 0,6 µm.

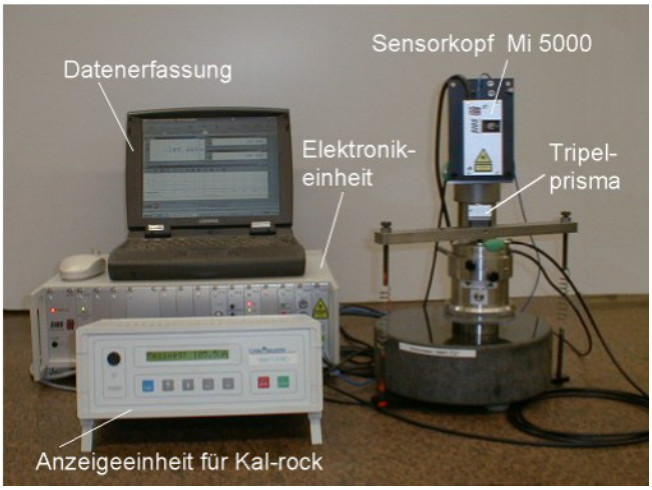

Fig. 5 Calibration of the depth calibration device with the help of the laserinterferometric reference device

Fig. 7 Calibration of the depth calibration device with the help of the line scale reference device

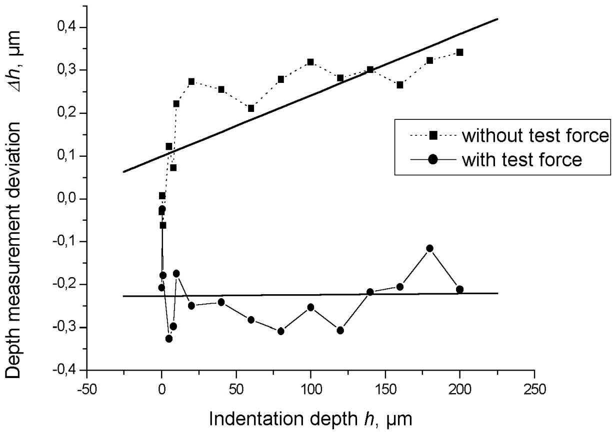

Fig. 6 Calibration results for measurements with or without test force

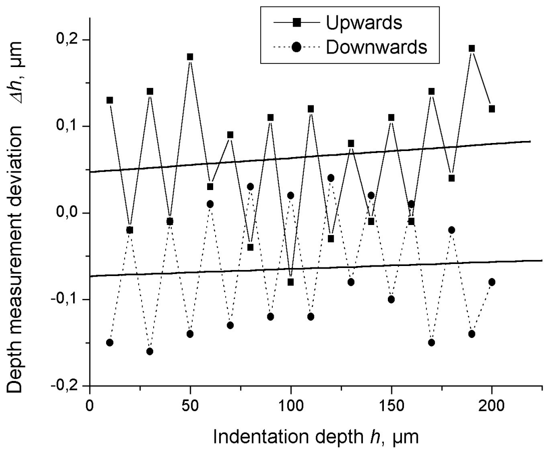

Fig. 8 Calibration results for the upward and downward movement of the depth calibration device with the line scale reference device

3.2 Reference device using a line scale

As a second independent reference device a special calibration device was used into which a line scale length measuring system with a resolution of 2 nm (type MT 1201 from Heidenhain Co.) was fitted. The very stiff frame of the device guarantees neglectable small deformations. The preliminary test force is exerted by a deadweight (m_0 = 10,00 kg) which acts directly on the top of the depth calibration device.

Fig. 7 shows the calibration of the depth calibration device with the line scale reference device and fig. 8 the calibration result. The maximum difference is 0,19 µm

3.3 Estimation of the calibration uncertainty using the depth calibration device

The calibration uncertainty using the depth calibration device is estimated by the following formula:

$$U_{CD} = k \cdot \sqrt{u_{LS}^2 + u_{ms}^2 + u_{CD\_R}^2 + u_{CD\_u\_d}^2 + u_{CD\_D}} \qquad (1)$$

with

u_{LS} - calibration uncertainty of the used length standard

u_{ms} - resolution of the depth calibration device

u_{CD_R} -standard uncertainty of the depth calibration device due to its repeatability

$u_{CD\_u\_d}$ - standard uncertainty of the difference between upward and downward movement of the depth calibration device

u_{CD_D} - longtime drift of the depth calibration device

u_{CD_R} is calculated as follows:

$$u_{CD\_R} = \frac{t \cdot s_{CD\_R}}{\sqrt{n}} \quad (2)$$

with:

s_{CD_R} - standard deviation for n repeated measurements

For s_{CD_R} = 160 nm and n = 40, t = 2,02 the following is received:
u_{CD_R} = 51 nm.

$u_{CD\_u\_d}$ is calculated in an analogous way. Firstly, from the absolute differences between up- and downward movement of the indenter $\Delta(h_u - h_d)$ the standard deviation $s_{CD\_u\_d}$ is calculated. Then the standard uncertainty follows from:

$$u_{CD\_u\_d} = \frac{t \cdot s_{CD\_u\_d}}{\sqrt{n}} \quad (3)$$

With $s_{CD\_u\_d}$ = 80 nm and n = 20, t = 2,09 the result is:
$u_{CD\_u\_d}$ = 37 nm.

Finally, for the values:

u_{LS} = 10 nm
u_{ms} = 100 nm
u_{CD_R} = 51 nm
$u_{CD\_u\_d}$ = 37 nm
u_{CD_D} = 0 nm

the expanded uncertainty U_{CD} = 0,24 (k = 2)µm is obtained.

4. APPLICATION OF THE DEPTH CALIBRATION DEVICE FOR THE DIRECT CALIBRATION OF A DEPTH MEASURING SYSTEM IN A HARDNESS TESTING MACHINE

The depth calibration device was used in order to carry out the direct calibration of the depth measuring system in a hardness testing machine of the type HP 250 (Manufacturer: WPM Leipzig, Germany). Fig. 9 shows the calibration result.

The depth measurement deviation of this hardness testing machine over the whole investigated range exceeds the error limit of 0,001 mm in EN ISO 6508-2, but in the practically used range between 0 and 140 µm the deviation amounts to less than 1,0 µm. The fitted quadratic course of the depth measurement deviation over the indentation depth can be used for a correction of the depth measuring system. This option is of special interest for computer controlled hardness testing machines where the fitted regression curves of the depth measurement deviation can be input for correction.

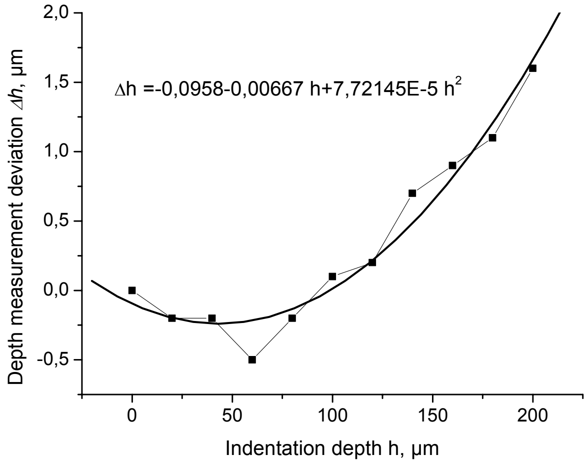

Fig.7 Calibration result of the depth measuring system in the hardness testing machine HP 250

5. CONCLUSION

The use of depth calibration devices of the investigated type will contribute to an accuracy raise of the Rockwell hardness measurements in industrial practice. In particular, it will be possible with sufficient small uncertainty to realise the direct calibration of the depth measuring system in Rockwell hardness testing machines according to the requirements of EN ISO 6508.

Calibration laboratories performing the calibration of hardness testing machines must carry out this task. Moreover, depth calibration devices are also necessary for the users of hardness testing machines in order to maintain a high quality level of their measurements.

REFERENCES

[1] ISO 6508-2: Metallic materials – Rockwell hardness test – Part 2: Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T)

[2] F. Löffler, A. Sawla, P. Strobel: Calibration of the Depth-measuring Device of Rockwell Hardness Testing Machines, Proc. Joint Intern. Conf. IMEKO TC3/TC5/TC20, September 23 - 27, 2002, Celle, Germany

Authors: Konrad Herrmann, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany Tel: +49 531 592 5140; Fax: +49 531 592 5105; e-mail: konrad.herrmann@ptb.de

Anton Stibler, ZAG Ljubljana, Dimiceva 25, 100000 Ljubljana, Slovenia; Tel: +3861 2804 4519; Fax: +3861 2804 4484 e-mail: anton.stibler@zag.si

Imre Patkovszky, MPA Hannover, Welfengarten 1a, 30167 Hannover, Germany; Tel: +49 511 762 2155; Fax: +49 511 762 3003; e-mail: patkovszky@ifum.uni-hannover.de

Peter Strobel, Bareiss Prüfgerätebau GmbH, Breiteweg 1, 89610 Oberdischingen, Germany; Tel: +49 7305 9642 0; Fax: +49 7305 9642 22; e-mail: strobel@bareiss.de

Febo Menelao, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany
Tel: +49 531 592 5140; Fax: +49 531 592 69 5145
e-mail: febo.menelao@ptb.de