Calibration of the depth-measuring device of Rockwell hardness testing machines

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Abstract

In addition to the indirect verification using reference blocks and a reference indenter, it is possible to realise the calibration by direct verification of the test force, the indenter, the depth-measuring device and the testing cycle. Some conditions of the calibration process, e.g. the verification range, and the necessary accuracy of the depth-measuring device are described in standard ISO 6508-2. With reference to these parameters, a new depth-measuring calibration device was developed. The study describes the function of this device and the calibration process. The advantages of this new process are that the measurement takes place in the axis of force application and that the calibration is independent of the Rockwell hardness scales. During calibration, the force stresses the calibration device but not the sensitive measuring sensor. Results of a real depth-measuring device verification are also presented.

1 Introduction

Apart from the indirect calibration of hardness testing machines by means of reference blocks, also a direct method can be applied for calibration. In this case, the test force, the indenter, the depth-measuring device and the testing cycle have to be calibrated. In standard ISO 6508-2, the admissible deviations from the measuring devices or standards are stated, and also from the components of the hardness testing machine to be tested. On the basis of these technical requirements, a device for the calibration of the depth-measuring device was developed. In this paper, the function of the calibration device as well as the calibration process and the results of the device calibration will be described.

2 State of the art

The calibration of the depth-measuring device for Rockwell hardness testing machines is, in the case of the indirect measurement method, carried out with reference blocks and a reference indenter. The hardness of a reference block is determined by means of the hardness testing machine to be calibrated. Afterwards, this hardness value is compared to the known value of the reference block. A disadvantage of this method is that for the calibration of a hardness testing machine several reference blocks have to be used so as to cover different hardness ranges and hardness scales. In consequence, the reference blocks wear out. The measurement uncertainties are limited by the calibration methods for the hardness testing machine and the reference block and by material inhomogeneities. Apart from this indirect method, according to standard ISO 6508-2 also a direct method can be applied to calibrate the hardness testing machine. According to that standard, the test force, the indenter, the depth-measuring device and the testing cycle have to be calibrated. Whilst the calibration of test force, indenter and testing cycle can be carried out by methods which are already known, only a few methods have been developed so far for the calibration of the depth-measuring device. The reason for this is that the calibration of the depth-measuring device has to be carried out at the preliminary test force for the hardness testing machine which, according to ISO 6508-1, is 98,07 N or 29,42 N, and that, at the same time, the requirements of ISO 6508-2 have to be complied with. To this effect, paragraph 4.4.2 of the standard says: "The instrument used to verify the depth-measuring device shall have an accuracy of 0,0002 mm." This means that the limiting deviation of the calibration device is 0,2 µm. Furthermore, this standard requires that calibration be carried out in different subranges and that, for this purpose, "the indenter shall be displaced by known values in the direction of increasing hardness values."

In [1], a device for the calibration of the depth-measuring device is described. With this device, length measurement takes place outside the axis in which the indenter is moved. For the length measurement, a Heidenhain electronic length measuring system - type MT 12 - is used [2].

3 Design example

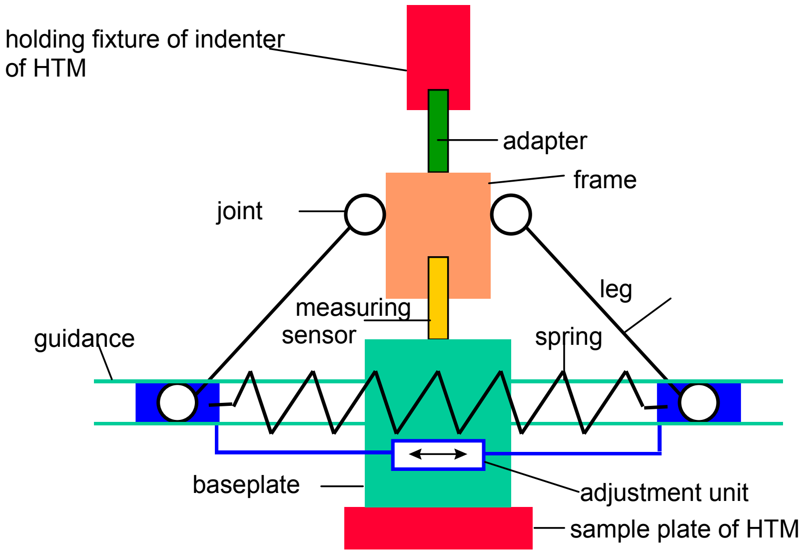
The above-mentioned requirements for a calibration device are complied with in the following design examples. The schematic diagram A in Fig. 1 shows the main elements of the device. The adapter is fastened in the hardness testing machine, and the baseplate is placed on the sample plate of the hardness testing machine. When the preliminary force is applied, the adapter is pressed against the frame on which the force is transmitted via two legs onto a spring and onto the baseplate. The adjustment unit displaces the legs which are carried in a guide at one end while, at the other end, they displace the frame and also the adapter via joints. The displacement takes place by specified intervals within the depth range of approx. 200 µm with the preliminary force being maintained. After each adjustment, the indication of the depth-measuring device of the hardness testing machine is compared with that of the measurement sensor (the calibration process). The length measurement takes place in the force application axis. The limiting deviation required in the standard for the calibration device becomes possible because the necessary adjustment unit and the preliminary test force are decoupled from the point of measurement and thus do not contribute to the measurement uncertainty budget. When the calibration is finished, the calibration device is dismounted and the indenter remounted into the holding fixture of the hardness testing machine.

Another design example is shown in the schematic diagram B in Fig. 1. In this case, the same main elements are used, but this time in a cylindrical set-up. With such a compact set-up, the dimensions of the device can be reduced considerably. Moreover, due to the cylindrical arrangement, a cost-advantageous design is achieved as the components are mainly manufactured by turning. As a result, an economical prototype series was realised without altering the measurement principle and the quality of the device, thus creating the basis for widespread use of the device.

This method avoids the above-mentioned disadvantages of indirect calibration and offers the following additional advantages:

- measurement of length variation in the load axis
- measurement under a preliminary test force
- measurement without the preliminary test force being applied to the measurement system
- calibration of the length measurement unit with only one device for all Rockwell scales and for the entire hardness range
- decoupling of the acting preliminary test force from the length measurement and at the same time measurement of the depth adjustment in the load axis and
- decoupling of the adjustment unit from the measurement unit of the calibration device.

Version A:



Version B:

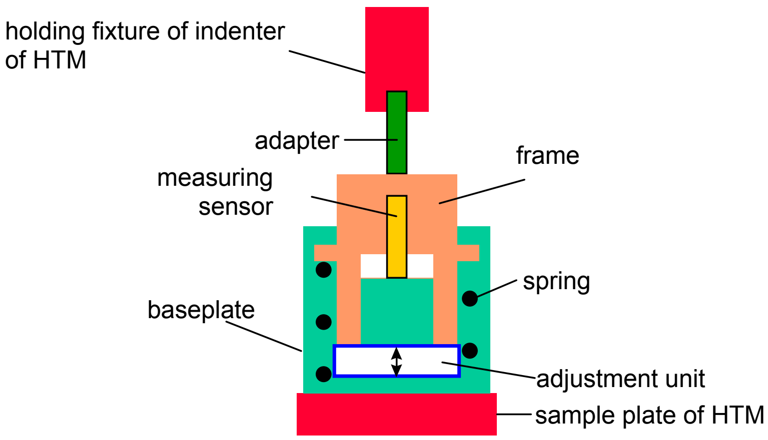


Fig. 1: Design example of the calibration device

4 Calibration process

For the following description of the calibration process, the calibration device according to schematic diagram A was used:

(1) Replacement of the indenter by an adapter and setting-up of the calibration device on the sample plate
(2) By triggering off the preliminary force setting on the hardness testing machine, the adapter is pressed onto the frame and stretches the spring via the legs.
(4) Positioning of the measuring sensor on the baseplate and folding-in of the adjustment unit.
(5) Adjustment of the adapter level by setting the adjustment unit, and step-by-step comparison of the indication of the measuring sensor with the indication of the depth-measuring device (the calibration process).
(6) Removal of the preliminary force.
(7) Dismounting of the calibration device and remounting of the indenter.

5 Measurement results

The comparison measurements were carried out on a conventional mechanical hardness testing machine according to the calibration process described above. After application of the preliminary force, the adjustment unit of the calibration device is coupled in. Now the adapter which is fixed in the machine holder is levelled down to the position which corresponds to the smallest hardness value of the hardness scale to be calibrated. From here, the adapter is adjusted step by step, each time by one hardness value, in the direction of increasing hardness. For each indication value of the depth-measuring device of the hardness testing machine, the associated value indicated by the calibration device is recorded. At the end, the intervals corresponding to one hardness value are calculated. For the hardness scales HRA to HRK, one hardness value corresponds to a variation of the depth by 2 µm (1 µm for the HRN and HRT scales). As during a hardness test the difference between the depth after application of the preliminary test force and the remaining depth after removal of the additional test force is always determined, this was also the case during this measurement. The results are shown in Fig. 2.

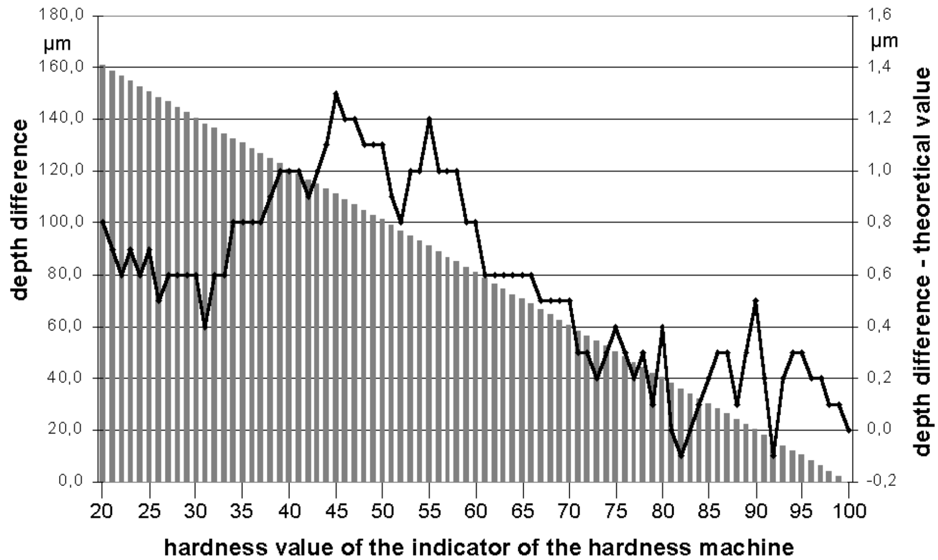


Fig. 2: Measuring results by comparing the values of the sensor and the hardness machine

The reference value for all measurements is the position of the adapter after application of the preliminary test force. In this measurement example, it is at the indication 100. For the indication 20, for example, which would correspond to a hardness of 20, a theoretical difference of (100 - 20) · 2 µm = 160 µm derives. In this case, however, a depth difference of 160,8 µm was measured from which the deviation from the theoretical value of 0,8 µm follows, which on the left in the diagram is scaled.

The total measurement deviations range from - 0,1 µm to + 1,3 µm. After adjustment of the depth-measuring device around a value of + 0,6 µm, the limiting deviation is at ± 0,7 µm. The limiting deviation of ± 1,0 µm required by the standard is thus complied with.

6 Contributions to measurement uncertainty

The factors influencing the measurement uncertainty of the calibration device and of the calibration method are in particular the following:

- limits of permissible errors of the measuring sensor
- axial misalignment between the adapter and the calibration device
- tilting of the adapter in relation to the measuring axis
- force variation during measurement
- resolution of the indication
- shocks

According to information from the manufacturer, the limit of permissible errors of the measuring sensor is ≤ 0,15 µm. At the Geometrical Standards Section of the PTB, the measuring sensor was calibrated additionally in the measurement range from -100 µm to +100 µm. For this purpose, in each subrange (0 to +100 µm and 0 to -100 µm), 10 comparison measurements were carried out starting with 0 up to higher absolute values and back again to 0. The result of these measurements in the subrange from 0 to –100 µm is shown in Fig. 3. The expanded measurement uncertainty is U = 0,5 µm and derives from the standard deviation by multiplication by the coverage factor k = 2. The calculation basis is the "Guide to the Expression of Uncertainty in Measurement."

Due to the manufacturing tolerances, the possible axial misalignment is 0,01 mm for the position adapter and 0,2 mm for other adapters which, however, were not used in the measurement described above. In connection with tilting, the axial misalignment can lead to a deviation.

The deviation resulting from the tilting of the adapter can be determined by means of the geometry relations of the calibration device. This way, tilting between the measurement axis of the hardness testing device to the measurement axis of the calibration device of 0,1° leads to a deviation of 2 µm. The deviation of the preliminary test force of ± 2 % which is admissible according to standard DIN EN ISO 6508-2 can bring about a change in length which is also dependent on the design and the materials used for the calibration device. For the calibration device shown in schematic diagram A, this means a deviation of 13 nm. The real variation of the preliminary test force, however, was considerably lower for the hardness testing machine used.

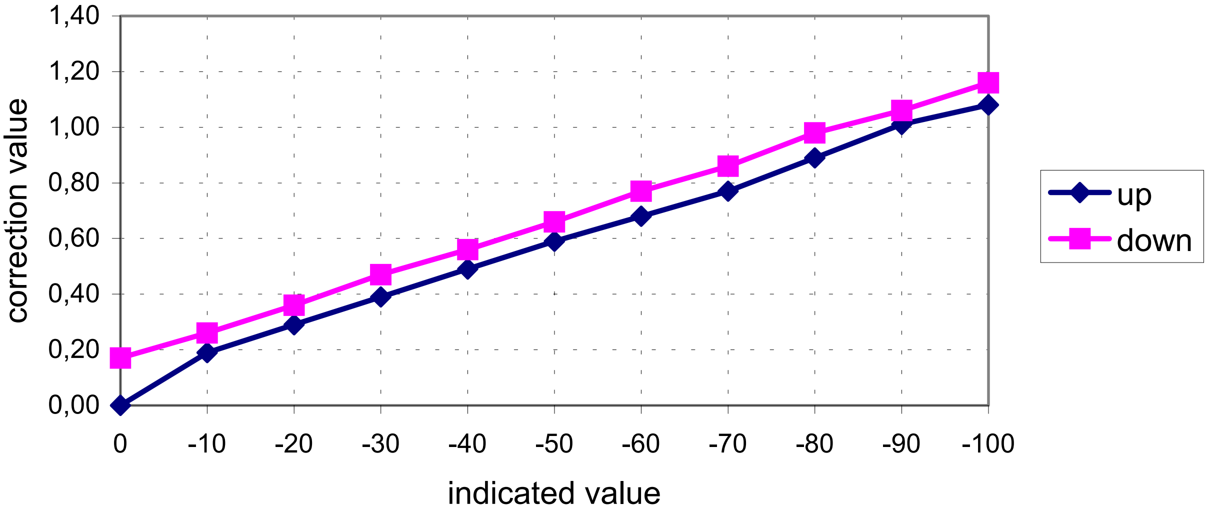


Fig. 3: Result of the comparison measurement in the range from 0 to -100 µm. The correction value derives from the indicated value of the measuring sensor minus the value of the standard measuring device.

The resolution of the indication depends strongly on the type of indication of the respective hardness testing machine. For a dial gauge, a resolution of ± 0,1 scale divisions can be assumed.

In the case of perceptible vibrations, the measurement has to be rejected because these vibrations can have a considerable influence on the measurement.

7 Summary

On the basis of standard DIN EN ISO 6508-1 and -2, a calibration device and an appropriate calibration method were developed. By means of this calibration method, the measurement values of the depth-measuring device of a hardness testing machine are compared to those of the calibration device. The depth-measuring device is thereby subjected to a load (preliminary test force). The function of the calibration device was tested in a comparison measurement. The measurement on a conventional, mechanically working hardness testing machine showed that the limiting deviation of ± 1,0 µm required by the standard is complied with.

9 Literature

[1] Pereira, M. F. F.: Calibration of hardness machines and machine parts; in VDI REPORT No. 1194, pp. 287 to 292, 1995

[2] N. N.: Operating Instructions of Heidenhain "Heidenhain-Metro MT 12 / MT 25 / MT 12B / MT 25B;" No. 227 366 94 5/96

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