VERIFICATION OF THE MICROSCOPE CALIBRATION RULER

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The article deals with the methodology of verification of the calibration ruler for the microscope. These calibration rulers are used for the calibration of measuring microscopes and are therefore always supplied without a calibration protocol. However, it is necessary to find a way to determine the measurement uncertainty when using a measuring microscope.

KEYWORDS

calibration, measuring microscope, calibration ruler, standard

1 INTRODUCTION

Measuring microscopes (Fig. 1) are currently more affordable devices for measuring the geometric dimensions of small components, but when using a measuring table, it is also possible to measure larger components that do not fit into the objective. This article focuses on measuring miniature components that have the measured dimension entirely in the field of view of the microscope objective. Most measuring microscopes come with software and a calibration ruler (Fig. 2) for this purpose, which allows you to calibrate the measuring microscope. The problem is, however, that this calibration ruler (Fig. 2) is not calibrated, and it is difficult to find a workplace for calibrating such rulers. We are trying to solve this problem by internal calibration [EA-4/02 1999, ISO 10360-7: 2011, JCGM 100 2008, JCGM 104 2009, JCGM 200 2012].

Figure 1. Measuring microscope

Microscope calibration ruler (Fig. 2) can be in various forms. Manufacturers often make it in the form of transparent foils with applied graduation scales. However, these foil calibration rulers are not very resistant to damage and also have a high coefficient of thermal expansion. There are several types of calibration rulers. Some have only linear scales. Some also display angular sections, grids, circular or arcuate parts. In this work, we deal with glass calibration rulers with a scale (Fig. 2). On this glass calibration ruler, two linear scales are applied inside the circle.

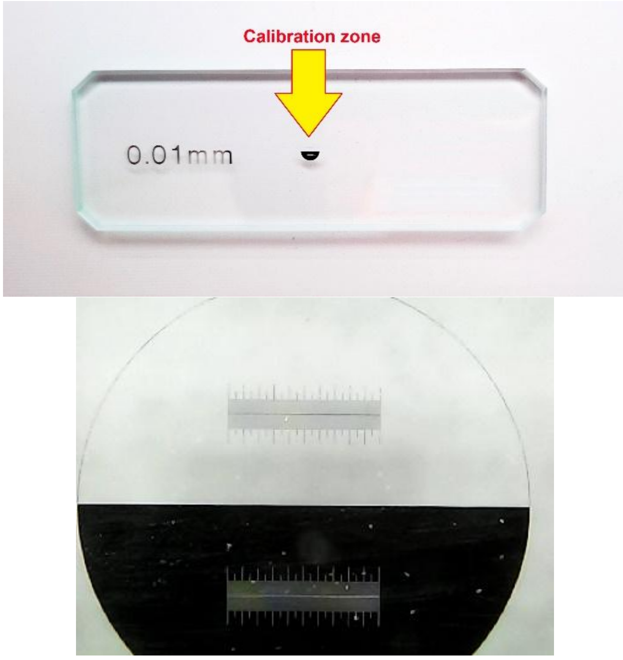

Figure 2. Microscope calibration ruler

2 MATERIALS, METHODS AND DEVICES

The calibration ruler (Fig. 2) has two identical linear scales, one in white on a black background and the other in black on a transparent background. Both scales have a total length of 1 mm and a **main scale division** (MSD) of 0.1 mm, while these sections (0.1 mm) are further divided by **smallest scale divisions** (SSD) with a resolution of 0.01 mm (Fig. 3). This information about the smallest resolvable value is also indicated on the calibration ruler. For the protection of the manufacturer, the information about the manufacturer and the serial number of the ruler are deleted from the ruler.

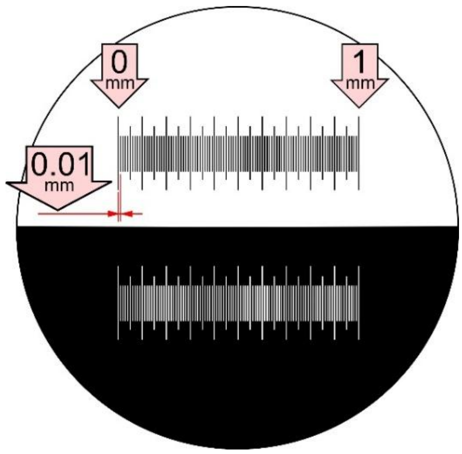

Figure 3. Microscope calibration ruler – description of scale

The first phase (Fig. 4) of ruler verification was carried out **only on the main scale division MSD**, i.e., the distances of the divisions 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9 and 1 mm from the 0 mm division were measured. The ruler is marked as longer scale lines. For most measuring microscopes, these scale lines are sufficient for calibration (Fig. 4).

The second phase (Fig. 5) of ruler verification was focused **only on measurements on the smallest scale divisions SSD**, i.e., the line from 0 mm to 0.1 mm was measured with a resolution of 0.01 mm. The distances of the scale divisions 0.01; 0.02; 0.03; 0.04; 0.05; 0.06; 0.07; 0.08; 0.09 and 0.1 mm from the first scale division 0 mm. This second phase is only useful for high-resolution measuring microscopes (Fig. 5).

All distances were measured 10 times to assess the variability of the data and evaluate the measurement uncertainty of the calibration ruler.

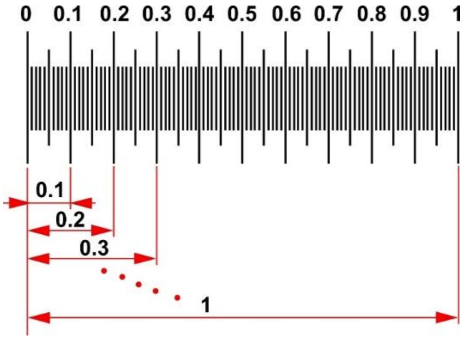

Figure 4. First phase - verification strategy of microscope calibration ruler verification – main scale divisions

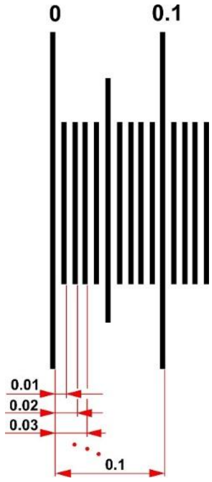

Figure 5. Second phase - verification strategy of microscope calibration ruler verification – smallest scale divisions

A high-resolution measuring microscope was used for the measurement, which was calibrated using reference gauge blocks. This measuring microscope is digitized with position measurement using precise encoder rulers and a measuring camera (Fig. 6).

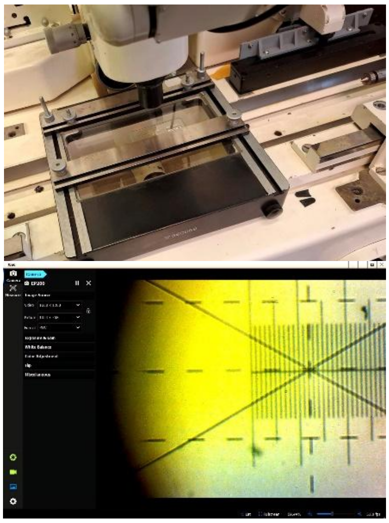

Figure 6. Calibration ruler verification on the reference measuring microscope

3 RESULTS

The sequence of measured dimensions for both stages is chronologically shown in Figures 7 and 8 for each nominal value. The variability of the measured dimensions is also visible from the curves of the measured values. From these curves (Fig. 7 and 8) it seems as if the dispersion of the data for the MSD stage type (Fig. 8) is smaller. However, this is because the data display is on a different scale.

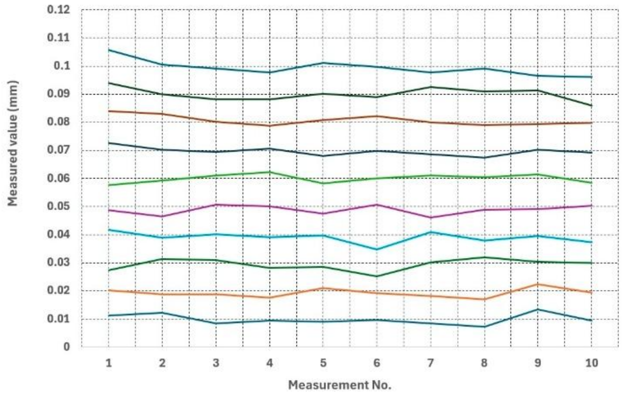

Figure 7. Measured values - smallest scale divisions SSD

Figure 8. Measured values - main scale divisions MSD

For a better presentation of the results, it is better to display the average measured values for the individual nominal values of the calibration ruler. Therefore, a graphic display of the average values for the individual verified scale divisions for the smallest scale divisions SSD (Fig. 9) and for the main scale divisions MSD (Fig. 10) is created.

The average values are determined from ten measurements taken at individual locations at a distance from the start of the scale for both measurement strategies.

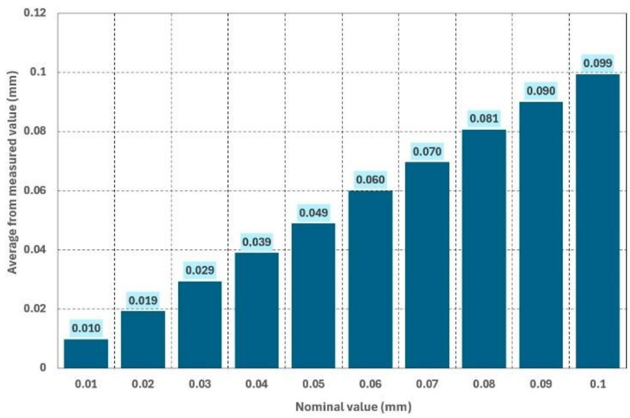

Figure 9. Average values from measurements - smallest scale divisions SSD

For the purposes of processing the measurement results, it is possible to present the results also in the form of average deviations from the nominal values. These deviations can be considered as systematic errors that can be corrected when calibrating the measuring microscopes. The deviations were determined as the difference between the average measured value l_c and the nominal value l_N:

$$\delta l = l_c - l_N \qquad (1)$$

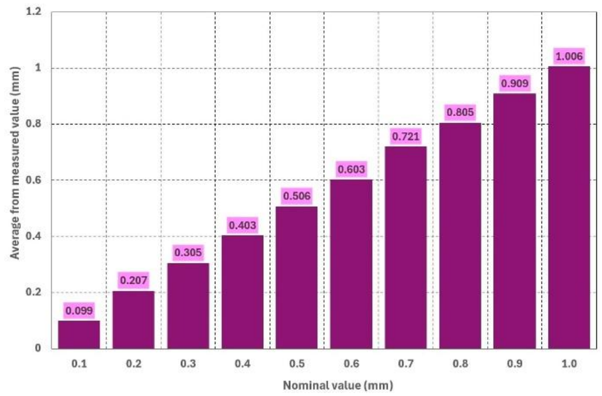

Figure 10. Average values from measurements - main scale divisions

The average deviations are shown again for the smallest scale divisions SSD (Fig. 11) and for the main scale divisions MSD (Fig. 12). These values show that for both phases of measurement the deviations are maximum up to 3% of the nominal value, which means that the calibration ruler is suitable for calibrating workshop measuring microscopes with a resolution of up to 10um for which this calibration ruler is intended.

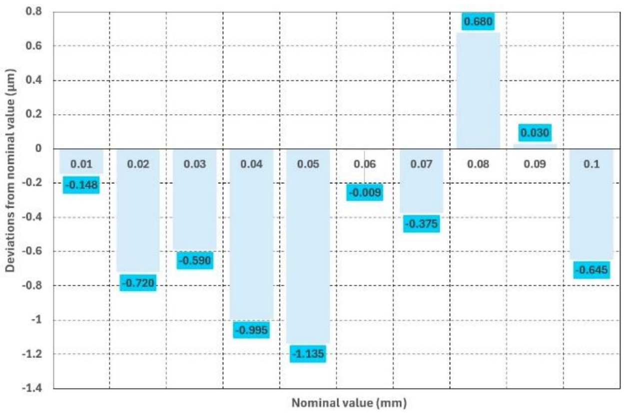

Figure 11. Average deviations of measurement values from nominal values - smallest scale divisions SSD

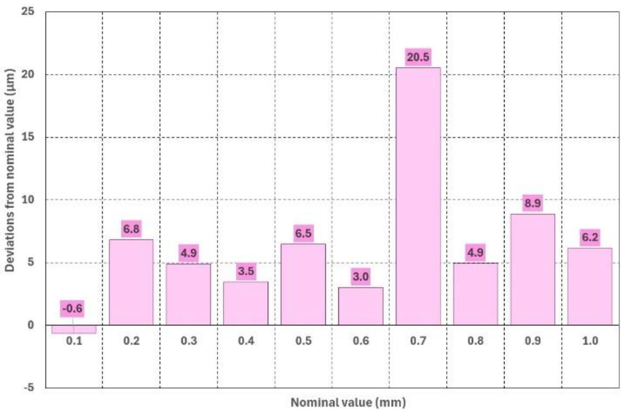

Figure 12. Average deviations of measurement values from nominal values - main scale divisions MSD

For the determined deviation values, it is also necessary to determine the uncertainties of their determination. From the uncertainty analysis, we can determine several sources of measurement uncertainties that need to be taken into account when calculating the uncertainties of deviation determination for a verified calibration ruler:

The combined uncertainty of average deviations determination is defined by:

$$u_c = \sqrt{u_{AM}^2 + u_{BRM}^2} \quad (2)$$

where

u_{AM} – standard uncertainty determined by method A (from realized measurement of deviations),

u_{BRM} – standard uncertainty of precision measuring reference microscope (Fig. 6) determined by method B from calibration certificate.

The determined values of combined uncertainties of determining the average deviations of the nominal values of the calibration ruler for the smallest scale divisions SSD (Fig. 13) and for the main scale divisions MSD (Fig. 14) are graphically displayed.

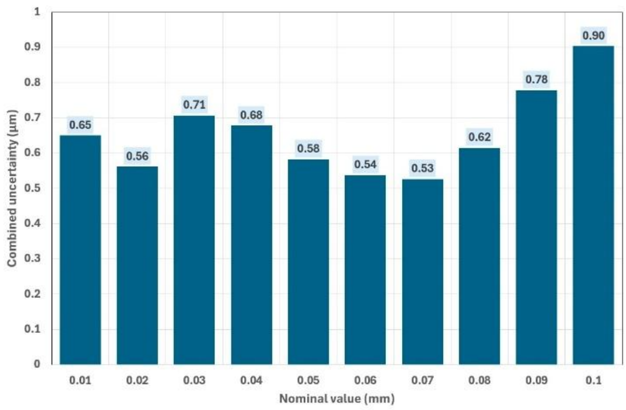

Figure 13. Combined uncertainty of calibration ruler - smallest scale divisions SSD

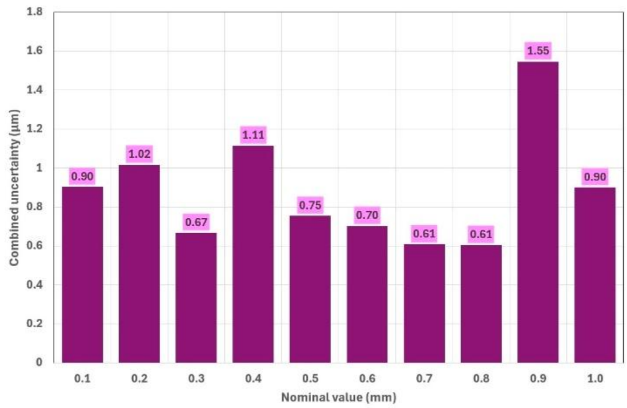

Figure 14. Combined uncertainty of calibration ruler - main scale divisions MSD

4 CONCLUSIONS

Nowadays, more and more miniature components are used in machines and devices, which are relatively complicated and difficult to measure with conventional manual measuring instruments. Measuring using coordinate measuring machines is a rather expensive investment that may not be profitable for every component manufacturer. Measuring toolmaker microscopes are an excellent alternative for measuring such components. The maximum permissible error of these types of measuring microscopes is at the level of 10um. These types of measuring microscopes, which we also use for conventional measurements, but for optical measurements carried out within the objective, need internal calibration using a microscope calibration ruler. These internal calibrations are recorded in the measurement software and when measuring at different heights from the objective, this calibration must be performed again.

But if we need to calibrate a measuring microscope, the calibration ruler must also be verified to meet our metrological requirements necessary for calibrating measuring microscopes. Based on this situation, this means that we need to know our calibration ruler in order to be able to report the measurement uncertainty for measurements made on measuring toolmaker microscopes.

In this work, we solved the problem of how to verify our calibration ruler, which was supplied to our measuring microscope as a standard accessory, but it was not supplied with a calibration certificate that would provide information about the systematic errors of our calibration ruler and also information about the uncertainty of determining its dimensions.

For the verification of such calibration rulers, our workplace has a reference measuring microscope that is able to verify this calibration ruler.

The result of the verification process is information about the current values of the scale division dimensions and at the same time we also have information about the uncertainty of determining these dimensions.

The verification results show that the calibration ruler successfully passed the verification test.

Only now is it possible to determine, when calibrating a measuring microscope, what contribution the calibration ruler currently used has to the measurement uncertainty.

Similar problems related to the balance of uncertainties in measurement, calibration and verification of measuring instruments and reference standards must also be addressed in other areas [Blatnicky 2020, Bozek 2016, Brada 2023, Bratan 2023, Duplak 2023, Hortobagyi 2021, Hroncova 2023, Kelemen 2021, Kelemenova 2021b, Klarak 2021, Klichova 2025, Koniar 2014, Kuric 2021, Machac 2023, Mascenik 2016, Mikova 2022, Pavlasek 2018, Peterka 2020, Pivarciova 2021, Romancik 2024, Semjon 2024, Stejskal 2016, Vagas 2024, Vagas 2025].

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