CALIBRATION CURVE OF SENSOR WORKING BY THE TRIANGULATION PRINCIPLE AND EFFECT OF TILT ON MEASUREMENT ABILITY

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Abstract

This paper deals with creating a calibration curve of a laser sensor that works on the principle of triangulation. It demonstrates the change of the calibration curve mainly by the different tilt angles of the sensor. The change in angle represents the effect of sensor mounting on the measurement results and the importance of taking proper mounting to obtain the most accurate measurement results. Calibration was performed under as stable ambient conditions as possible and using the optical standard as a suitable instrument for calibrating the sensors. The following article highlights the importance of calibration. The effect of sensor inclination on the calibration curve and the importance of correct sensor installation on measurement accuracy.

Keywords: Measurement, triangulation, calibration, calibration curve.

1 Introduction

Measuring instruments and measuring devices are currently subject to high precision requirements. It was necessary to develop measuring instruments and devices of such quality and precision that they could measure with sufficiently high accuracy. Therefore, the quality requirements of the measuring devices are now high. What ensures that a measuring device, measuring instrument or sensor works correctly, provided that the correct conditions of measurement and its use are met is calibration. Calibration can be expressed in various ways, such as data, calibration function, diagram, calibration curve or table [1]. This paper deals with the findings of the influence of the tilt sensor on its accuracy and repeatability. These were detected when calibrating the sensor. As a result of the calibration, a calibration curve was created at several sensor tilt angles, which show at first glance the changes in measurements at the different tilt angle of the triangulated sensor.

2 Meaning of the calibration curve

The operation of detecting and documenting data deviations that indicate a measuring instrument from a conventionally true value of a measured quantity is called calibration. The result of the calibration may be an indication, a calibration function, a calibration diagram, a calibration curve or a calibration table. However, the International Vocabulary of Basic and General Metrology Terms (VIM) does not define these terms in any detail or specifically describe the output documentation that arises during the calibration process [2]. Calibration should not be confused with the adjustment of the measuring system or with verification of the calibration. The calibration curve represents the relationship between the measurement sensor indication and the corresponding value of the measured quantity [3].

Each measuring instrument should be calibrated before placing it in normal operation or when the use of the measuring instrument has changed significantly. Furthermore, if the specified calibration time has elapsed, and also when the instrument starts to display inconsistent data [4]. The calibration interval may be shortened or extended for certain applications. If the sensor resp. the measuring device shows long-term stable results, the calibration interval can be extended. If there are any doubts about the correctness of the sensor data resp. of the measuring device, the sensor should first be checked for damage. If so, find the cause and then remove it. If not, the calibration interval should be halved [5, 6].

3 Description of measuring devices

Modern laser transducers based on the triangulated measurement principle are based on the fact that if the beam is reflected from the detected object at a constant angle, the distance of incident of the reflected beam on the front of the sensor is proportional to the distance of the detected object from the sensor. Nowadays there are many different standards. Their quality must be as high as possible. The most modern standards are currently optical standards. They are designed in different designs depending on how they are used in practice. Interferometer is an instrument designed for high precision measurements. [7]

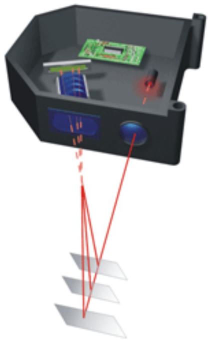

Fig. 1 *Diagram of the triangulated sensor*

Fig. 2 *Triangulation sensor optoNCDT 1420*

Its function is based on the principle of light interference. Advantages of the interferometer as well as the other mentioned standards are very high measuring accuracy, high speed and ability to measure angles. The interferometer is one of the most accurate and flexible systems currently used to calibrate transducers and measuring machines and instruments [8]. The Renishaw XL - 80 laser interferometer is shown in Fig. 2.

Fig. 3 *Laser head XL – 80*

Fig. 4 *Interferometer Renishaw*

4 Measuring by a sensor when changing the tilt angle

A very important factor in the measurement is to ensure the same conditions during the measurement as well as all repeated measurements. These relate not only to the measuring system itself but also to the environment in which the measurement takes place. It is the influence of the environment that has a considerable effect on the measurement and it is very difficult to ensure in particular temperature stability, which is very important during calibration [9, 10]. The measurements were carried out in a closed room under the same conditions. The conditions under which measurements were taken are shown in Table 1.

Table 1 *Measurement conditions*

Room air temperature	25 ° C
Atmospheric pressure	986 hPa
Air humidity	40 %
Number of people in the room	2
Cycle type	Linear
Measuring range	0 – 10 mm
Step size	0,5 mm
Angle adjustment accuracy	0,05 °
Powering the triangulating sensor	1,48 V / 0,03 A

For the purposes of measurement was assembled measuring assembly, which consisted of a sliding table on which the detected object was placed, measuring optics interferometer. For measurements on the measuring assembly, the triangulated transducer with holder was placed on a digital spirit level. Using it was tilted first by an angle of 0.20º and later by an angle of 0.60 º. The measurements result in calibration curves. They show the deviations of the values indicated by the triangulation sensor and the reference values represented by the laser interferometer. The measurement assembly is shown in Fig. 5 and Fig. 6.

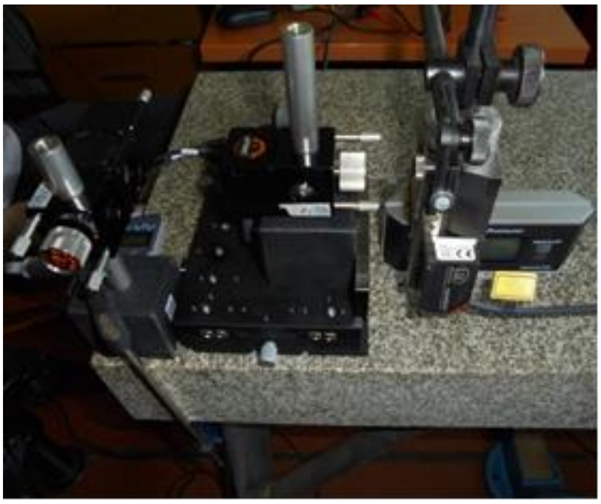

Fig. 5 *Measuring assembly*

Fig. 6 *Connection of the sensor optoNCDT 1420*

5 Measurement results and change of calibration curve

Using the prepared measuring set, a series of measurements were performed in order to detect deviations of the triangulation sensor from the measurement standard represented by a laser interferometer. After measurement, the values indicated by the triangulation sensor and the laser interferometer were entered in the table. Subsequently, they were subtracted from each other and the deviation values were determined [11, 12]. Using these values a calibration curve was created for the sensor without tilting respectively. with an angle of 0º. At the end of the last measurement, the sensor was mounted on a digital spirit level inclined at an angle of 20 ° and measurements were repeated. The same procedure was carried out at an angle of 40 ° and 60 °.

Measurements were repeated several times for each sensor position because of higher accuracy of the measured values. After processing all measurements, separate calibration curves were created for each sensor position measured. The graphs show that the graphs differ in these measurements due to the different tilt angle settings of the triangulation sensor. For the first measurements, the sensor was tilted by 0º, the calibration curve is shown in Fig. 7. In the second series of measurements it was an angle of 0.20º, the calibration curve is shown in Fig. 8. Subsequent measurements were made at an angle of 40 °, the calibration curve is shown in Fig. 9. The highest angle was 60º in the last series of measurements, the calibration curve is shown in Fig. 10.

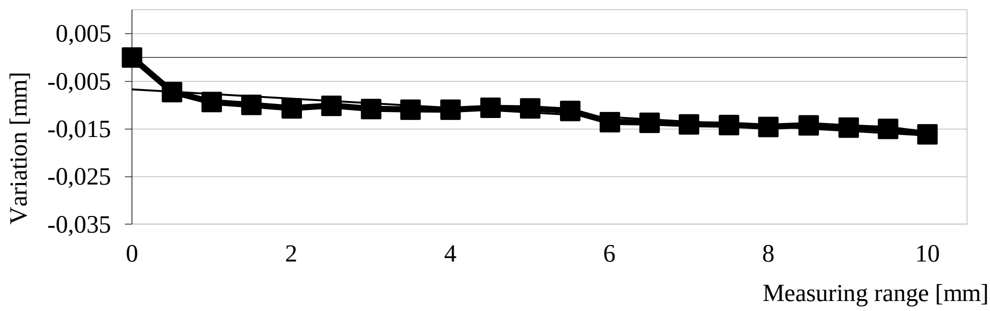

Fig. 7 *Calibration curve at 0º tilting*

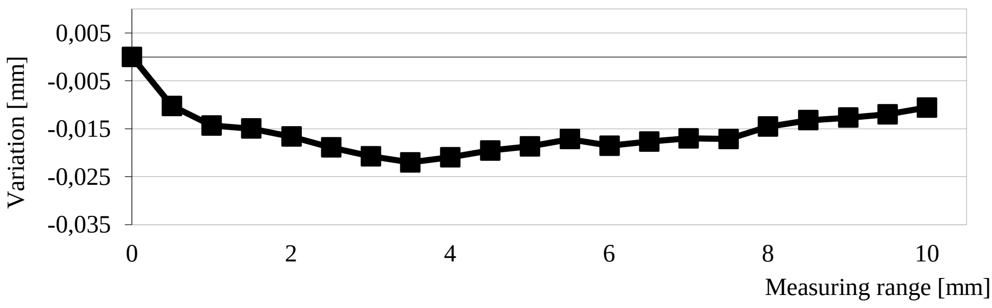

Fig. 8 *Calibration curve at 20º tilting*

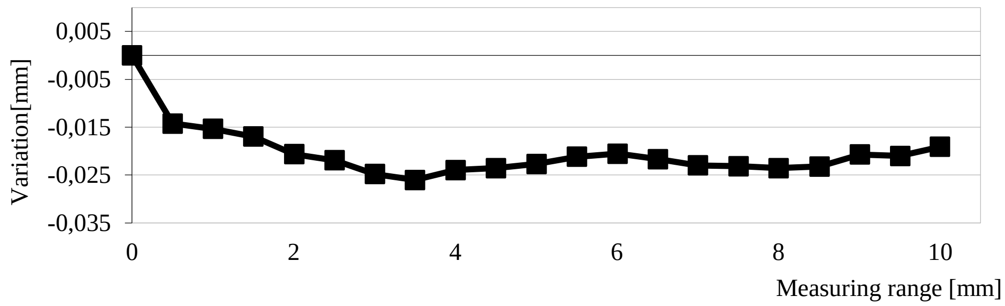

Fig. 9 *Calibration curve at 40° tilting*

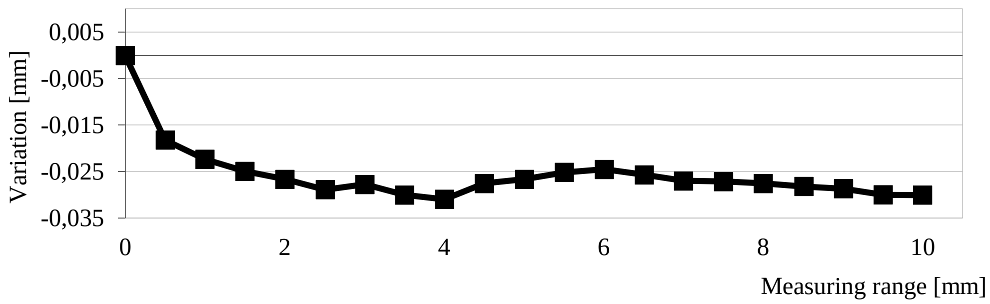

Fig. 10 *Calibration curve at 60° tilting*

A common graph of all measurements was created to compare the results and the differences in the calibration curves with the different tilt of the triangulation sensor. In this comparison, the difference in the calibration curves is clearly shown. The comparison shows the effect of tilting on the calibration curve. Gradually, as the tilt angle increases, the deviations of the triangulation sensor from the value represented by the standard and at the same time between the angles increase. As a result, the tri-regulating sensor is sensitive to adjustment. When using the sensor, this must be taken into account and quality mounting must be ensured. A comparison of the calibration curves of all series of measurements is shown in Fig. 11.

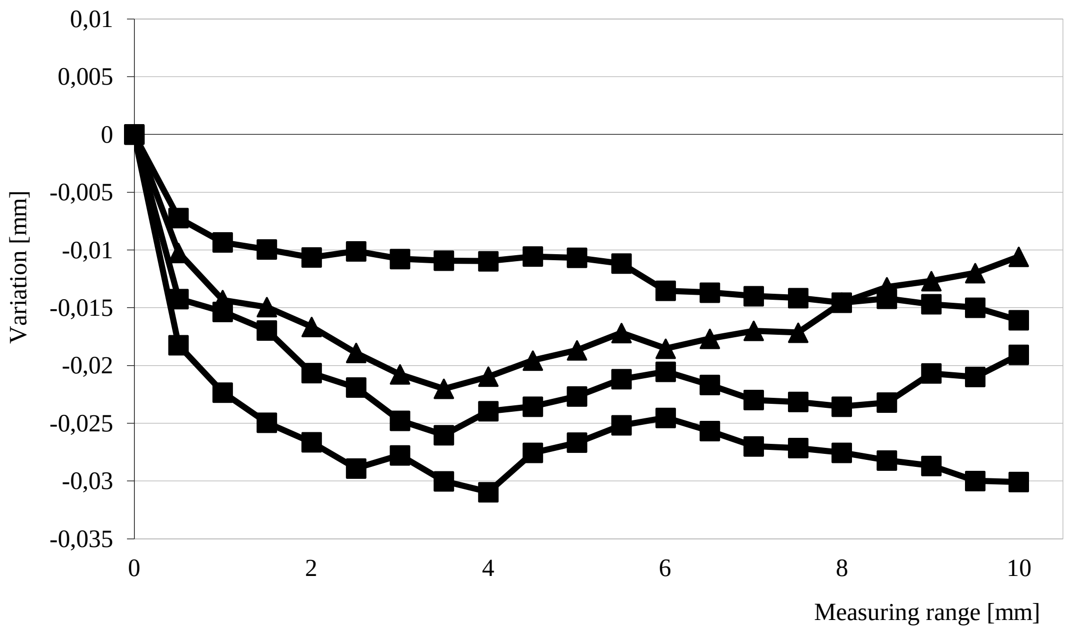

Fig. 11 *Changing the calibration curves*

6 Conclusion

Several series of measurements were performed, the purpose of which was to find out how the sensor working on the principle of triangulation will behave when changing the direction of the laser beam on the impact surface of the sensor. In this case, a change in the beam orientation is a change in the tilt angle of the entire sensor. The question was what effect this change would have on the accuracy and measuring ability of the sensor. The calibration curves show the deviations of the values indicated by the triangulation sensor and the reference values represented by the laser interferometer. The calibration curves were the same for each measurement. very similar. They only changed if the measurement conditions, such as the tilt angle of the sensor, have changed. This implies that the repeatability error is small compared to the measurement error. Conversely, the accuracy of the sensor varied over the entire measuring range. The calibration curve graph shows that at the beginning of the measuring range at a distance of 0 to 2 mm, the triangulation sensor measures with greater accuracy than for measurements in the range of 2 to 10 mm. Comparison of the calibration curves shows the effect of tilting on the calibration curve. This implies that the triangulated sensor is very sensitive to the angle at which it is mounted. When using the sensor, this must be taken into account and quality mounting must be taken into account, as this can directly affect the accuracy of the measured values.

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