Gauge Block Interferometer Designed for the Calibration of Short and Long Gauge Blocks

P. Phuaknoi[1], J. Buajarern[1], A. Tonmueanwai[1]

[1]*Dimensional metrology department, National institute of metrology (Thailand), Pathumthani, Thailand* adisak@nimt.or.th

Abstract

This paper describes the design, construction, commissioning and testing of a new gauge block interferometer (GBI) for the gauge block measurement at NIMT. The optical interferometer and the gauge blocks are both situated inside the chamber. Temperature stabilization of 20±0.2 ^{o}C can be achieved and the stabilization can be maintained for days. The configuration of the system is unique in the way that both short and long gauge block can be calibrated with the same system in a single measurement installation.

1 Introduction

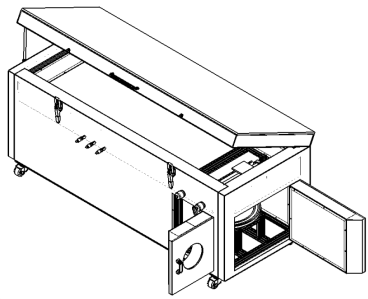
Gauge blocks play a crucial role in maintaining traceability to the 'Metre' in dimensional metrology. The most accurate method for calibrating the length of gauge block is to use optical interferometer [1]. At NIMT, lengths of gauge blocks are measured by the gauge block interferometer (Mitutoyo). Two frequency stabilized He-Ne lasers were used as the illumination giving wavelengths of 633 nm and 543 nm. The measurement chamber environment was controlled and the temperature was kept constant at 20±0.2 ^{o}C. Length of gauge block from 0.5 mm up to 100 mm can be measured with the number of gauge blocks limited to 12 pieces. Due to this limitation, the preparation process and temperature stabilization time of 2-6 hours, gauge block calibration time is approximately 3 pieces per day. This fact causes serious problems to NIMT and our customers. In order to serve the gauge block (grade K or 00) calibration service to all regular customers, calibration intervals must be at least 3 years.

According to ISO 3650, gauge block longer than 100 mm shall be aligned in horizontal orientation [2]. Thus, grade K gauge block length only up to 100 mm can be calibrated with uncertainty of $Q[28, 0.47 \cdot 10^{-6} \cdot L]$ nm at $k = 2$. Gauge blocks longer than 100 mm are calibrated by other NMIs.

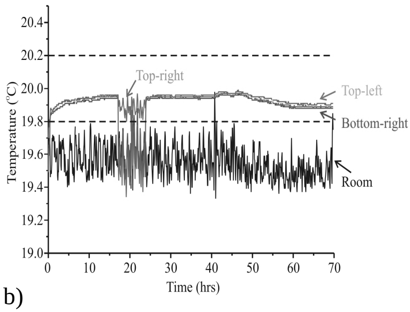
As a result, NIMT decided to design, to construct and to develop a GBI system. In order to minimize the spending budget, the system was designed in a way that both short and long gauge blocks can be measured by using the same optical interferometer system.

2 Gauge block interferometer system

The overall structure of the GBI system is shown in Fig. 1a. The chamber is designed to have 2 doors, top and front sides, which can be opened when the gauge blocks are to be installed for a measurement, or taken out after the measurement. Dimensions of the system are 1729 mm x 929 mm x 948 mm. The chamber is partitioned into two parts. The upper part is occupied with the optical interferometer system and 2 sets of long gauge block supports. The lower part contains a rotary table and a short gauge block housing plate. The number of gauge blocks that can be installed in this system is 2 for long gauge blocks and 30 for short gauge blocks.



a)



b)

Figure 1: a) GBI system b) Temperature variation inside chamber

2.1 Thermal insulating chamber

The chamber is situtated in the laboratory under a controlled environment of 20±1 ^{o}C. The chamber wall is composted of 2 mm thick steel sheet with thermal insulators inside. The temperature stability measurement was performed. Three temperature sensors were placed inside the chamber, two at the upper part and one at the lower part. Another temperature sensor was placed outside the chamber to monitor ambient temperature. After allowing the temperature inside the chamber to be stabilized with room temperature for 5 hours, chamber was sealed and the temperatures inside the chamber were recorded continuously for 70 hours. The experiment was repeated several time and results are plotted as shown in Fig. 1b.

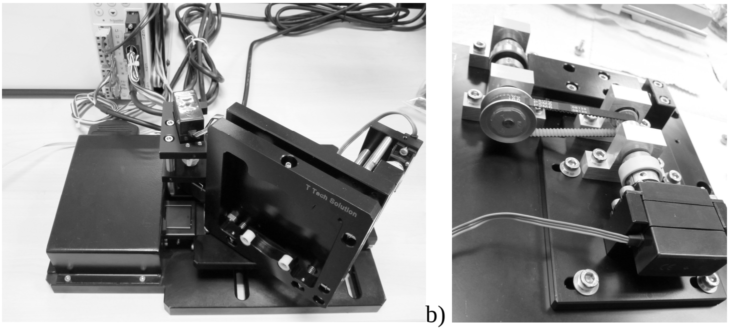
a)  b)

Figure 2: Translation and flip stage a) for reflection mirror and b) for the optical wedge

It should be noted that temperatures inside the chamber took approximately 6 hours to stabilize. The temperature inside chamber is stable at 20±0.2 °C with any variation in temperature at any position inside the chamber being less than 0.02°C. LAB 36 of UKAS recommended that the temperature within the interferometer should be maintained within 20°C ± 0.5°C and variations in temperature shall not exceed 0.1°C per hour, this chamber is suitable for gauge block calibration by using optical interferometer technique [3].

2.2 Tranlating mirror

The moving mirror for long gauge block measurement is designed in a way that collimated laser beams can incident on the measuring face of the gauge block at any given position. The total transverse length of the translation stage is 91.30 mm. Mirror can be tilted around both x- and y-axis for up to ±100 μm through a PC with a resolution of 2 μm. The mirror mount can also be flipped 45° allowing the laser beam to incident on another mirror that is located behind and to travel to the lower part of the chamber allowing length of short gauge blocks can be measured in Fig. 2a.

Movement of the optical wedge is controlled by the servo motor and gear as shown in Fig. 2b. Transverse length of the translation stage is equal to run-out of the camshaft, 50 μm. The minimum transverse speed of 0.17 μm per second can be achieved which is adequate for digitizing the interferogram image of static state of the GBI.

2.3 Rotary table and gauge block housing plate

The gauge block housing plate is a round plate made from aluminum with 30 grooves at 12 degrees intervals. Rotation is controlled by the servo motor which has runout lower than 10 μm. The system is fully automated and can be manipulated externally if require.

2.4 Optical interferometer

The laser interferometer is based on the classical Twyman-Green arrangement using a method of exact fractions for high-accuracy calibration of the gauge blocks. The alignment of the optical components and the beams was done on the optical breadboard that acts as a divider dividing the GBI system into two layers. The optical components are arranged such that the beam double-passes the required length. Three wavelengths were used, 633 nm, 532 nm and 780 nm.

3 Conclusion

The GBI system was designed, constructed, commissioned and tested for the absolute measurement of gauge blocks. This unique design allows the absolute length of gauge blocks, from 0.5 mm to 1000 mm, to be measured by the same system and in a single preliminary set-up. Future works include checking the stability of the optical interferometer components and evaluating the overall uncertainty for the GBI system.

Acknowledgement

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