Prototype of Depth Standard for Elastomer Hardness Tester

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Abstract. National Institute of Metrology (Thailand) has fabricated the prototype of depth standard to calibrate the depth of indentation for elastomer hardness tester according to ISO 18898, ASTM D2240 and ASTM D1415. It was designed as a displacement device consisting a linear scale inside which can measure the indentation-depth covered the measuring range from 0-2.5 mm. The depth standard can acquire the value of indentation depth in accordance with the scale of elastomer hardness tester indicated from 100 shore to 0 shore in steps. The calibration for the prototype of depth standard was carried out by a set of gauge blocks. The accuracy of the prototype was within ±1 µm which met the requirement according to ISO and ASTM standard. Then, the depth standard was used as a part of the indentation-depth measuring system. The calibration stand which was the other part of the indentation-depth measuring system was investigated as a problem issue due to the stand deformation during the indentation depth calibration. NIMT solved the problem by installing another laser measuring device to compensate the movement of elastomer hardness tester due to the deformation of stand. This paper also pointed out the use with a caution of depth calibration procedure by gauge blocks according to ASTM D2240.

1. Introduction
The calibration of depth of indentation was one of the significant requirement for elastomer hardness tester according to the international standard of ISO 18898 [1], ASTM D2240 [2], and ASTM D1415 [3]. It required the length measuring instruments consisting the measuring axes to measure the indentation depth between 100 Shore to 0 Shore. Based on this concept, NIMT had fabricated the prototype of depth standard using linear scale attached to the measuring axes aligned for the movement in the vertical direction with simultaneous reading the displacement. The schematic design of the prototype of depth standard with linear scale was shown in figure 1.

NIMT also investigated the calibration stand, as a part of length measuring system, which obviously showed the deformation and caused to the movement of elastomer hardness tester during the calibration. A laser measuring device was attached to the elastomer hardness tester to confirm the movement and also compensate the depth of the elastomer hardness tester as shown in figure 2. Furthermore, the paper described the use with awareness for depth calibration procedure with dimensional gauge block based on ASTM D2240.

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2. Fabrication on prototype of depth standard machine
The prototype of the depth standard was fabricated with the concept of a displacement device for a length-measuring system. The measuring axes attached to linear scale model ST34, Mitutoyo, was used to displace the indenter of the hardness tester and measure its depth of indentation in the vertical movement with its scale indication from 100 Shore to 0 Shore in step. The fabricated depth standard was final assembled presented in figure 3.

3. Results and discussions
3.1. Calibration of depth standard
A set of gauge blocks was used as a standard to provide the accuracy of the depth standard shown in figure 4. The calibration range was 15 mm fully covered to the operation range of indentation depth for all elastomer hardness testers. The accuracy of the depth standard was within ±1 µm which met the requirements for measuring instruments used for calibration according to ISO18898, ASTM D2240, and ASTM D1145 as shown in figure 5.
3.2. Calibration results of depth of indentation using single column calibration stand

Once the depth standard was successfully calibrated, it was used to calibrate depth of indentation on elastomer hardness tester. Shore D was selected as an obvious example of the hardness tester since it provided the largest spring force on elastomer hardness testers (4.5 kgf at 100 Shore). The single column calibration stand and the depth standard were setup as the depth calibration system presented in figure 6. NIMT found that there was some parts of the single column calibration stand caused the deformation at approximately 80 µm due to the applied spring force from the indenter of shore D. This provided a highest error of depth indentation on elastomer hardness tester to 35 µm out of the tolerance compared to the international standard as shown in figure 7.

![Figure 6. Calibration setup of elastomer hardness tester using single column stand.](image)

![Figure 7. Depth calibration results using single column stand for Shore D.](image)

3.3. Calibration results of depth of indentation using double column calibration stand with laser measuring device

The huge error of depth calibration when using single column stand confirmed that the deformation of the stand can affect the depth calibration results. NIMT solved the problem by using double column calibration stand with another laser measuring device. The double column stand can provide significantly smaller deformation compared to the single column stand. Furthermore, the laser measuring device was installed to detect the movement of the elastomer hardness tester and then compensate the depth to determine the real indentation depth. The calibration setup and results of depth of indentation using double column calibration stand with laser measuring device was presented in figure 8 and 9, respectively. The results was obviously showed that the depth error was within the standard tolerance.

![Figure 8. Calibration setup of elastomer hardness tester using double column stand with laser measuring device.](image)

![Figure 9. Depth calibration results using double column stand with laser measuring device.](image)

3.4. Depth calibration issue on ASTM

In this section we pointed out the depth calibration procedure of elastomer hardness tester according to ASTM D2240-15 [2]. The dimensional gauge blocks were used as a standard for depth calibration by
arrangement of the gauge blocks to verify the relationship between the indenter travel and indicated display hardness scale as shown in figure 10. However, it did not mention the material uses of gauge blocks. There are several types of elastomer hardness tester depended on the geometry of the indenters and the applied spring force. In case that the shape of the indenter was not sharp and the applied spring force was not large, the gauge block was suitable for use. However, carefully consider should be taken when the indenter tip was relatively sharp and the applied spring force was quite large such as Shore D. NIMT found that there was some sign of pressing as the hole on the surface of steel gauge block when apply the force at 100 shore D as shown in figure 11. The surface appearance and the depth profile was examined by scanning confocal chromatic instrument. The hole was approximately 4.5 micron which can make the result error about 0.2 shore as shown in figure 12. However, the defect was not significantly obvious when use the dimensional gauge block made by tungsten carbide (WC). The defect appeared on WC and the hole about 1 µm was shown in figure 11 and 12, respectively. It pointed out that depth calibration of Shore D should use gauge blocks made by WC rather than steel or ceramic to eliminate the defect on gauge block.

4. Conclusion
The prototype of depth standard for elastomer hardness tester was fabricated to calibrate the depth of indentation for elastomer hardness tester. The depth standard was calibrated and confirmed that its accuracy met the requirement to the international standard. The depth of indentation was successfully calibrated by the depth standard with double column stand and laser measuring device. This paper showed the carefully concern for choosing suitable gauge block on depth calibration on Shore D.

5. References
[1] ISO 18898, Rubber- Calibration and verification of hardness testers, 3rd edition, 2016.
[2] ASTM D2240-15, Standard test method for rubber property- Durometer hardness, 2015.
[3] ASTM D1415, Standard test methods for rubber property- International hardness, 2012.

Figure 10. Depth calibration setup according to ASTM D2240.

Figure 11. Surface appearance after applying the force at 100 Shore D a) steel and b) WC.

Figure 12. Depth profile of hole surface on steel and WC gauge block.