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VICKERS INDENTER SHAPE MEASUREMENT BY USING SCANNING CONFOCAL CHROMATIC INSTRUMENT

Tassanai Sanponpute [1], *Wasin Limthunyalak* [2], *Febo Menelao* [3] *and Dieter Schwenk* [4]

[1,2] National Institute of Metrology Thailand (NIMT), Pathumthani, Thailand,
[1] tassanai@nimt.or.th and [2] wasin@nimt.or.th
[3] Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany, febo.menelao@ptb.de
[4] Materialprüfungsamt Nordrhein-Westfalen (MPA NRW), Dortmund, Germany, schwenk@mpanrw.de

Abstract – The measurements of Vickers indenter angles had been studied with different instruments. Most of them are specially designed for this purpose. Scanning confocal chromatic instrument is one possibility. In this study, the geometry of Vickers indenters was measured by such instruments. This study involved calibration, investigation of stability and comparison of measurement results on Vickers indenters.

Keywords: Vickers indenter, Confocal chromatic probe

1. INTRODUCTION

One of well known instrument for measuring shape of Vickers indenter is an interference sine bar. It is based on the principle of interferometer and autocollimator to measure the angle between opposite faces of a pyramidal indenter. Measurement with the confocal microscope had also been studied. However, the result showed that the distortion of the indenter image varied with the numerical aperture of the objective lens.

Non-contact 3D scanners which uses confocal chromatic probe are very interesting [1]. The probe is a confocal microscope with pinhole. The objective lens creates high axial chromatic dispersion. Lights with different wavelength are focused at different point along optical axis. The probe senses the distance of object by analysing reflected wavelength with a spectrometer. Lateral scanning system performs a scanning of the surface to be measured in (X,Y) plane. The detection point is the size of focus spot of 2.2 µm. Effect of numerical aperture on optical distortion of the image is not significant.

In this research, the non contact 3D scanner with chromatic probe was calibrated. The system was then used to measure the geometry of Vickers indenter. Stability and repeatability of measurement ware studied. Results were compared with NMIs's calibration results. Informal comparison results are reported.

2. NON-CONTACT 3D SCANNER WITH CONFOCAL CHROMATIC PROBE

The confocal chromatic probe is one of four modules in the nano-hardness testing system model NHT^2 from CSM Instrument. The system consists of a positioning X-Y stage and four probing modules which are instrumented indentation hardness module, atomic force microscope (AFM), confocal chromatic probe and optical microscope as shown in Fig 1.

Fig.1. Modules in nano-hardness testing NHT^2 : (a) instrumented indentation hardness tester, (b) AFM, (c) confocal chromatic probe, (d) microscope.

The geometry of a Vickers indenter was measured by confocal chromatic probe. Parameters are measured as follow;

- the angle between opposite the faces
- the angle between axis of the pyramid and axis of the indenter holder
- the corner angle of square base of the pyramid.

Except the line conjunction was measured with an AFM.

The scanning image is obtained by moving the sample under confocal chromatic prob. The moveable x-y stage consists of ball screw and the position is controlled by rotary encoder. The maximum scanning length of x-y stage is 245 mm x 120 mm with smallest increment step of 0.033 µm. The confocal chromatic probe measures in z direction. The measuring range of the probe is 130 µm with a resolution of 0.005 µm.

2.1. Calibration of non-contact 3D scanner with a confocal chromatic probe.

Firstly, x and y axis of the scanning table were investigated by scanning over a linear scale at 12 mm in both directions. It can be concluded that the length of x and y axis consisted of combination of span error and periodic error as shown in Fig. 2.

The span error of the x-axis was 0.07 % of reading which can be reduced by setting an appropriate span coefficient. While the shape of periodic error on the y-axis gave sinusoidal wave at 2 µm peak to peak and 1 mm period. The periodic error can probably cause from non-linearity of the ball screw pitch which cannot be eliminated.

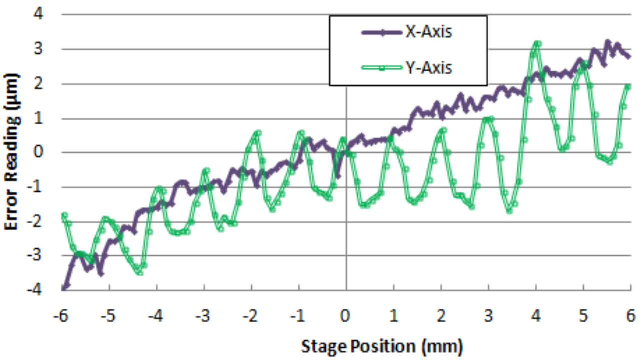

Fig.2. Error of x-y stage investigated by scanning on a linear scale.

However the working area of an Vickers indenter is approximately 500 µm x 500 µm x 100 µm (width x length x height), the calibration on 2,000 µm x 2,000 µm x 120 µm was chosen, in order to cover the working area.

A linear interferometer, Agilent 5519A, was used as standard equipment to calibrate x,y and z axis. It was found that the error in x and z axis showed a span error of 0.06 % and 0.05 % respectively. However the error in both axis can be compensated with span coefficient. In contrast to the y-axis, it clearly showed a periodical error. To reduce this error, the result was compensated with sinusoidal function. Error before fitting and fitting function error were shown in Fig. 3.

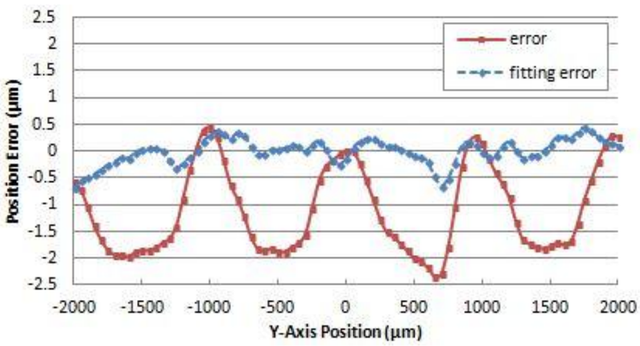

Fig.3. Error of y stage calibrated with linear interferometer.

Result in z-axis calibration has been ambiguous. Due to short moving length of the z stage at only 3 cm, the alignment of laser interferometer is probably not well enough. Therefore calibration with other equipment such as piezo- stage should be performed to confirm the result.

3. MEASUREMENT SETUP

The shape of a pyramidal indenter can be measured by scanning confocal chromatic probe directly on the indenter tip area. Scanning area on the indenter tip was 600 µm x 600 µm. In order to measure the angle between axis of the pyramid and axis of the indenter holder, seating holder and reference frame were created for each indenter. Top of seating surface and both side of reference frame were flat and parallel. The objective of the reference frame was transferring plane of seating holder to the same level as indenter tip. The scanning area of reference frame in this study was 6 mm x 6 mm. The measurement setup is shown in Fig. 4.

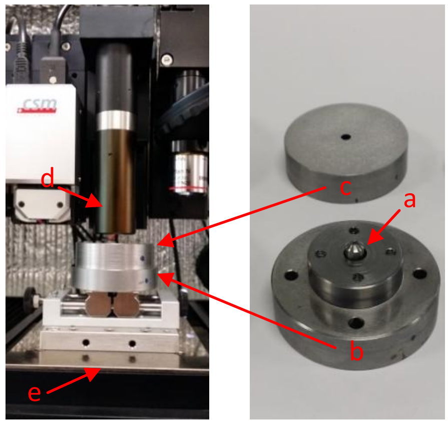

Fig.4. Indenter to be measured (a), seating holder (b) and reference frame (c), confocal chromatic probe (d) and scanning x-y stage (e).

In order to reduce mechanical drift, x-y scanning resolution of each image was set to 300 x 300 pixels which corresponding to 17 minutes scan time. The scanning images of indenter tip area and reference frame is shown in Fig. 5. The surface to be measured were reconstructed by fitting data points in each section with plane equation. The angles obtained by using vector operation on such planes.

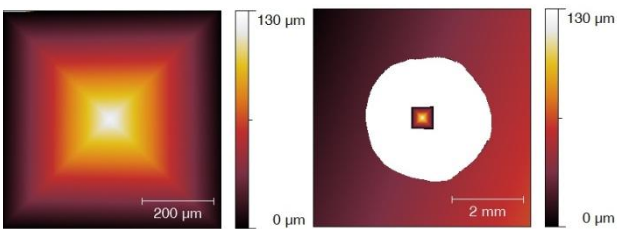

Fig. 5. (Left) Fine scanning image of a Vickers indenter, (Right) Rough scanning image of Vickers indenter together with reference frame.

4. RESULT AND DISCUSSION

4.1. Stability

The stability of opposite-face angle measurement was studied by scanning one indenter for 33 times within 7 days, with fix indenter position on the stage. In order to obtain effect from re-positioning the machine, the measurement was divided into 3 parts, separated by turning off electrical system and then restart the instrument. Each time after the instrument restart, the stage automatically moves to home position and reinitializes then moves backward to previous indenter position. The opposite-face angle of the indenter calculated from 3D image of each scan. Results of measurement is show in Fig. 6.

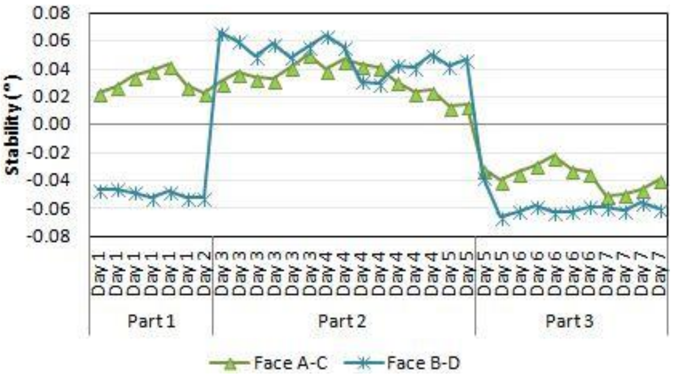

Fig. 6. Stability of opposite face angle measurement.

It could conclude that the effect of reinitialize the system could be a dominant factor that cause the stability of opposite-face angle measurement. The deviation of result between different parts is up to 0.05º-0.1° on the other hand the distribution of results in each part is only 0.02º-0.03°. It was possibly caused by inaccuracy of repositioning home position. Reinitializing the system with different home position directly affects the calibration curve of the stage which effects the stability of confocal chromatic instrument is the reinitializing of the stage.

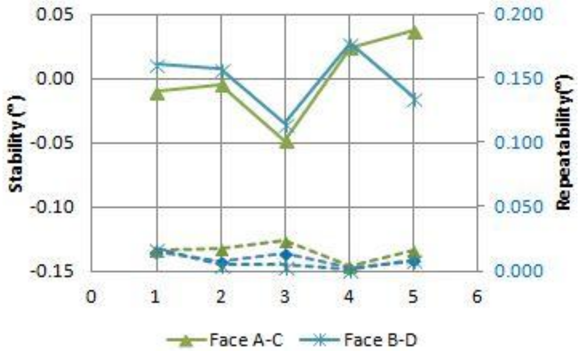

Fig. 7. Stability (solid line) and repeatability (dash line) of opposite face angle measurement.

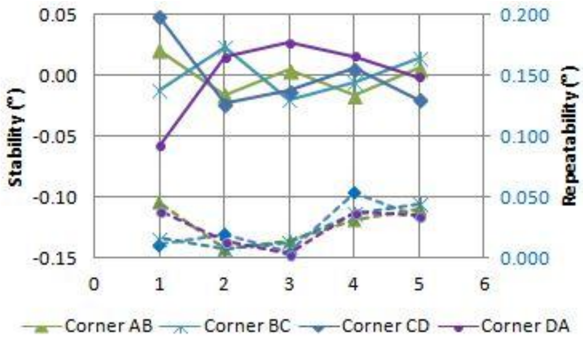

Fig. 8. Stability (solid line) and repeatability (dash line) of corner angle of square base measurement.

4.2. Reproducibility

Result in previous section shows that reinitializing is a source of reproducibility and it is a condition in practical use. In order to study stability of the instrument in real condition, the indenter was measured again in five series of three repeats. Intervals among each series were at least one week. For each series, the experiments were re-setup. The indenter was taken out and put back with best alignment. Average results from all series were used to examine the stability in reproducibility condition. The repeatability was expressed in range of three repeats. The stability and repeatability of opposite face angle and base corner angle were shown in Fig. 7.and Fig. 8.

The stability was ± 0.05° and ± 0.025° for the measurement of angle between the opposite faces and the measurement of corner angle of the square base of pyramid, respectively. The repeatability was 0.025° and 0.05° for the measurement of angle between the opposite faces and the measurement of corner angle of the square base of pyramid, respectively. Result of opposite face angle measurement agree with experiment in 4.1. It confirms that main factor which effects the stability of confocal chromatic instrument is the reinitializing of the stage.

These stability of the system were relatively small compared to permissible error of ISO 6507-2:2005 as shown in Table 1.

Table 1. Stability and repeatability of measurement compared to permissible error in IS0 6507 [2][3].

Parameter	Stability	Repeativity (range)	Permissible error	
			ISO 6507-2	ISO 6507-3
Opposite face angle	±0.05°	0.025°	±0.5°	±0.1°
Corner angle	±0.025°	0.05°	-	±0.2

4.3. Comparision of results

In this study, results of indenter shape measurement were informal compared. Results of measurement by scanning confocal chromatic instrument and atomic force microscope at NIMT were compared with calibration results by PTB and MPA NRW.

Three indenters were used in this comparison. They were described as following :

1. The first indenter (S/N: 47181), manufactured by DTS, was used as an artifact in regular force Vickers hardness (≥ HV5). The results of this indenter were compared with calibration results form PTB and MPA-NRW.

2. The second and the third indenter (S/N: 5089 and S/N: 56337), manufactured by Akashi, were used as artifacts in low force Vickers hardness test (≥ HV0.2) and micro force Vickers hardness test (≥ HV0.01), respectively. The results of both indenters were compared with calibration results from MPA NRW only.

The comparison result of the angle between opposite faces, the corner angle of the square base of pyramid and the line of junction between opposite faces are shown in Fig. 8., Fig. 9. and Fig. 10., respectively.

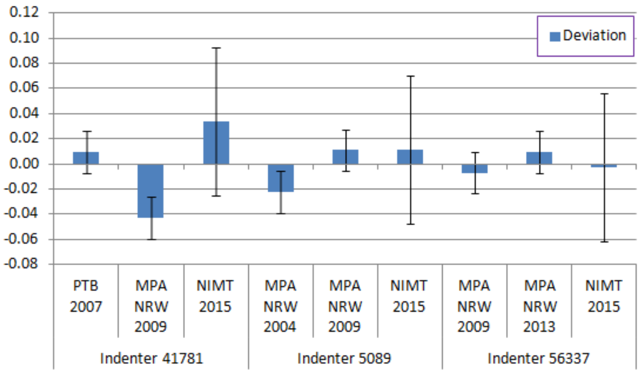

Fig. 8. Informal comparison of angle between opposite face measurement (three indenters).

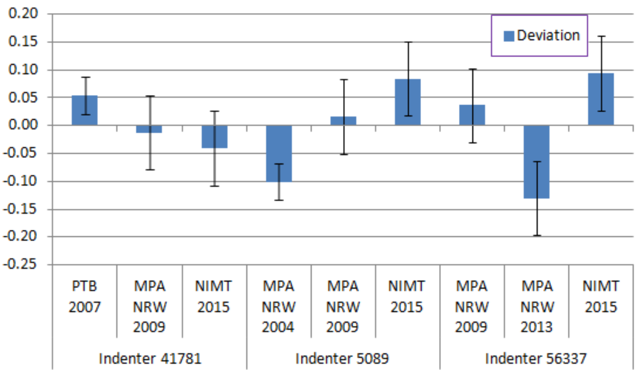

Fig. 9. Informal comparison of angle between pyramid and indenter axis holder measurement (three indenters).

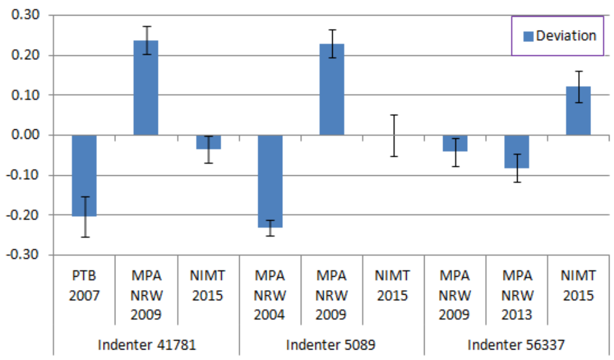

Fig. 10. Informal comparison of line of conjunction measurement (three indenters).

5. CONCLUSIONS

It was presented that, scanning confocal chromatic instrument are capable to measure geometry of Vickers indenter. The calibration results are in agreement with ISO 6507-2. However, if the problem on reinitializing system is solved, the result might be in accordance with ISO 6507-3, too.

REFERENCES

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[3] ISO 6507-3 : 2005 Metallic materials – Vickers hardness test – Calibration of reference blocks.