A NEW CALIBRATION TECHNIQUE FOR AUTOCOLLIMATOR BY USING A SMALL ANGLE GENERATOR AND LASER INTERFEROMETER

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ABSTRACT

This paper presents a new calibration technique for autocollimator. It is well-known equipment by using an optical instrument measured small tilting angles of a reflecting face and used for the calibration of standard angle. The technique bases on the directed comparison by using the angular interferometer and a new design of a small angle generator which has a low eccentric error. It was found that the result of X-axis and Y-axis errors are less than 1% of nominal value with uncertainty of calibration ±0.06 arcsec. This calibration technique is good for length standard laboratory that are searching for a new angular calibration technique in order to keep and maintain angular measurement standard as complying with the traceability chart of length standard.

KEYWORDS: Calibration, Optical instrument, Autocollimator, Small angle generator, Angular interferometer.

1. INTRODUCTION

The autocollimator [1] is a well-known optical instrument measuring small tilting angles of a reflecting face and used for the calibration of angle standards such as indexing table, polygon and angle gauge block. There are two types of autocollimators, one is the visual setting type incorporating a micrometer reading or scale graticule reading. The other is the photoelectric setting type automatic reading. In this paper employed the autocollimator of the photoelectric (charged couple device: CCD) setting type. The interferometric angle measuring method was applied to verify its accuracy. The autocollimator calibration technique uses the He-Ne laser interferometer measurement system[2] at the wavelength 633 nm (angular interferometer) with the low eccentric error of a small angle generator. We have found that the calibration results of X-axis and Y-axis errors are less than 1% of nominal value with the calibration uncertainty of ±0.06 arcsec.

2. PRINCIPLES

This angular measurement system which is used for the autocollimator calibration based on Michelson's interferometry method. The Interferometric angle measuring instrument can resolve extremely small angle and has an wide measuring range, as shown in Figure 1.

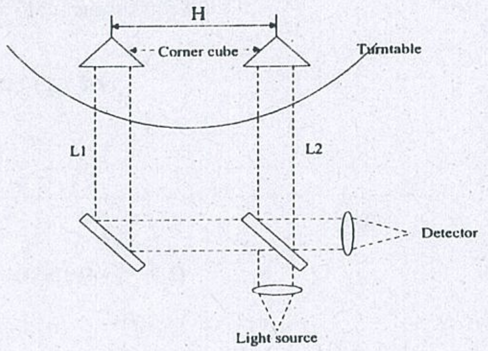


Figure 1 Angle measuring interferometer

The light source of angle measuring system is He-Ne laser at the wavelength of 633 nm used to illuminate the interferometer. The interferometric techniques are specially to zeeman-split two-frequency lasers. When the turntable with two corner cubes rotates, shown in Figure 1. The fringes at the detector will change and the rotating angle can be determined by counting the number of fringes changed. This device uses sine principle, the distance between the poles of two corner cubes (H) represents the hypotenuse of right-angled triangle and the measured value change in the path difference of the reflected beams(L1,L2). ΔL_1-ΔL_2 represents the opposite side of the triangle.

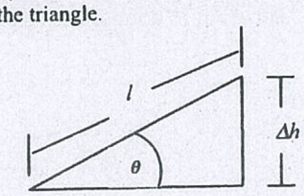


Figure 2 Sine principle of small angle generator

$$\sin\theta = \frac{\Delta h}{l} \quad (1)$$

$$\Delta h = h_1 - h_2 \quad (2)$$

When

$$l = H = \text{Arm length of Angular Reflector}$$

Sine or tangent principle as shown in the Equation (1). The small angle generator, depicted in Figure 2. An arm of fixed length forms the hypotenuse or adjacent side in a right-angled triangle, and the corner cube of interferometer as previous described in Figure 1. The angle is made of the length of the opposite side which is accurately formed by micrometer head. A small angle generator must have the function of measuring and setting the small angle.

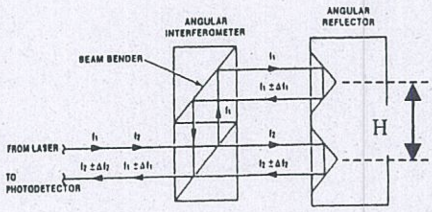


Figure 3 Angular measurement system of HP 5528A laser measurement system

The angular measurement system shown in Figure 3 based on the principle of linear measurement system, the corner cube distance or arm length of angular reflector (H) is approximately 32.61mm. The light source (He-Ne laser) would generate or split two frequencies (f_1, f_2) but the angular interferometer has fringe difference of $f_1 \pm \Delta f_1$, as Equation (4) and $f_2 \pm \Delta f_2$ as Equation (5) *represents* $\Delta L_1 \cdot \Delta L_2$, as Equation (6).

$$f_1 \pm \Delta f_1 = h_1 \quad (4)$$

and $$f_2 \pm \Delta f_2 = h_2 \quad (5)$$

Hence $$\Delta L_1 \cdot \Delta L_2 = h_1 - h_2 = \Delta h \quad (6)$$

The autocollimator calibration was set the same diagram as Figure 4. The small angle stage moved by adjusting the micrometer head. And the reading error of autocollimator would be read directly from the fringe counter of laser measuring system.

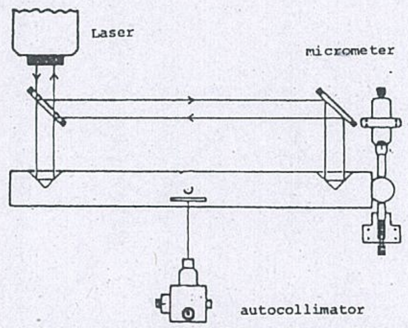


Figure 4 A small angle generator and laser measurement system

3. EXPERIMENT

This experiment used the comparison method. The setting up of autocollimator was performed by using a small angle generator and the HP's 5528A laser interferometer, as shown in Figure 5. The angular interferometer system was placed on the top of small angle generator. The angular interferometer equipment were required, namely laser head, angular interferometer, angular reflector.

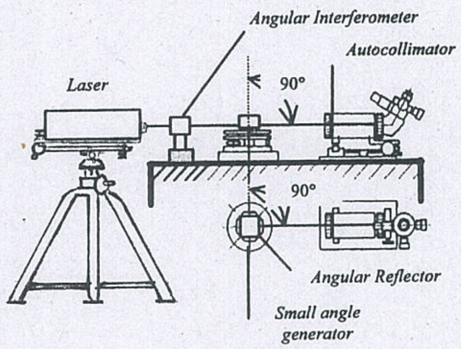


Figure 5 The autocollimator calibration by using small angle generator with laser interferometer

The angular reflector (Figure 3) placed on the top of the small angle generator and aligned the laser measuring system, as shown in Figure 5 follows this procedure.

1.The alignment techniques were performed by the angular measurement of instruction manual of HP 5528A Laser measurement system and Autocollimator [3].

2.The angular interferometer must be located symmetrically on between the center line of two corner cube and the reflector mirror. In order to avoid the eccentricity error was occurred, as described in Figure 6.

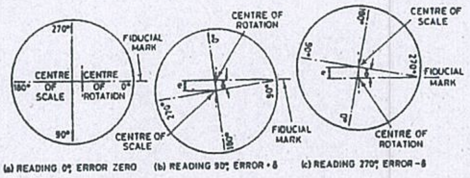


Figure 6 The angle errors due to a divided circle being mounted eccentric by an amount ***e*** *(e:Eccentricity)*

The error passes from 0 to +δ, through zero again to -δ, and the maximum angular error between any two reading is 2δ and from the diagrams δ radians = *e/R*.. Therefore the maximum which will occur in this case if the small angle is rotated between reading of 90° and 270°, will be 2*e/R* , where *e* is the eccentricity, and *R* is the radius at which the readings are taken.

3. To set zero both Fringe counter of angular measurement system and autocollimator readout display. Then, to adjust the micrometer head in the clockwise (+X) and the counter clockwise (-X) direction from 0 to +/– 1000 arcsec. in order to take reading.

4. To rotate the autocollimator light source slightly to counterclockwise or clockwise direction 90 degree (see autocollimator instruction manual) for alignment of Y–axis calibration and repeat the item 1 to 3 again.

4. RESULTS

The results of calibration error both the graph of X-axis and Y-axis as shown in Figure 6 and Figure 7 respectively. Those are shown the relation between the angular measurement reading and the autocollimator reading. The error of both clockwise and counter-clockwise direction is calculated from the different the angular measuring system and the autocollimator. The maximum error of +X-axis(clockwise) is 0.75% at 700 arcsec and -X-axis(counter-clockwise) is 0.87% at 900 arcsec. The maximum error of +Y-axis(clockwise) is 0.2% at 900 arcsec and -Y-axis (counter clockwise) is 0.1% at 1000 arcsec. They have been found that their maximum error were less than 1% of reading for both axes. The uncertainty evaluation was followed by ISO/TAG 4 [4]. The sources of uncertainty budgets are resolution and accuracy of the laser measurement system. The total uncertainty of autocollimator is ± 0.06 arcsec at confident level 95%.

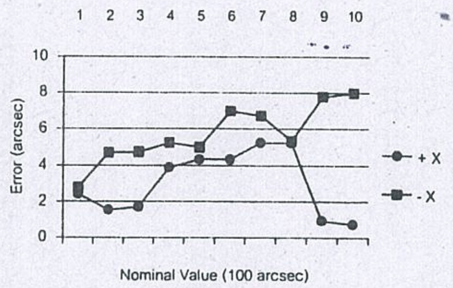


Figure 7 The autocollimator calibration of X-axis

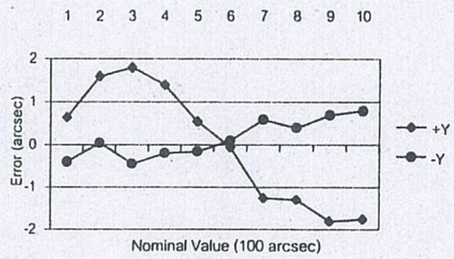
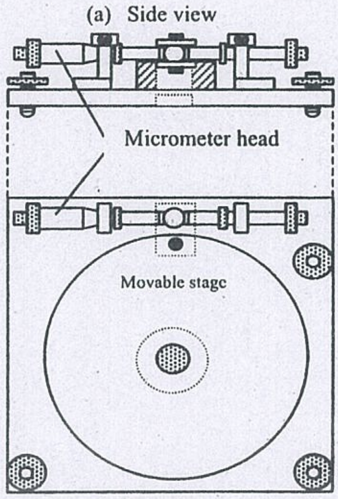


Figure 8 The autocollimator calibration of Y-axis

5. CONCLUSION

The calibration technique of the new design of small angle generator as shown in Figure 9 and the result of error is less than 1% of reading with the uncertainty evaluation is ± 0.06 arcsec.

(a) Side view



(b)Top view

Figure 9 The new designed drawing of small angle generator. (a) side view, (b) top view if we eccentrically placed the angular interferometer on the movable stage of small angle generator.

It is quite clear that this new design of small angle generator can be controlled very precisely and smoothly. The resolution of this design is as fine as several nanoradians.

6. REFERENCES

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