Verification of Squareness Measurement Methods on a Machine Image Inspection System

Huay-Chung LIOU[1], Chung-Chi TANG[1], Tzeng-Yow LIN [1]
[1]*Center for Measurement Standards / Industrial Technology Research Institute, Taiwan*
Pascal_liou@itri.org.tw

Abstract

A machine vision system is an automated image inspection for a wide range of products, with the advantages of low cost and non-contact. The accuracy of machine vision systems depend on the quality of the stages, which are related to factors such as linearity, squareness, and flatness. The most important factor is squareness, which is also difficult to measure.

The squareness on a machine system is measured by three methods with different optical artefacts. Two of these methods are the diagonal and the cross-diagonal methods with a linear scale of one-dimension. The one-dimension linear scale is calibrated, and implies that all the scale distances are known. The calibrated linear scale is put on the principal diagonal of the work table on a machine vision system, and the scale distances are measured by the CCD camera. We obtain the value of squareness through calculation and analysis. The third method of squareness measurement uses a two-dimensional optical artefact, which is transparent and coated with a T-shaped pattern. The reverse and cross-calibration method is applied to this optical artefact in order to measure the squareness of the T-shaped pattern and the squareness of the motion stage simultaneously. The three machine image methods for the evaluation of squareness yield a consistent result with a maximum deviation of less than 0.2″.

1 Introduction

The accuracy of machine vision systems depend on the quality of the stages, which are related to factors such as linearity, squareness, and flatness. The most important factor is squareness, which is also difficult to measure with high accuracy.

This study uses three different image methods to measure squareness for a high precision stage. The diagonal method, the cross-diagonal method with a one-

dimensional linear scale, and the T-shaped pattern reversal method are used for squareness measurement in this study. This paper presents the principles of measurement of these three optical image methods, and performs experiments to illustrate these. For the three methods, the deviations of the squareness error curve were less than 0.2″.

2 Measurement principles for squareness measurement with optical artifact

2.1 Measurement principles for the diagonal method with one-dimensional linear scale

A linear scale whose distance is already known is used to measure the scale distance with a CCD. The linear scale is put on the principal diagonal of the work table of an x-y stage, and the scale distances are measured. The measurement deviation of the scale distance will be affected by the squareness of the x-y axes. The diagonal measurement result could be used to caculate the x-y squareness.

2.2 Measurement principles for the cross-diagonal method with a one-dimensional linear scale

The other method to measure squareness with a calibrated one-dimensional linear scale is the cross-diagonal method. This method has been used to measure the squareness of a CMM by J.-P. Kruth[1] . It could also be used to measure the squareness of an AOI (Automated optical inspection) stage with a one-dimensional linear scale. It measures not only a diagonal direction of 45°, but also the diagonal direction of 135° relative to the x-axis.

2.3 T-shape pattern reversal measurement method for squareness

We used a two-dimensional standard optical artifact (as shown in Figure 1) with a T-shaped pattern to measure the squareness of machine vision system [2][3][4]. The standard artifact was placed on the work table of the stage and the CCD camera on the stage is used to measure the T-shaped pattern. The difference between the measured angle of $\angle$BOC and 90° is ρ. The equation is given as below:

$\rho = \omega - \psi$ (as Figure 1-(C))…… ...Eq. 1

Where the ω is the sqaureness of T-shaped pattern & ψ is the squareness of stage

The standard artifact is placed in reverse on the work table of the stage (as shown in

Figure 2), so we could get the measurement result as:

$\rho' = -\omega-\psi$ (as Figure 2-(C)) ····· Eq. 2

The squareness of ω & ψ could be obtained as below:

$\omega = (\rho-\rho')/2$ ····· Eq. 3

$\psi = (\rho+\rho')/(-2)$ ····· Eq. 4

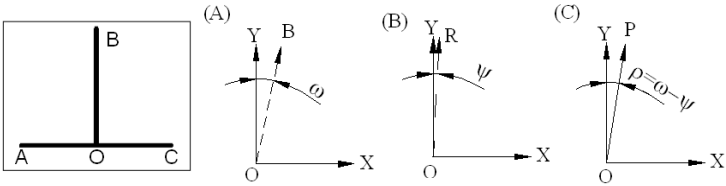

Figure 1 Schematic diagram of straight placement of the T-shape pattern standard artifact

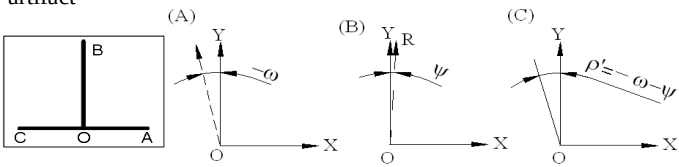

Figure 2 Schematic diagram of reversed placement of the T-shape pattern standard artefact

3 Experiments and results for squareness measurement

Squareness testing was performed using an Ultra-QV (Mitutoyo) two-dimensional image measurement instrument for different methods

3.1 Measurement principles for the cross-diagonal method with a one-dimensional linear scale

We used a one-dimensional linear scale with a low expansion coefficient (650 mm long). The pitches of all points on the linear scale were calibrated in advance. The diagonal method and cross-diagonal method were used to measure the squareness of the stage. The squareness is shown in Figure 3.

3.2 Squareness testing by the T-shaped pattern reversal measurement method

The T-shape pattern standard artefact was a two-dimensional lined grid pattern. The bottom horizontal line and the center vertical line were selected as the test T-shaped pattern. The measurement results of the squareness error curves were obtained by the T-shaped pattern reversal measurement method. We obtained the squareness of the T-shaped pattern standard artefact itself, as well as the squareness of the Ultra-

QV.The measurement results of these three methods of performing squareness measurements of the two-dimensional measurement stage of the Ultra-QV is shown as figure 3.

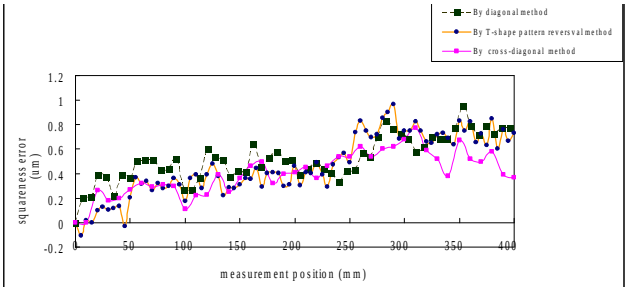

Figure 3 Squareness error curves of the Ultra-QV obtained by different methods

4 Conclusion

The variations in the squareness between these triple methods were less than 0.2″. The uncertainty of each measurement method is evaluated. The uncertainty is 0.7″ and 0.55″ for the diagonal method and cross-diagonal method for the measurement range of 400 mm. The largest contribution to the measurement uncertainty is from the calibration of the standard linear scale. The uncertainty of the T-shaped pattern reversal measurement method is 0.4″ and is smaller than the others .The squareness of the motion stage and the squareness of T-shaped pattern are obtained simultaneously.

References:

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