

EVALUATION OF PERFORMANCE TEST OF CMM

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Abstract – The performance tests described in ISO 10360series are too complicated to be executed in high frequency. The simplified test on the scale errors and the angular errors is proposed. In this article, the simplified artefacts with some balls are located at some different locations on CMM and are measured by CMM. The results are compared in the difference of the artefacts and the locations. In the comparison, the uncertainties of the performance test are considered.

Keywords: CMM, daily test of performance, uncertainty, simplified test artefact

1. INTRODUCTION

The CMMs are widely used in the manufacturing field. As the CMMs are too complicated to keep their performance within the specified limits, they should be verified regularly. Even if some deterioration of the performance are found in a regular test, it is impossible to know when its performance is deteriorated. So the performance should be verified in every measurement. However, the performance tests described in ISO 10360series are too complicated and time consuming to be executed in high frequency.

The simplified test to focus on the scale errors and the angular errors, which are major error sources, is proposed. It is examined how the locations and heights of the artefacts affect the test result of CMM performance. As a result of the examined repeatability of the test of CMM performance, the uncertainty of performance test is estimated.

2. MODEL OF SIMPLIFIED TEST

The simplified test should be executed to test the performance of CMM in short time every day. So, test method should be simplified and the artefact should be handled easily.

The CMM generally has 21 geometric errors, which are two straightness errors, a scale error and three angular errors on each axis and three squareness errors between two axes. In the simplified test, there are 6 greater errors, i.e. 3 scale errors and 3 squareness errors.

In performance test of CMM, some calibrated lengths are measured by CMM.

The balls are much easier artefacts than the blocks and the other artefacts to be dealt in order to measure the calibrated length. In this paper, the center coordinates of balls shall be

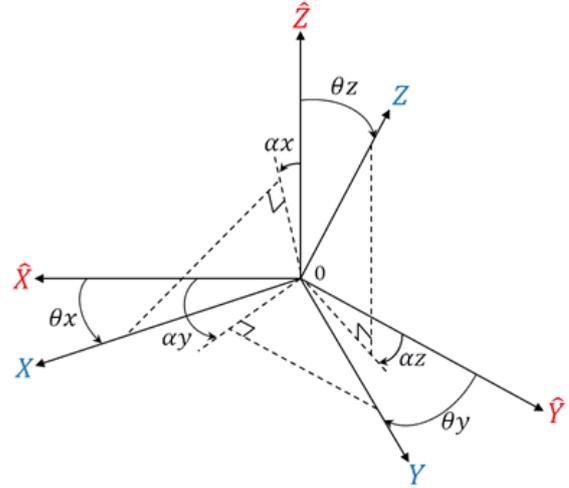


Fig.1 Model of actual and ideal coordinate system of CMM

calibrated and the lengths between two balls are compared with the measurement results by CMM.

The model of simplified test is shown in Figure 1.

\hat{X} is the actual coordinate system of CMM and \hat{X} is the ideal coordinate system of CMM. x is the actual coordinates measured by CMM and \hat{x} is the ideal coordinates. K is scale factor matrix and T is rotational matrix. $L_{j,k}$ is the calibrated length between j -th ball and k -th ball.

The scale errors and squareness errors are calculated by Least Squares Method of which criteria is (4).

$$\mathbf{x} = \mathbf{KT}\hat{\mathbf{x}} \quad (1)$$

$$\mathbf{K} = \begin{pmatrix} kx & 0 & 0 \\ 0 & ky & 0 \\ 0 & 0 & kz \end{pmatrix} \quad (2)$$

$$\mathbf{T} = \begin{pmatrix} \cos\theta_x & \cos\alpha_y\sin\theta_y & -\sin\alpha_z\sin\theta_z \\ -\sin\alpha_x\sin\theta_x & \cos\theta_y & \cos\alpha_z\sin\theta_z \\ \cos\alpha_x\sin\theta_x & -\sin\alpha_y\sin\theta_y & \cos\theta_z \end{pmatrix} \quad (3)$$

$$f_i = \sqrt{(\hat{\mathbf{x}}_j - \hat{\mathbf{x}}_k)^T \cdot (\hat{\mathbf{x}}_j - \hat{\mathbf{x}}_k)} - L_{j,k} = 0 \quad (4)$$

3. CMM AND ARTEFACTS

Figure 2 shows the CMM used in the performance test. It is manufactured by MITUTOYO and the measuring volume is 700x1000x700[mm].

The specification of the artefacts is shown in Table 1. Figure 3 shows the pictures of the artefacts. Figure 3(a) is Quick Check(QC, developed by Trapet Engineering) and Figure 3(b) is Ball Pyramid(BP, developed by NMIJ). The shape of QC is a tetrahedron and the shape of BP is a quadrangular pyramid. Both artefacts consist of the balls. QC has 4 balls and BP has 5 balls. The balls are supported by the carbon fiber rods, and the length between two balls are stable and calibrated.

Table 1. Specifications of artefacts

	Quick Check	Ball Pyramid
Size[mm]	530×449×425	420×420×352
Shape	Tetrahedron	Quadrangular Pyramid
Number of Vertexes	4	5
Material of rod	Carbon Fiber	

4. EXPERIMENT OF LOCATION OF ARTEFACTS AND ARTEFACTS

The magnitude of the scale errors and the squareness errors are dependent on the location of the artefact. The following experiments are performed in order to investigate the reproducibility and the repeatability of both artefacts.

- (1) to set the artefact at different location
- (2) to set the artefact at different height

Figure 4 shows the location of the artefacts.

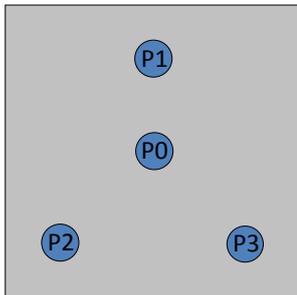


Fig.4 The location of the artefacts.

4.1. At the different locations

The scale errors and the squareness errors are not identical in whole measuring volume of CMM.

In order to examine how the location of artefacts affect on the performance test, the artefacts are set on the some different location on CMM table.

The location of test is shown in Figure 4.

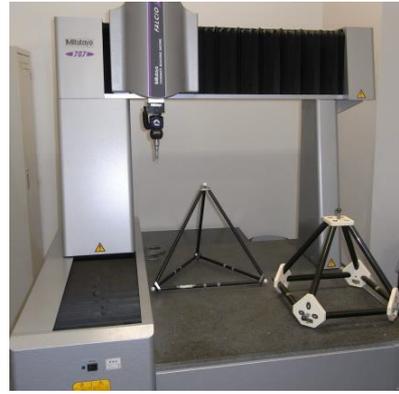


Fig.2 CMM (FALCIO APEX707/ MITUTOYO) and the artefacts..



(a) Picture of Quick Check..



(b) Picture of Ball Pyramid.

Fig.3 Pictures of artefacts

The artefacts are set at the location shown in Figure 4 and measured 5 times at same location. The experimental results of QC are shown in Figure 5 and those of BP are shown in Figure 6.

Figure 7 shows P-value of scale errors and squareness errors are calculated by ANOVA method. It is proved that k_y and x_{ty} of QC are affected and k_x and x_{ty} of BP are affected by the difference of locations of the artefacts.

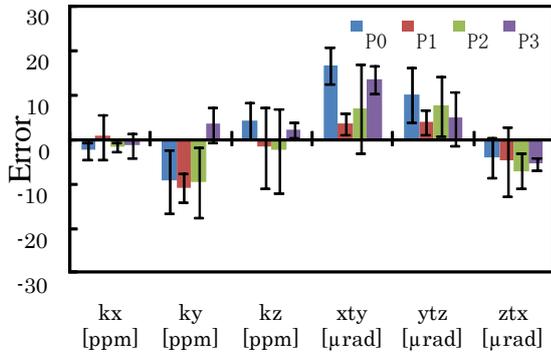


Fig.5 Scale errors and squareness errors by QC are measured at 4 different locations.

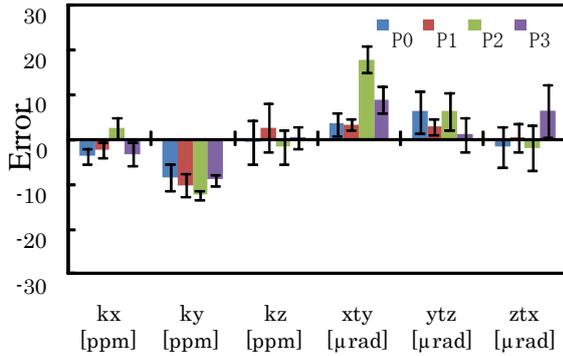


Fig.6 Scale errors and squareness errors by BP are measured at 4 different locations.

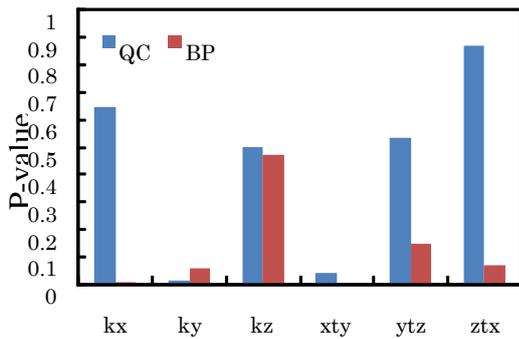


Fig.7 P-value of scale errors and squareness errors are calculated by ANOVA method

4.2. At the different heights

It is proved that the difference of location of artefact affects the test result in 4.1. Here, it is investigated whether the difference of height of artefact affects the test result.

The height of the artefact is selected from 0mm, 20mm, 40mm and 60mm. These heights are selected considering the measuring volume and size of the artefact.

The artefact are set at the selected height and measured 5 times.

The experimental result of QC is shown in Figure 8 and that of BP is shown in Figure 9.

Figure 10 shows P-value of scale errors and squareness errors are calculated by ANOVA method. It is proved that xty

and ytz of QC are affected and whole squareness errors of BP are affected by the difference of height of the artefacts.

The some scale errors and squareness errors are not stable in five repeated measurements. The raw data, i.e. the measurement result of the length between two balls, are investigated. It is proved that the lengths are measured within the accuracy of CMM, so the variation of the scale errors and the squareness errors occur from the precision of CMM. It is necessary to take the uncertainty of test into account.

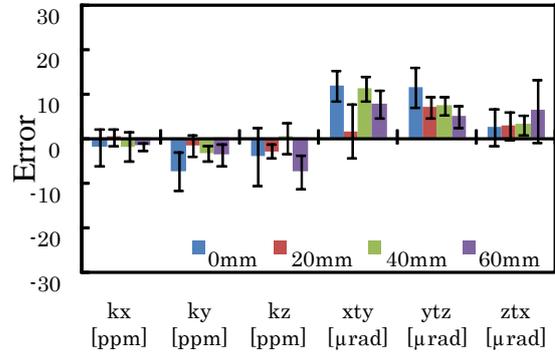


Fig.8 Scale errors and squareness errors by QC are measured at 4 different height.

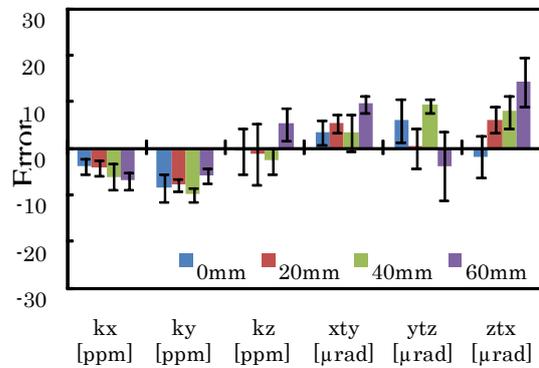


Fig.9 Scale errors and squareness errors by BP are measured at 4 different height.

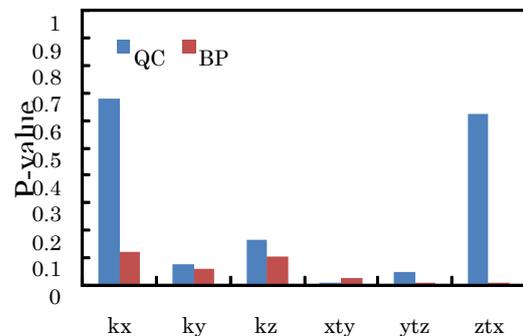


Fig.10 P-value of scale errors and squareness errors are calculated by ANOVA method.

5. UNCERTAINTY OF SIMPLIFIED TEST

The uncertainty contributor is the measurement error of the length between two balls. The uncertainty is estimated by the computer simulation. When the length between two balls

is measured, the standard uncertainty of the measurement is within $3\mu\text{m}$. At first, a lot of random numbers of which mean is 0 and standard deviation is 1.5, are generated. They are added to the measured lengths between two balls. This calculation is repeated 1,000 times on each length. After that, the scale errors and squareness errors are calculated about 1,000 set of generated data. Finally, the uncertainty of the scale errors and squareness errors are estimated.

In simplified test, when some scale errors and/or squareness errors are out of the conformance zone, it is judged that the CMM has the large errors and is in extraordinary status.

6. EXPERIMENTS

The test procedure should be simplified in order to test the CMM performance in a short time every day.

It is examined where the artefact is set.

If these conditions are not important to test the CMM performance, the test procedure could be simplified more.

Two fixing methods are tested.

(1) Artefacts are fixed on the surface plate.

(2) Artefacts are fixed on CMM table directly.

Figure 11 shows the result of scale errors about above (1) and (2). The k_x , k_y and k_z are the scale errors in fixing method (1). The k_x' , k_y' and k_z' are the scale errors in fixing method (2).

Figure 12 shows the result of squareness errors about (1) and (2). The x_{ty} , y_{tz} and z_{tx} are the squareness errors in fixing method (1). The x_{ty}' , y_{tz}' and z_{tx}' are the squareness errors in fixing method (2).

The result in fixing the artefact on the surface plate is better than that in fixing the artefact on CMM directly.

7. CONCLUSION

In this paper, simplified CMM test is proposed to test the scale errors and squareness errors in geometric errors of CMM.

Two artefacts, Quick Check and Ball Pyramid, are used. The scale errors and squareness errors are tested in following conditions.

- (1) the difference of locations of the artefacts
- (2) the difference of height of the artefacts
- (3) the difference of fixing method

It is proved that the results show the good repeatability and the different location and height show the different results. Especially, x_{ty} , squareness error between x axis and y axis, is affected by fixing method of the artefact.

It is proved that the artefact should be fixed rigidly.

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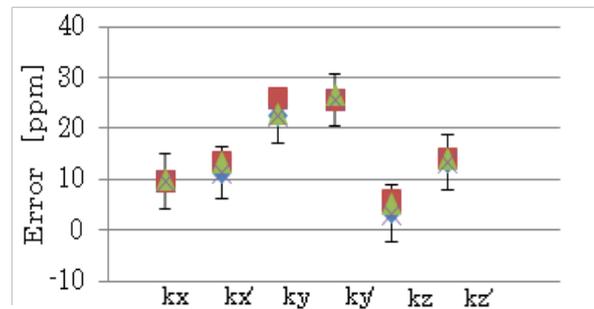


Fig.11 Scale errors

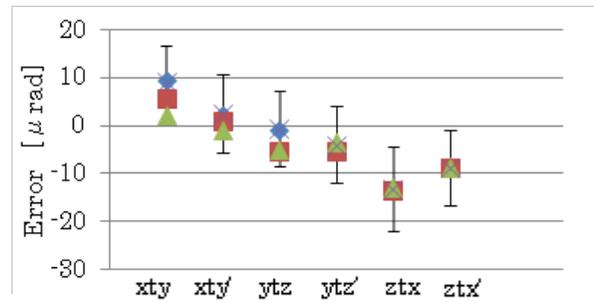


Fig.12 Squareness errors

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