

# COMPARISON OF DAILY CHECK ARTEFACTS OF CMM

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**Abstract:** (250 Words)

The Coordinate Measuring Machines are recommended to be tested in an adequate time. In the case that the CMM is tested and the unexpected large errors or failure are found, it is difficult how to deal the data just before. So it is necessary to find the large errors or failure as soon as possible. Therefore it is better to test the CMM everyday or every measurement cycle. But this idea is very time consuming.

As the most errors happen in the squareness and scale errors, the squareness errors and scale errors are tested every week using two artefacts, e.g. the QuickCheck and Ball Pyramid. The QuickCheck is developed and sold by Trapat Engineering. The Ball Pyramid is developed by NMIJ. Both artefacts have balls in three dimensional space and the coordinates of center of balls are referred.

As the squareness errors and scale errors are dependent on the location, these artefacts are set on some locations in some orientations.

These result is analyzed by ANOVA method.

We show the scale errors are independent on the location and orientation of the artefacts. we show the squareness error between X-axis and Y-axis is large and dependent on the location of the artefacts.

We also compare the results from both artefacts.

**Keywords:** CALIBRATION, CMM, ARTEFACT

## 1. INTRODUCTION

The Coordinate Measuring Machines are recommended to be tested in an adequate time. In the case that the CMM is tested and the unexpected large errors or failure are found, it is difficult how to deal the data just before. So it is necessary to find the large errors or failure as soon as possible.

In this paper, very limited errors, the scale errors and the squareness errors, are tested by the simplified CMM test.

In this CMM test, Quick Check and Ball Pyramid are used as the artefacts. These artefacts are set on different locations and different height.

This paper describes the comparison of both artefacts.

## 2. MODEL OF SIMPLIFIED TEST

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

The CMM generally has 21 geometric errors. In simplified test, 6 greater errors, scale errors and squareness errors, are considered to execute the test in short time.

The balls are much easier artefacts than the blocks and the other artefacts to be handled. In this paper, the center coordinates of balls shall be calibrated and the distances

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

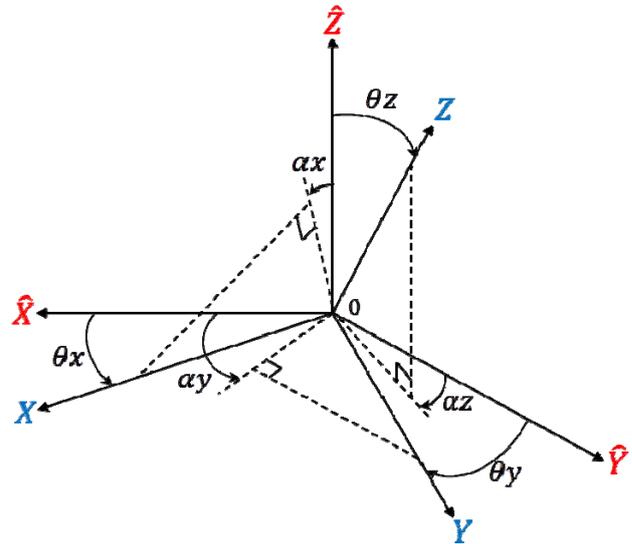


Fig. 1: Model of actual and ideal coordinate system of CMM

$$\mathbf{x} = \mathbf{K}\mathbf{T}\hat{\mathbf{x}} \tag{1}$$

$$\mathbf{K} = \begin{pmatrix} k_x & 0 & 0 \\ 0 & k_y & 0 \\ 0 & 0 & k_z \end{pmatrix} \tag{2}$$

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

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

The model of simplified test are shown in Fig.1.

X is the actual coordinate system of CMM and X-hat is the ideal coordinate system of CMM. x is the actual coordinates measured by CMM and x-hat is the ideal coordinates. K is scale factor and T is rotational matrix. L<sub>j,k</sub> is the calibrated distance between ball-j and ball-k.

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

### 3. ARTEFACTS

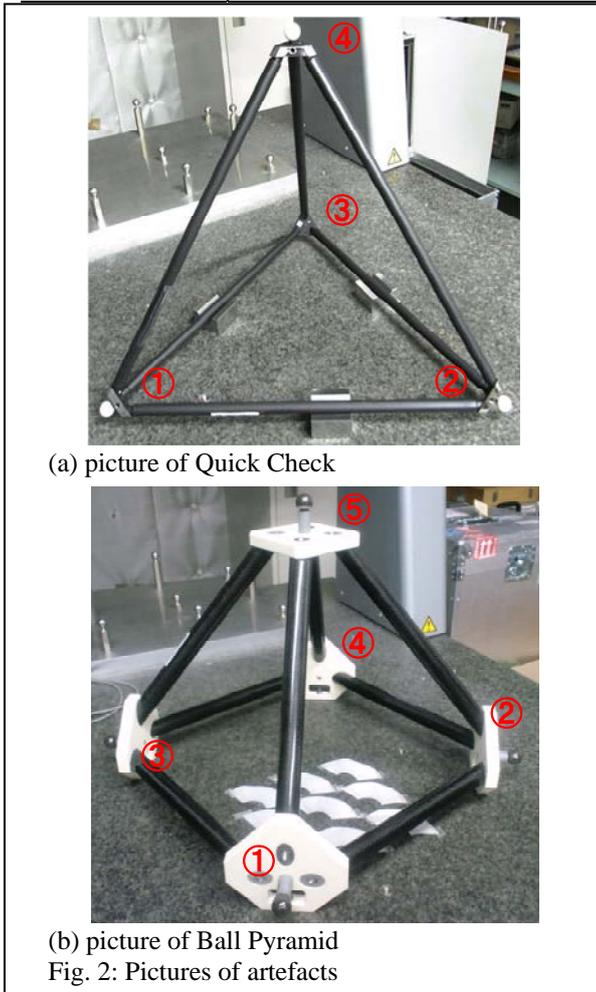
The specification of the artefacts are shown in Table 1 and the pictures are shown in Fig.2. Both artefacts consist of the balls. Two balls are connected with carbon fiber.

Quick Check(QC) was developed by Trapet Engineering. Ball Pyramid was developed by NMIJ.

The shape of QC is a tetrahedron and the shape of BP is a quadrangular pyramid. The coordinates of vertexes of QC and BP are 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	Carbon Fiber	



### 4. EXPERIMENTS

The following experiments are performed to investigate the reproducibility and the repeatability of both artefacts.

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

#### 4.1 Set and reset the artefact

In simplified test, the scale errors and the squareness errors are greater than the others. In order to use these artefact in daily test, the artefact should be easily set up and removed. The artefacts are set at the center of CMM table, measured 5 times at same location and removed. This process are repeated 3 times. After that, the scale errors and squareness errors are calculated.

The experimental result of QC is shown in Fig.3 and that of BP is shown in Fig.4.

It is proved that scale errors and squareness errors show the good repeatability when both artefacts are set and removed.

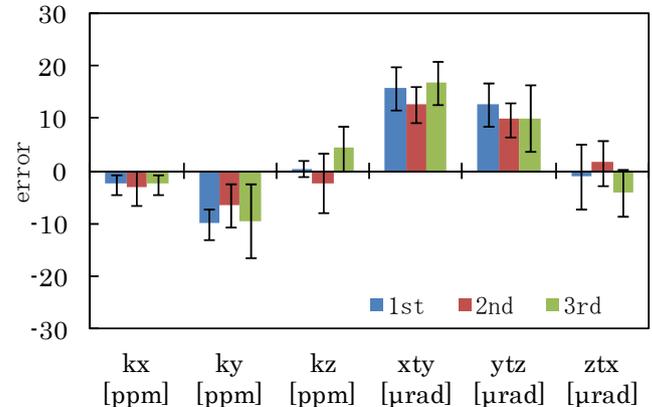


Fig. 3: Scale errors and squareness errors by QC are measured 3times

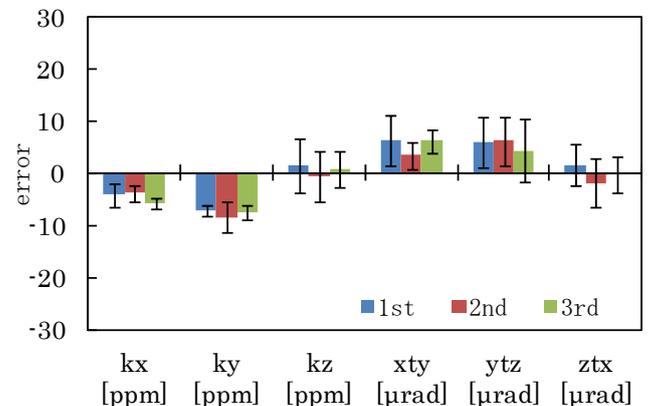


Fig. 4: Scale errors and squareness errors by BP are measured 3 times

#### 4.2 set the artefact at different location

The scale errors and the squareness errors are not identical in whole measuring volume of CMM. In order to reduce the location of test, the artefacts are set on the different location on CMM table.

The location of test is shown in Fig.5.

The artefacts are set at the location shown in Fig.5 and measured 5 times at same location. The experimental result of QC is shown in Fig.6 and that of BP is shown in Fig.7.

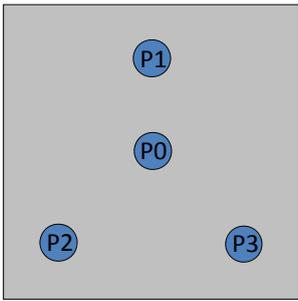


Fig. 5: The location of the artefacts

Fig.8 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.

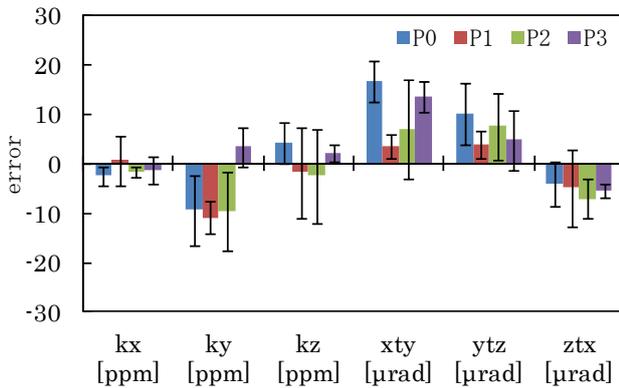


Fig. 6: Scale errors and squareness errors by QC are measured at 4 different locations

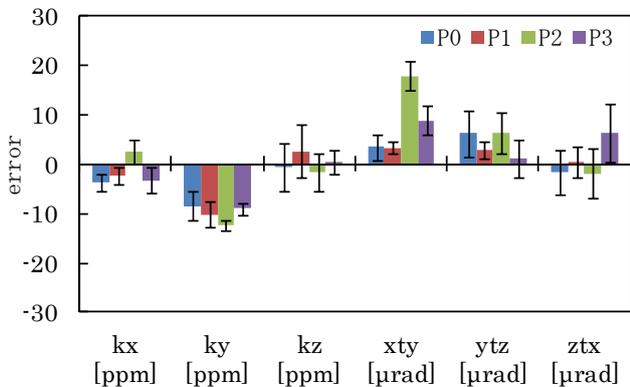


Fig. 7: Scale errors and squareness errors by BP are measured at 4 different locations

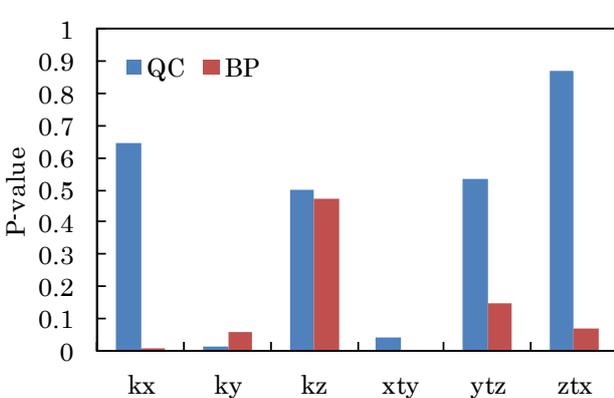


Fig. 8: P-value of scale errors and squareness errors are calculated by ANOVA method

### 4.3 set the artefact at different height

The difference of location of artefact affects the test result. In 4.3, 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 for 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 Fig.9 and that of BP is shown in Fig.10.

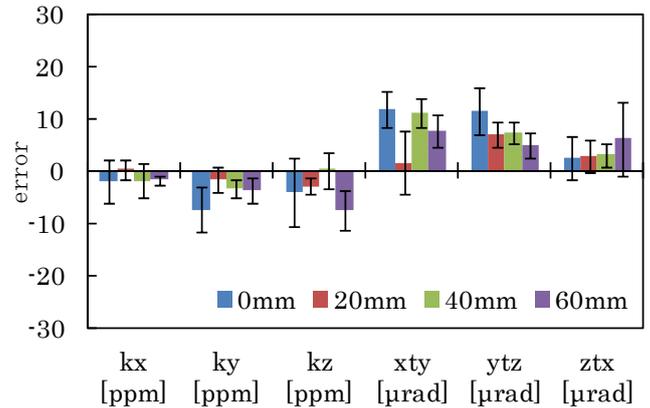


Fig. 9: Scale errors and squareness errors by QC are measured at 4 different height

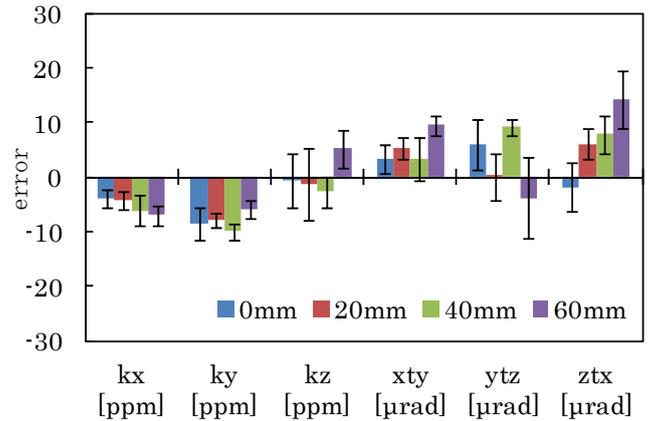


Fig.10: Scale errors and squareness errors by BP are measured at 4 different height

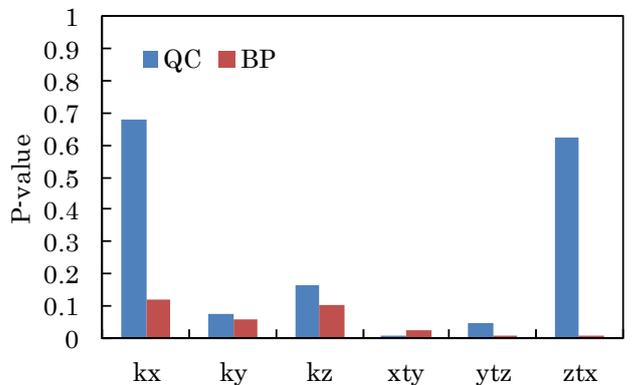


Fig. 11: P-value of scale errors and squareness errors are calculated by ANOVA method

Fig.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.

## 5. SUMMARY

In this paper, simplified CMM test is proposed to check 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 condition.

(1) the artefacts are set on same location to investigate the repeatability.

(2) the artefacts are set at different locations.

(3) the artefacts are set at different heights.

It is proved that the results shows the good repeatability and the different location and height show the different result. Especially, xty, squareness error between x axis and y axis, is affected by the artefact.

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