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COMPARISON OF ARTIFACTS FOR INTERIM CHECK OF CMM

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Abstract: Coordinate Measuring Machine (CMM) is often used for geometrical measurement due to its precision and general versatility. Recently the case that the CMM is placed in production line environment, is increasing. There are a lot of factors which make precision of measurement worse, like dust, thermal fluctuation, a physical collision and so on. To check these influences to precision of measurement, daily inspection of CMM is necessary. In previous research, the method of daily inspection of CMM was proposed. The result of inspection by two artifacts with different ball layout is shown.

Keywords: CMM, INTERIM CHECK, ARTIFACTS

1. INTRODUCTION

In industry, the Coordinate Measuring Machine (CMM) is used as a major method of geometrical measurement due to its precision and general versatility. Conventionally, the CMM is placed in a thermostatic chamber. However, the case that the CMM is placed in production line environment, is increasing. There are a lot of factors which make precision of measurement worse, like dust, thermal fluctuation, a physical collision and so on. To check these influences to precision of measurement, daily inspection of the CMM is necessary.

However, study of CMM is mainly about calibration in controlled environment like a thermostatic chamber. So some researchers have studied about daily inspection of CMM. In addition, it is unfeasible to calibrate the CMM everyday due to its cost.

In previous research, the method of daily inspection of CMM was proposed. This method treats the scale errors of each axis and the squareness errors between axes from the geometric errors of CMM. The result of inspection by two artifacts with different ball layout using the proposed method is shown in this paper.

2. INTERIM CHECK METHOD

The interim check method is proposed in this paper. The method assumes three axes are straight, and treats the scale error of each axis and squareness error between each axis from the geometric errors of CMM, due to simplification of the procedure.

The simple error model of CMM is shown in Fig.1. $\hat{X}\hat{Y}\hat{Z}$ coordinate system is ideal coordinate system, i.e. three axes are orthogonal axes and their unit lengths are identical.

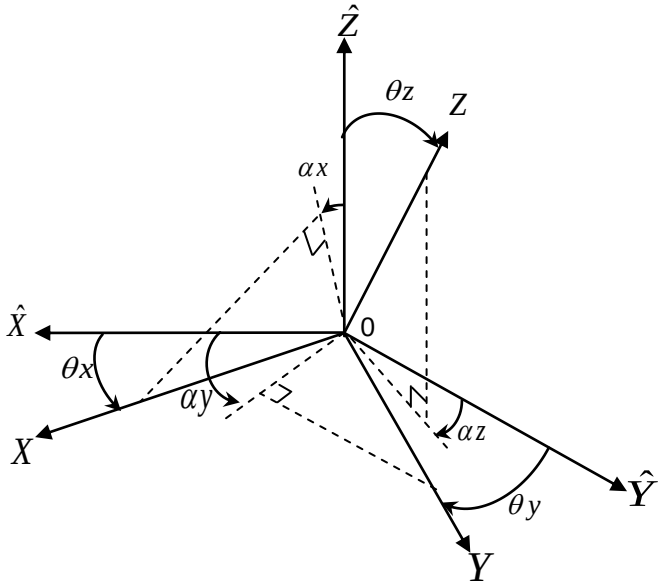

Fig.1 Schematic diagram of two coordinate system

XYZ coordinate system is the coordinate system of CMM, i.e. three axes aren't orthogonal and their unit length are not identical due to scale error and squareness error.

In this case, these two coordinate systems have relationship expressed by Eq. (1)

$$\mathbf{x} = \mathbf{KT}\hat{\mathbf{x}} \tag{1}$$

$$\mathbf{T} = \begin{pmatrix} \mathrm{Cos}\theta x & \mathrm{Cos}\alpha y\mathrm{Sin}\theta y & -\mathrm{Sin}\alpha z\mathrm{Sin}\theta z \\ -\mathrm{Sin}\alpha x\mathrm{Sin}\theta x & \mathrm{Cos}\theta y & \mathrm{Cos}\alpha z\mathrm{Sin}\theta z \\ \mathrm{Cos}\alpha x\mathrm{Sin}\theta x & -\mathrm{Sin}\alpha y\mathrm{Sin}\theta y & \mathrm{Cos}\theta z \end{pmatrix} \tag{2}$$

$$\mathbf{K} = \begin{pmatrix} kx & 0 & 0 \\ 0 & ky & 0 \\ 0 & 0 & kz \end{pmatrix} \tag{3}$$

Where $\mathbf{T}$ is matrix of which components are basis of XYZ coordinate system, it describes squareness error. These angle parameters, θx, θy, θz, αx, αy and αz, are defined in Fig.1. Squareness error is calculated by inner product of $\mathbf{T}$'s each column. $\mathbf{K}$ is the diagonal matrix of which components are scale error of each axis, it describes scale error.

These parameters are estimated such as the following function is zero,

$$f_i = \sqrt{\left(\hat{\mathbf{x}}_j - \hat{\mathbf{x}}_k\right)\cdot\left(\hat{\mathbf{x}}_j - \hat{\mathbf{x}}_k\right)} - L_{j,k} \qquad (4)$$

, where $\hat{\mathbf{x}}$ is defined in Eq. (1).

Where i is the number of equation, $\mathbf{x}_j$, $\mathbf{x}_k$ ($1 \leqq j < k \leqq n$) is the j-th and k-th measurand, n is the number of coordinates which should be measured. $L_{j,k}$ is the calibrated value of artefact which corresponds to the length calculated by $\mathbf{x}_j$ and $\mathbf{x}_k$. Here, the total number of equations is described by $N = {}_nC_2$. Let p be number of parameters, in case of $N \geqq p$, parameters are calculated by Least Squares Method which minimizes $\sum_{i=1}^{N} f_i^2$

3. EXPERIMENTS

3.1 Equipment of measurement

This section describes the equipment of measurement. QuickCheck(QC) and Ball Pyramid(BP) are used as artifacts. QC was developed in Trapet Precision Engineering. BP was developed in National Institute of Advanced Industrial Science and Technology. As shown in Fig.2, QC has a tetrahedral geometry and BP has a pyramid geometry. These artifacts the lengths between each of vertex are calibrated. The specification of artifacts is shown in Table 1.

The CMM used in this experiment is FALCIO-Apex 707 by Mitutoyo (Fig.3). The specification of FALCIO-Apex 707 is shown in Table 2.

(a) QuickCheck(QC) (b) Ball Pyramid(BP)

Fig.2 Appearance of artifacts

Table 1 Specification of the artifacts

Artifact	QuickCheck(QC)	Ball Pyramid(BP)
Size[mm]	530×449×425	420×420×352
Geometry	Tetrahedral	Pyramid
Vertex	4	5
Material of arm	Carbon fiber	Carbon fiber

Fig.3 Appearance of FALCIO-Apex707 (Mitutoyo)

Table 2 Specification of FALCIO-Apex707 (Mitutoyo)

Measurement range[mm]	705×705×605
Resolution[um]	1
MPE_E[um]	1.2+3L / 1000
MPE_P[um]	1.6

3.2 Comparison of artifacts with different ball layout

In this paper, two artifacts are used. Because of differences in shape and size, it is considered that these differences affects the estimated parameters. So, the influence is investigated.

The procedure of measurement is shown following.

(1) Set the artifacts at the center of measuring range of CMM.
(2) Measure the vertex coordinates of artifacts.
(3) Calculate the parameters by the proposed method.

3.3 Verification of the effects of arrangement position

CMM's sources of errors are the factors that arrangement position of artifact, thermal environment and so on. To investigate the effects of arrangement position, experiments changing the arrangement position are performed in a similar experimental procedure to that in 3.2. The arrangement points set three points on the XY-plane (Fig.4).

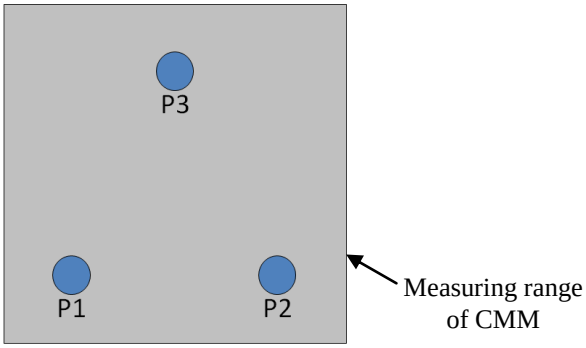

Fig.4 The arrangement points at the XY-plane

3.4 Verification of the effects of different height

To investigate the effects of height of bottom of artifacts, experiments changing the height of bottom of artifacts are performed in a similar experimental procedure to that in 3.2.

In this Experimental condition, the artifact bottom is set at the center of measuring range of CMM. In experiments, the height was changed from 0 mm to 60 mm by 20 mm.

4. RESULTS

4.1 Result of comparison of parameters (two artifacts)

This section shows the result of comparison of parameters for different artifacts. Results of comparison of parameters are shown in Fig.5. Results of Fig.5 are calculated by the proposed method. This figure is plotted with error value as a vertical axis and the calculated parameters as a horizontal axis. And Error bar indicates the standard deviation in Fig.5. The unit of the scale error parameters (kx, ky and kz) is ppm, and the squareness error parameters (xty, ytz and ztx) is μrad.

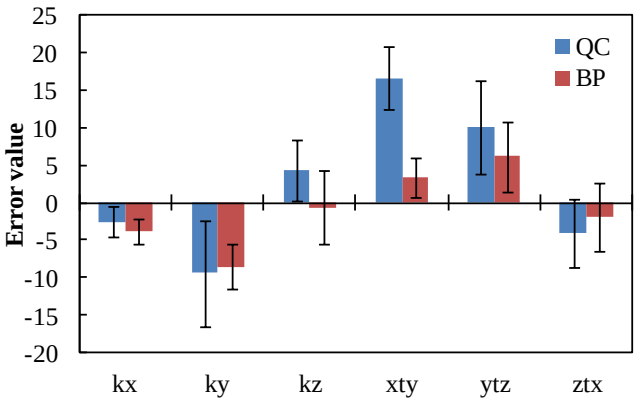

Fig.5 Comparison of parameters (two artifacts)

4.2 Result of arrangement position

4.2.1 Result of comparison of parameters (in different position)

This section shows the result of comparison of parameters for position of two artifacts. Results of comparison of parameters are shown in Fig.6 and Fig.7. P1, P2 and P3 are the position of artifacts is shown in Fig.4.

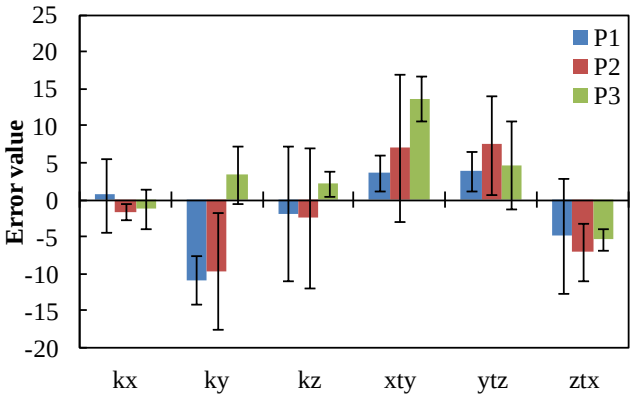

Fig.6 Comparison of QC parameters (in different position)

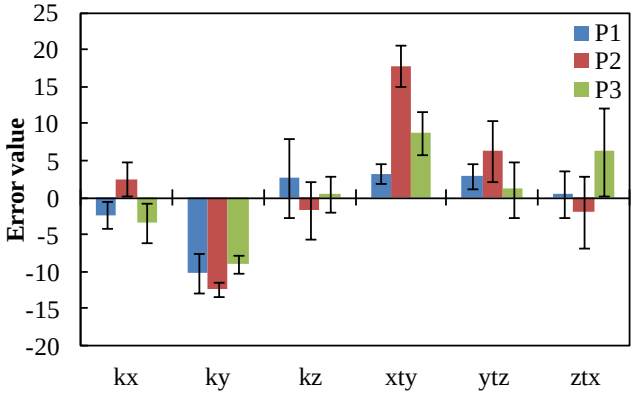

Fig.7 Comparison of BP parameters (in different position)

4.2.2 Result of statistical test (in different position)

This section shows the result of statistical test that factor is position where artifacts are set. The significance level of statistical test is set at 5%. The result of statistical test of parameters is shown in Table 3. In the case of "○", there is the difference that realization probability is 0.05 or less, and is meaningful and means that there is the difference by the position.

Table3 Result of statistical test (in different position)

	kx	ky	kz	xty	ytz	ztx
QC	×	○	×	○	×	×
BP	○	○	×	○	×	○

4.3 Result of different height

4.3.1 Result of comparison of parameters(in different height)

This section shows the result of comparison of parameters for the height of two artifacts. Results of comparison of parameters are shown in Fig.8 and Fig.9.

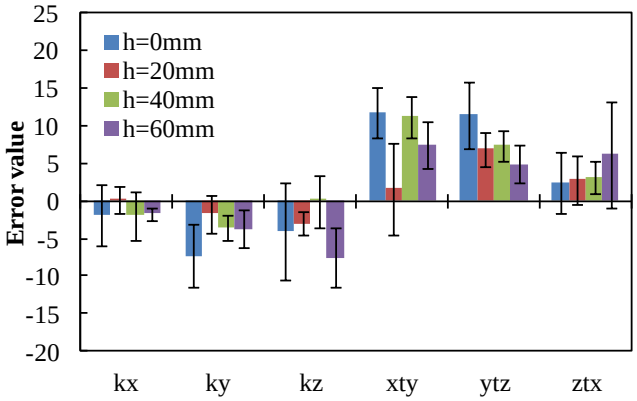

Fig.8 Result of comparison of QC parameters (in different height)

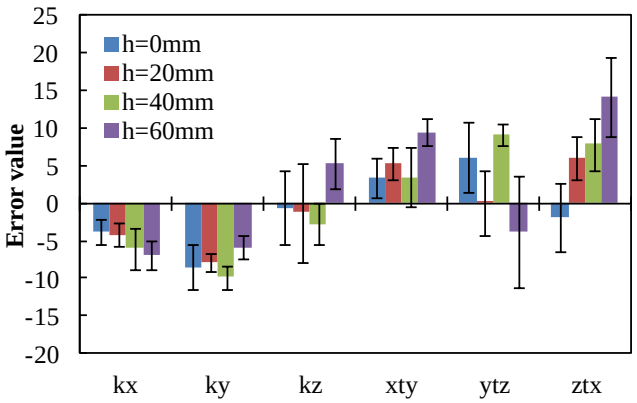

Fig.9 Result of comparison of BP parameters (in different height)

4.3.2 Result of statistical test (in different height)

This section shows the result of statistical test that factor is height where artifacts are set. The significance level of statistical test is set at 5%. The result of statistical test of parameters is shown in Table 4. In the case of "○", there is the difference that realization probability is 0.05 or less, and is meaningful and means that there is the difference by the placement height.

Table 4 Result of statistical test(in different height)

	kx	ky	kz	xty	ytz	ztx
QC	×	×	×	○	○	×
BP	×	○	×	○	○	○

5. DISCUSSION

5.1 About result of comparison of different artifacts

When two artifacts are compared in Fig.5, it turns out that xty of BP is quite smaller than that of QC. Moreover, the result with the BP was closer to a true value on the whole.

5.2 About result of different position

In Fig.6, the influence by the different position of QC shows changing the value sharply about ky of P3.

In the case of result of BP (Fig.7), the different position has a remarkable effect on kx and xty.

Comparing the results of the two artifacts in Table 3, both artifacts have a meaningful difference in ky and xty. Moreover, BP also has a significant difference in kx and ztx. Because the parameter of BP has the small standard deviation, it was proved that many significant differences came out. Specifically, the average of the standard deviation of BP was 3.0 and that of QC was 4.9. It is necessary to examine how to take stable data from now on.

5.3 About result of different height

In Fig.8, the different height of QC influences kz and xty. And about ytz, there was a tendency for the error value to become smaller as height increasing.

In the case of result of BP (Fig.9), the different height has a remarkable effect on kz, ytz and ztx. Moreover, there was a tendency for the error value to become larger as height increased by ztx.

Comparing the results of the artifacts in Table 4, both artifacts have a meaningful difference in xty and ytz. Moreover, there were parameters in which BP has many significant differences like the statistical test result of the different position of 4.2. Because standard deviation of each artifact parameter is comparable in the experiment of different height, it is proved that BP tends to come out of the influence of different height.

6. CONCLUSION

This paper describes the interim check method of CMM and the influence of which the factor becomes CMM's errors cause using the method. The important points of this paper are shown in following.

(1) It turned out that the tendencies of the scale errors and the squareness errors presumed by the artifact differed.

(2) It was proved that the different position of artifacts influenced ky of the scale errors and xty of the squareness errors.

(3) It was proved that the different height of artifacts influenced xty and ytz of the squareness errors.

7. REFERENCES

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