Effect of Focus Movement Correction on Measurement Accuracy of X-ray CT System

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Need for 3D Measurement System

Design  Production  Verification/Check

3D CAD  Production  Product (Prototype)  Measurement  3D Measurement Data

NC Machine  CMM

Data comparison

Reconsider the Spec  Correct the Condition
Dimensional CT System

Increase the number of measurement points → **Non-contact type**

Internal measurement → **Need for X-ray CT System**

Standard → **Define the ISO Standard (2020)**

<table>
<thead>
<tr>
<th></th>
<th>Probe Type</th>
<th>Optical Type</th>
<th>Dimensional CT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantage</strong></td>
<td>• <strong>High Accuracy</strong></td>
<td>• <strong>High Throughput</strong></td>
<td>• <strong>High Throughput</strong></td>
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<tr>
<td></td>
<td>• <strong>Defined Standard</strong></td>
<td>• <strong>Low Price</strong></td>
<td>• <strong>Measure Inside</strong></td>
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<tr>
<td><strong>Disadvantage</strong></td>
<td>• <strong>Low Throughput</strong></td>
<td>• <strong>Low Accuracy</strong></td>
<td>• <strong>Low Accuracy</strong></td>
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<tr>
<td></td>
<td>• <strong>Surface Only</strong></td>
<td>• <strong>Surface Only</strong></td>
<td></td>
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<tr>
<td><strong>Accuracy</strong></td>
<td>0.4~10 µm</td>
<td>4~50µm</td>
<td>4~50µm</td>
</tr>
<tr>
<td></td>
<td>◎</td>
<td>○</td>
<td>◯</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>Surface</td>
<td>Surface</td>
<td>Surface Inside</td>
</tr>
<tr>
<td></td>
<td>△</td>
<td>△</td>
<td>◯</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>some days</td>
<td>10~20min</td>
<td>60min</td>
</tr>
<tr>
<td></td>
<td>×</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td><strong>Operability</strong></td>
<td>difficult</td>
<td>easy</td>
<td>easy</td>
</tr>
<tr>
<td></td>
<td>×</td>
<td>◯</td>
<td>◯</td>
</tr>
</tbody>
</table>
Configuration of Dimensional CT System

- SRD axis
- Projection Data
- CT Image
- Acquisition Data
- Θ axis
- SDD
- X-Ray source - Detector
- SRD
- X-Ray source - Rotation center
- X-ray Detector
- X-ray Source
- SRD axis
Magnification error in high magnification range

In the high expansion region, the deviation of the SRD is greatly affected.

$$\text{Magnification} = \frac{SDD}{SRD}$$

$$\text{Magnification} (\text{offset } SDD) = \frac{SDD + \Delta sdd}{SRD}$$

$$\text{Magnification} (\text{offset } SRD) = \frac{SDD}{SRD + \Delta srd}$$

$$SDD = 1000 \text{ mm}, \quad \Delta srd = 1 \text{ mm}, \quad \Delta sdd = 1 \text{ mm}$$

The Error Ratio of Magnification and SRD

High Magnification

Low Magnification (Large FOV)
Factors of deterioration of measurement accuracy

As these factors accumulate, error in measurement accuracy
The causes of focal point movement are as follows.

- **Electron Beam Control**
- **Thermal Deformation of Tube Head**

As focal shift occurs, as device geometry fluctuates, the measurement accuracy decreases.
With the algorithm for measuring the focal shift amount developed, the focal point movement during continuous irradiation was detected as follows under certain X-ray irradiation conditions.
Take a measurement workpiece with two spheres (φ 5 mm alumina balls) with a CT device. Measure sphere distance from reconstructed CT data.
During the continuous irradiation of X-rays, repeated CT scans were performed to plot the distance variation between spheres. By correcting the focal point shift, it was possible to suppress the inter-sphere distance variation within the target ±1.0 μm range.
Summary

- With the developed algorithm, X-ray focal shift could be detected.
- By correcting the focal point movement amount, the inter-spherical distance fluctuation amount could be suppressed to $\pm 1.0 \text{ um}$ or less.