Performance Evaluation of On-machine Measurement Software

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In order to perform on-machine measurement using a touch probe on machining centers, it is necessary to create an NC program, just as an NC program is required to command the cutter path during machining. However, the macro program provided in the machine tools can only measure simple shapes such as the width of grooves and the inner and outer diameters of circles. In recent years, measurement software that automatically generates NC programs has become widespread. In this study, two types of measurement software were compared by measuring the workpieces specified in ISO standard for testing the accuracy of machines. These measurement software are intended for contour shape measurement on a machining center, and can output the difference between the coordinates of the measurement points specified on the 3D model and the actually measured values. By using these measurement software, it was found that inspections that cannot be measured by macro programs can be performed.

1. Introduction

In on-machine measurement using a touch probe, the touch probe is attached to the spindle of the machine tool, so it contributes to high accuracy for the position of the workpiece and other factors. However, on-machine measurement also has a measurement error, and this error affects the machining error of the finished product. However, since machining errors include not only geometric errors of the machine tool (positioning, repeatability, straightness, squareness, etc.) but also machining errors due to tool deformation and wear, on-machine measurement with touch probes is useful.

However, on-machine measurement with a touch probe requires NC programming, just as a machining center requires an NC program to command the tool path. The measuring macro programs provided with machining centers can only measure simple shapes such as groove widths and inner and outer diameters of circles, so measuring software that automatically generates NC programs has become popular in recent years.

In this study, the measurement results of two types of measurement software that automatically generate NC programs are compared, the above-mentioned errors are clarified, and more effective measurement methods are examined.

2. Calibration

Pre-travel and directional characteristics can be corrected by calibration. Calibration is the process of measuring a dimensionally guaranteed object with a touch-trigger probe and relating the results to the deviation from the reference dimension. Calibration of touch-trigger probes is usually performed using a ring gauge or a reference sphere.

2.1 Calibration using a ring gauge

This method uses an NC macro program provided with the machine tool for calibration to measure three or four points on the inside diameter of a ring gauge and calibrate the ±X-axis feed and ±Y-axis feed pre-travel amounts and the center offset distance between the spindle center and the stylus tip ball from the results. This method is also called datuming. Some machine tools are equipped with NC macro programs that calibrate the -Z-axis feed pre-travel amount by measuring a block gauge. The compensation amount obtained by these methods is used when measuring with the NC macro program.

The calibration methods are shown below. First, the center of the spindle and the center position of the ring gage are aligned using a dial gage. Next, the specified NC macro program is started to initiate calibration, which measures the measuring points for 4-point measurement and determines the offset distance between the spindle center and the stylus tip ball. The compensation amount is then measured using either the three-point or four-point measurement method selected. The compensation obtained from the measurement is automatically stored in the machine tool.

2.2 Calibration using a reference sphere

Calibration using a reference sphere is not provided on the machine tool, but is performed using on-machine metrology software, which determines errors such as pre-travel by measuring a minimum of 25 reference sphere measuring points as defined in ISO 230-10[3]. This calibration method measures the reference sphere from various angles, including the measurement points defined in ISO 230-10, to create a three-dimensional radial error map along the reference sphere, and determines the amount of correction for each approach angle. The software used in this study uses linear interpolation. Therefore, the directional characteristics are also constructed at the same time.

3. Equipment and Software Used

3.1 Machine tool

DMU75monoBLOCK (Fig. 1) 5-axis machining center with swiveling table from DMG MORI CO. is used in this study. It has three linear axes (X, Y, Z) and two rotary axes (A, C) on the table side.

Fig. 1 DMU75monoBLOCK

3.2 Measurement Software

NC gauge V3.5 from HXEAGON and Form Control V4 from BLUM were used. These softwares are intended for contour measurement in machining centers. NC Gage V3.5 is a software that enables intuitive measurement by inputting or teaching the parameters of the measuring points, and after measurement, it can calculate and output the geometric error of the actual measured values. Form Control V4 is software that outputs the difference between the coordinates of the measurement points specified on the 3D CAD model and the actual measured values. The followings show the functions of both NC Gage V3.5 and Form Control V4.

1. Contour measurement on a machining center
2. Measurement of standard geometric elements and detection of analytical machining errors
3. Register additional touch probes and styli
4. Measurement with 5-axis indexing
5. Automatic generation and transfer of NC macro programs during measurement
6. Calibration function of touch-trigger probes

4. Method and Conditions of Experiment

The flow from machining to on-machine measurement was actually performed. The workpiece to be measured was M1_160, described in ISO 10791-7[2]. Figure 2 shows the shape of the workpiece.

In this experiment, roughing, finishing, and on-machine measurement were performed on a 170 mm A2017 blank in this order. Before measurement, the blanks were allowed to acclimatize to temperatures overnight without removing the clamps in order to remove the effects of cutting heat. When actually performing JIS B 6336-7 inspections, the machine was removed from the machine and a CMM was used for measurement. In order to imitate this, the machine was removed from the machine once and re-installed for measurement. The results were compared using HXEAGON's NC gauge V3.5, BLUM's Form Control V4, and a measurement program program created by the company itself.

A touch trigger probe that had been calibrated with a reference sphere immediately prior to measurement was used, and measurements were taken at an approach speed of 100 mm/min and an approach distance of 5 mm. Measurement points were set approximately every 10 mm for straightness, every 15° for circularity, and every 45° when the center of a circle was required, and the reference plane was set to be as large a square as possible with five points per side. Figure 3 shows the measurement points.

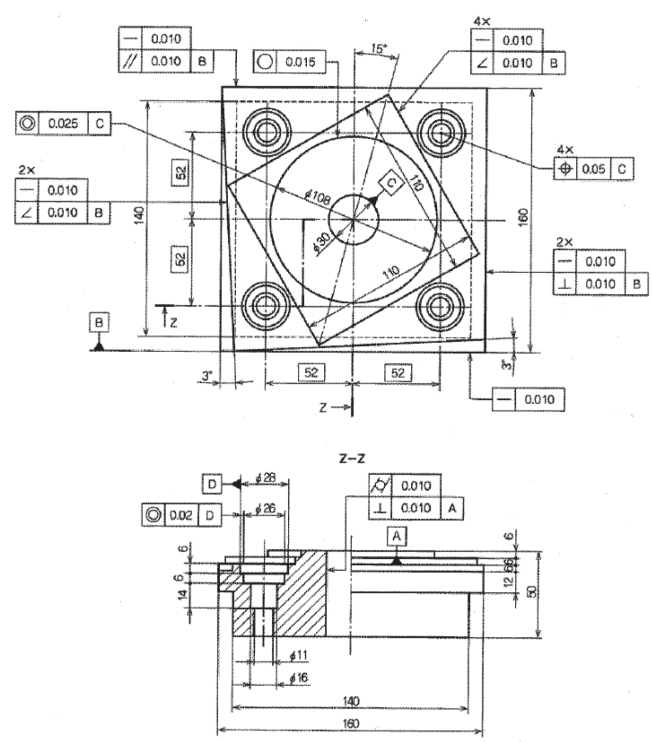

Fig. 2 Shape and standard value of workpiece ISO 10791-7, M1_160

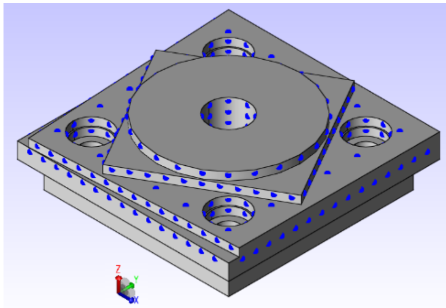

Fig. 3 Measurement point of workpiece ISO 10791-7, M1_160

5. Experimental Results

Tables 1 shows the ISO 10791-7, M1_160 geometry measurement results, and Fig. 4 shows the definitions of the measurement point numbers used in Table 1.

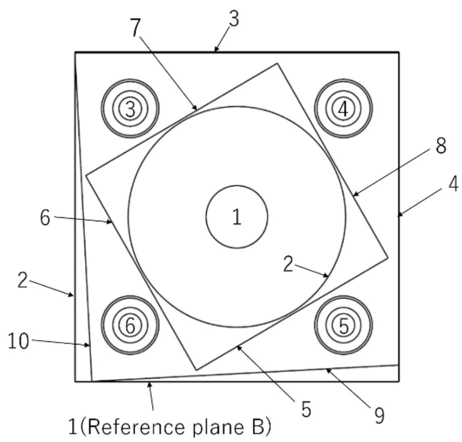

Fig. 4 Definition of the number of each measurement point

Table 1 Measuring conditions

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I	Measurements by macro program using OMP60
II	Measurement with NC gauge using OMP60
III	Measurement by Form Control using OMP60

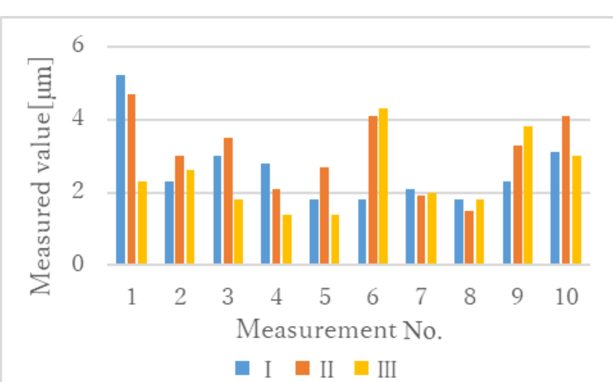

Fig. 5 Straightness of each side

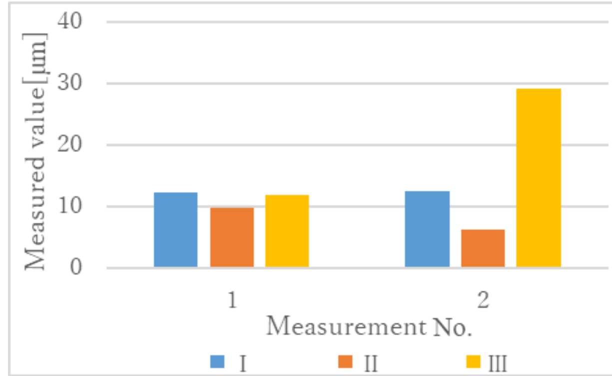

Fig. 6 Cylindricity and roundness

6. Considerations and Conclusion

1. Straightness has a slight error, but the trend is similar regardless of which measurement software is used. Therefore, it is safe to assume that the measurement results are not affected by the measurement software.
2. When using the macro program, only ring gage calibration can be performed, and since the directional characteristics cannot be compensated, measurements from multiple directions, such as circular, are subject to large errors. This indicates that the macro program is not suitable for measurements from multiple directions, such as circular shapes.
3. Since the amount of correction is determined by linear interpolation for the approach direction not measured at the time of calibration, it can be seen that it is better to use a touch-trigger probe with directional characteristics close to a circle even if calibration is performed when measuring a circular or free-form shape.

In the future, we plan to compare the measurement results with different machine tools and/or touch probes, as well as the measurement results with the macro program installed in the ma chine tools.

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