An Application of Finished Test Pieces in ISO 13041-6 for Performance Evaluation of CNC Turning Centres

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Abstract

Currently, several mechanical parts are produced from CNC machines including CNC turning centre. Since workpieces have to pass the accepted criteria, machines with sufficient performance have to be selected for production. Before selecting CNC turning centres, however, manufacturers need to know performance of their machines. In this research, a new technique for evaluating performance of CNC turning centres is introduced. A major benefit of this technique is that manufacturers can evaluate their machine performance by themselves (no experts are required). Using the testing results, additionally, the machined part geometry can be approximated in advance. Experimental results also supported that this new technique can be used in industry.

Keywords*:* Finished Test Piece, ISO 13041-6, Performance, CNC Turning Centre

1. Introduction

Currently, both NC and CNC turning machines have been used widely in Thailand. One of serious problem is that owners don't know an exact performance of their machines. This is because they need spend a lot of money and time for machine performance assessment. As a result, manufacturers cannot plan the production with high efficiency.

For machine tools, experts classify CNC performance testing into two categories. The first category includes direct measurement methods, and the second category is indirect measurement methods.

For the direct measurement methods of CNC turning centres, testers usually employ ISO 230 series and ISO 13041 series as testing standards. Major equipment for these test methods are laser interferometer, ball-bar and/or dial-gauge (Fig. 1). Testing results can be used for several machine adjustments. Since the testing results are quasi-static errors, manufacturers cannot know the extent of the difference between true product geometry and its design geometry.

For the indirect measurement methods, testers usually use ISO 13041-6 for evaluating the performance of CNC turning centres. This testing uses three finished test pieces for evaluating machine performance (just compliance or not compliance).

Unfortunately, both methods cannot tell that workpieces can be produced following the geometrical product specifications (GPS) or not.

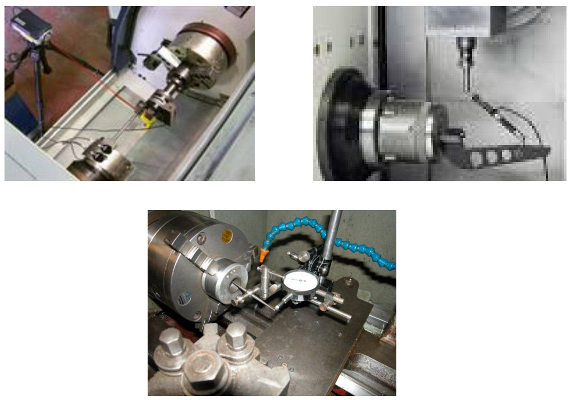

Fig. 1 Examples of testing instruments [1-3]

In this research, hence, a new technique for evaluating performance of CNC turning centre which is modified from ISO 13041-6 has been proposed. This new technique can predict whether the machine can produce finished workpieces following the geometrical product specifications (GPS) or not. Additionally, the new technique spends a shorter testing time and a lower testing cost compared with other techniques.

2. ISO 13041-6

ISO 13041-7 test conditions for numerically controlled turning machines and turning centres – part 7: accuracy of a finished test piece is an ISO standard for supplying information as wide and comprehensive as possible on tests which can be carried out for comparison, acceptance, maintenance or any other purpose. It can be used for both numerically controlled turning machines and turning centres [4].

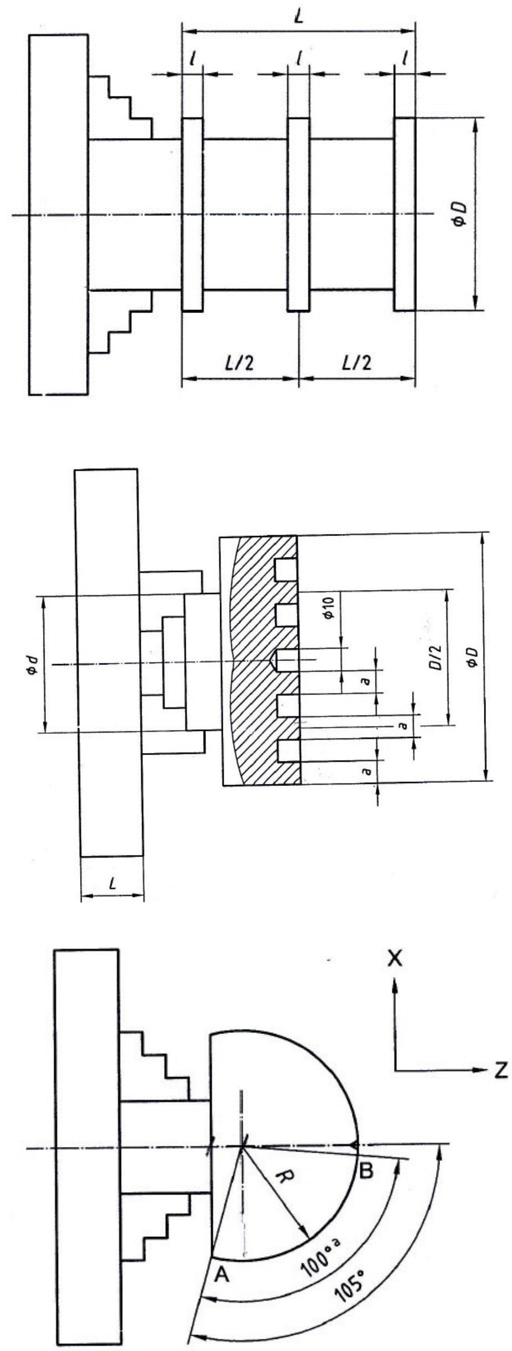

Fig. 2 Three finished test pieces shown in ISO 13041-6 [4]

In order to apply ISO 13041-6, reference shall be made to ISO 230-1, especially for the installation of the machine before testing, warming up of the machine, description of measuring methods, evaluation and presentation of the results [4]

There are four types of test piece. The first is a cylindrical test piece. The second is a flatness of surface test piece. The third is a test piece machined under different kinematic conditions. The last is a circular test piece. Examples for these test pieces are shown in Fig. 2.

Tooling, cutting parameters (cutting speed, feed rate and depth of cut), and pre-machined blank need to be done following the standard. A coordinate measuring machine (CMM) must be used as the major measuring instrument.

Using this ISO standard, test pieces can provide some useful information for evaluating machine performance. This information includes:

1) Cylindricity
2) Consistency of machined diameters
3) Flatness
4) Circular deviation
5) Squareness
6) Parallelism
7) Straightness
8) Accuracy of the angles
9) True position of holes
10) Concentricity of outer holes to inner holes

3. A New Technique for CNC Turning Centre Performance Evaluation

A concept of the new technique for evaluating performance of CNC turning centre is to convert tolerance values of the test piece to tolerance per unit length of each tolerance type (as shown in Fig. 3). Additionally, the uncertainty of measuring equipment is relevant in this concept.

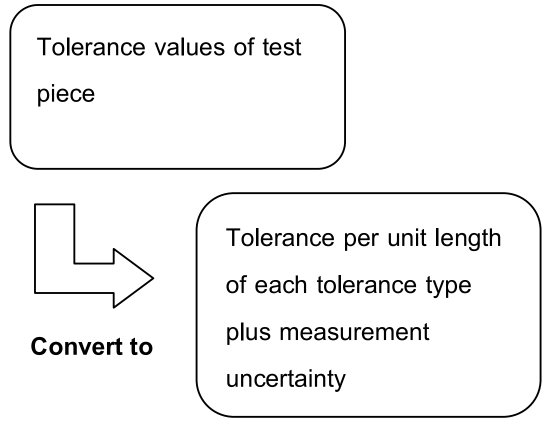

Fig. 3 A new technique for CNC turning centre performance evaluation

4. Experimentation

4.1 Equipments and Materials

Major equipment and material employed in this research are:

CNC Turning Centre - Hass (Model: ST10)

CMM – Brown & Sharpe (Model: PMM-C700)

Tool insert No.WNMG080404MA (for endface and roughness)

Tool insert No.TNMG160404R2G (for finishing)

Stainless steel SUS304

4.2 Experimental Set-up

In this research, a cylindrical, a flatness of surface and a circular test pieces of ISO 13041-6 standard with sizing in category 1 were used as standard test pieces (shown in Fig. 4). The method for preparing the blank, including selection of cutting parameters, was done by following the recommendation mentioned in the ISO standard.

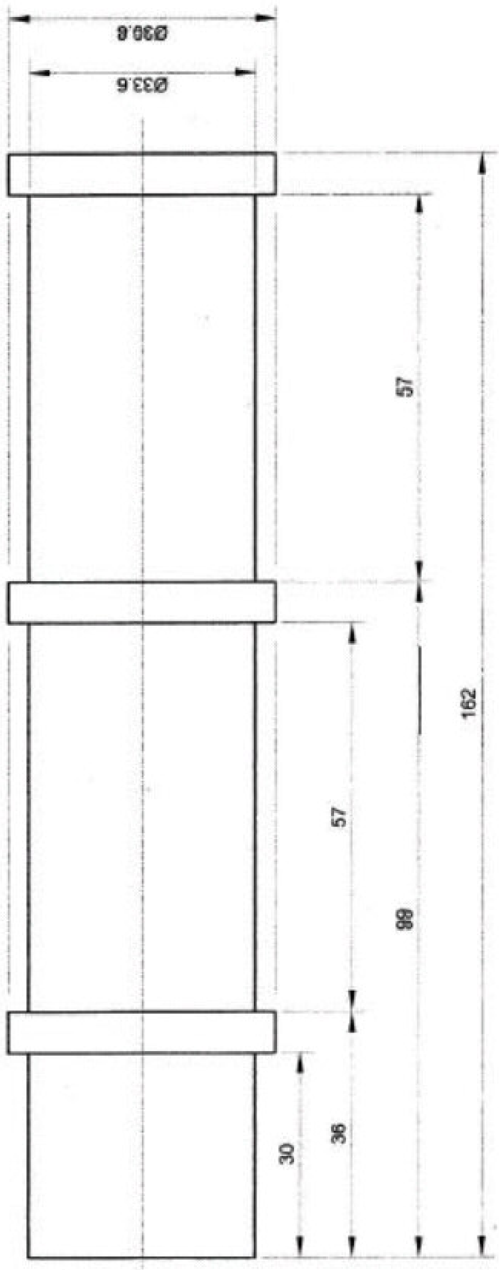

Fig. 4 Drawing of three test pieces

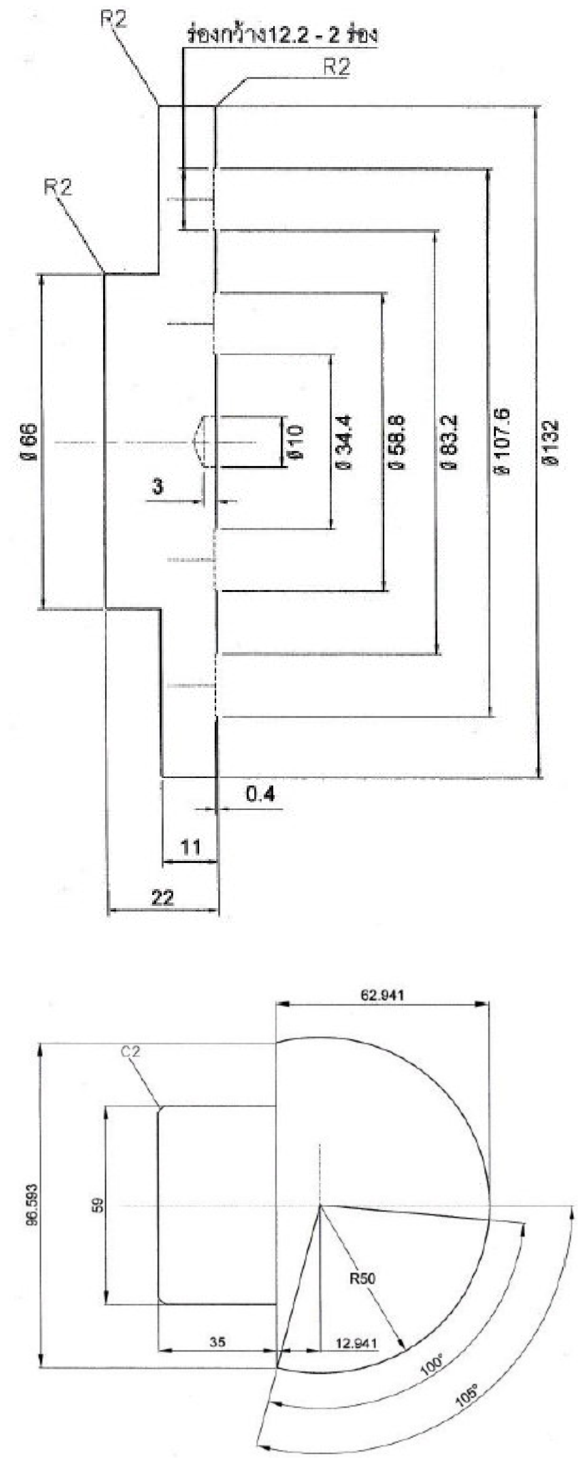

Fig. 4 (cont.) Drawing of three test pieces

When the machining process finished, the test pieces were assessed by measured tolerance values using the CMM machine. The 4–object of tolerance (mentioned in ISO 13041-6) was recorded. Then, these tolerance values were converted to tolerance per unit length of each tolerance type plus the measurement uncertainty.

For testing the concept of the new technique for evaluating performance of CNC turning centre, the design shown in Fig. 5 was used as a case study. Before production, the calculated tolerance was used to predict the dimension of the workpiece. After the machining process was finish, the exact and the predict dimensions were compared.

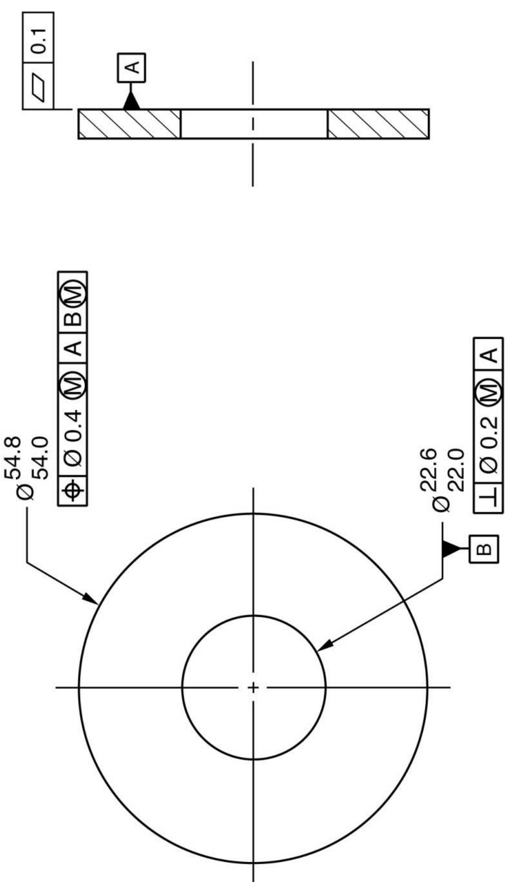

Fig. 5 A case study.

5. Results and Discussion

5.1 Testing of CNC turning Centre Performance

As stated in Section 4, the performance of CNC turning centre was assessed by followed ISO 13041-6. In this research, a cylindrical, a flatness of surface and a circular test pieces were employed (Fig. 2).

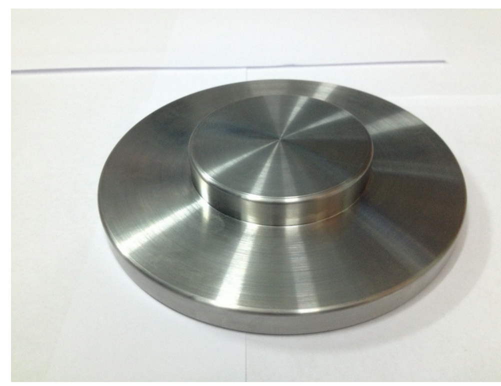

Fig. 6 An example of pre-machined blank of a flatness of surface test piece

Before machining these test pieces, pre-machine blanks (Fig. 6) were prepared under recommendation of ISO 13041-6. Employing cutting parameters specified in ISO 13041-6, three test pieces were made and shown in Fig. 7.

Employing the CMM machine to measure the test pieces (Fig. 8), test results were recorded and shown in Table 1. Considering Tables M1, M2 and M4 of ISO 13041-6: 2005(E) (Fig. 9), it was found that there are some tolerance objects which could not pass the accepted criteria. These are the consistency of machined diameters and the flatness. From these results, the owner needs to refurbish this machine as soon as possible although it can be used for making low accuracy workpieces.

Fig. 7 Examples of test piece

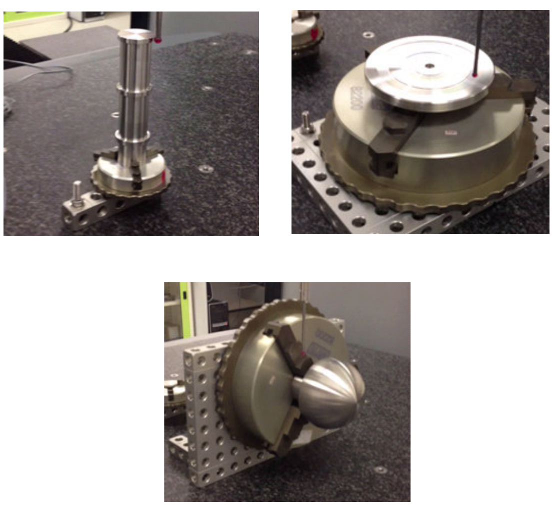

Fig. 8 Measuring of a test pieces by using CMM machine

As mentioned in Section 3, the test results following ISO 13041-6 need to be converted to tolerance per unit length with uncertainty. The uncertainty value can be determined from 1) the actual uncertainty of CMM machine that is reported in the certificate of calibration, or 2) the permissible error of CMM machine calculated following ISO 10360-2.

In this work, the uncertainty value was taken from the permissible error of the CMM machine (ISO 10360-2). This value can be calculated from $\Delta U = \pm(3.9 + 4L/1000)$ μm. Since the unit length that is used in this research is 100 mm, the uncertainty is $\pm$ 4.3 μm.

The following step shows an example of calculation. Supposing, the flatness needs to be converted into the form of tolerance per unit length with uncertainty. As shown in Table 1, the measuring value is 15 μm for 132 mm length (radius). For the length of 100 mm, the tolerance value per unit length (100 mm) is $\frac{15\times 100}{132}\pm 4.3$ = 11.4 μm/ 100 mm (radius) $\pm$ 4.3 μm. The rest of converted values are shown in Table 1.

5.2 Predicting Workpiece Dimension by using the Introduced Concept

As mentioned earlier, 3 of 4 test pieces were used in the experiment. Hence, only 4 tolerance objects including cylindricity, consistency of machined diameters, flatness and circular deviation of a 100° can be a estimated tolerance value per unit length (shown in Table 1).

Considering the case study shown in Fig. 5, it was found that there are three GD&T need to be concerned. However, only the flatness can be predicted before machining. This is because the rest GD&T need to be predicted from a test piece machined under different kinematic conditions which wasn't done in this research.

Using information mentioned in Table 1, he predicted flatness is calculated. The value is about 6.2 μm ± 4.3 μm (calculated from Eq. 1). Compared with the real tolerance values measured by the CMM machine (5.3 μm ± 0.8 μm), the result showed that the new concept, introduced in this research work, can be used to predict the workpiece dimensions.

6. Conclusions

Experimental results, shown in Section 5, indicate that the proposed technique can be used for evaluating performance of CNC turning centres. By applying this technique, additionally, machined part manufacturers can approximate geometric error of their product in advance.

7. Acknowledgement

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8. References

[1] http:// www.renishaw.com/en/renishaw-enhancing-efficiency-in-manufacturing-and-healthcare--1030 (accessed on 30 May 2013).

[2] http://www.realmeca.com (accessed on 30 May 2013).

[3] http:// www.practicalmachinist.com (accessed on 30 May 2013).

[4] ISO 13041-6:2005 (First Edition) Test Conditions for Numerically Controlled Turning Machines and Turning Centres – Part 6: Accuracy of A Finished Test Piece.

Table. 1 A cylindrical, a flatness of surface and a circular test pieces

Object		Measuring Value (μm)	Measuring Value per Unit Length with Uncertainty (μm)
	A cylindrical test piece		
a)	Cylindricity	5	12.6 μm / 100 mm (radius) ± 4.3 μm
b)	Consistency of machined diameters	15	37.9 μm / 100 mm (radius) ± 4.3 μm
	A flatness of surface		
c)	Flatness	15	11.4 μm / 100 mm (radius) ± 4.3 μm
	A circular test pieces		
d)	Circular deviation of a 100°	25	50 μm / 100 mm (radius) ± 4.3 μm

$$54.4\,mm\,(radius\ of\ a\ case) \times \frac{11.4\,\mu m\,(flatness\ per\ unit length\ indicated\ in\ Table\ 1)}{100\,mm} \qquad (1)$$

Tolerance			
Machines with horizontal workholding spindle			
	Category 1	Category 2	Category 3
a) circularity	0,005	0,005	0,005
b) consistency of machined diameters	0,01	0,015	0,02

(a) Tolerance indicated in Table M1

Tolerance			
Machines with horizontal workholding spindle			
	Category 1	Category 2	Category 3
Flatness	0,010	0,015	0,020

(b) Tolerance indicated in Table M2

Tolerance			
Test piece designation: ISO 13041-6:	M4-50	M4-100	M4-150
Nominal *R*:	50	100	150
Circular deviation:	0,025	0,045	0,070

(c) Tolerance indicated in Table M4

Fig. 9 Some information of Tables M1, M2 and M4 of ISO 13041-6: 2005(E)