Measuring of positioning, circularity and static errors of a CNC Vertical Machining Centre for validating the machining accuracy

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ABSTRACT

A CNC machine tool performance depends on the machine accuracy status which is very important to determine the end product compliance to the specification. The accuracy of the machine can be measured and analyzed; hence the errors' impact can be predicted on a workpiece. This paper presents three types of accuracy tests performed on a CNC Vertical Machining Centre, how the accuracy status affect the end product quality and what are the corrective actions to be taken. First, the laser test to determine the linear positioning accuracy, second the ball bar test to determine the circularity accuracy and third, the static accuracy test to determine the machine current static accuracy status and finally the cutting test to determine the actual machine accuracy effect on a work piece. Machine tool's errors can be diagnosed and minimize or eliminated by either electronic compensation or mechanical maintenance and sometimes both need to be done.

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1. Introduction

Manufacturing industries have been using CNC machine tools to control the quality of their product and to improve the production efficiency. The leverages of CNC machine tools in industries can improve the company capability to meet market demand which is fast and increasing. High demand in precision product manufacturing is one of the key elements of CNC machineries application in the manufacturing industries [1]. The accuracy of machining processes are very critical in meeting complex products with tight dimensional tolerances. The accuracy of machined parts depends on the machine accuracy. The state of machine tool accuracy has a huge impact on the quality of the end products [2].

However, errors in machining can cause inaccuracies to the process which directly affect the quality of the end products. The sources of the general machining errors include table positioning, cutting parameters, thermal response characteristics, geometric dynamic, machine geometric defect, vibration and wear of the cutting tools [3]. Many studies have been carried out on the methods to identify measure and overcome the errors.

Machining errors are unfavourable and hard to avoid once they emerge during machining, but they can be identified and measured, therefore counter measure can be taken to minimize or eliminate the source. Mekid and Ogedengbe [4] have identified three main sources of errors namely geometrical errors, thermal induced errors and load induced errors. They have also classified these errors

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Fig. 1. Vertical Machining Centre (VMC800).

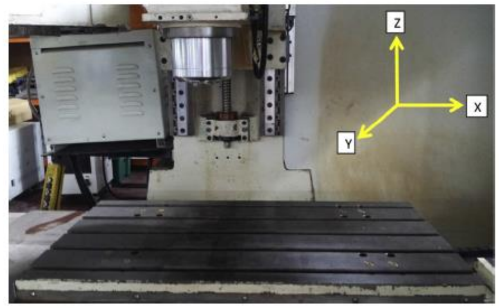

Fig. 2. X, Y and Z axes directions.

as systematic and random errors where the former is easier to manage than the latter. Some efforts on predicting and compensating errors in machine tools have been summarised in their paper. The basis of error prediction start with categorising whether the errors are caused by either geometric, thermal or load induced error. The machine elements such as ball screw, guide ways and machine table can contribute to the geometric errors and it can be predicted as early as during machine assembly. Thermal induced errors mainly cause by the heat generated by the mechanical drive system, bearing frictions and temperature change during cutting process. The load induced errors arise from cutting process where the cutting forces cause temporary deformation to the machine structure. Even though error avoidance is the basic way of building accurate machine tool but due to investment cost rising exponentially with the accuracy level, the error compensation is a more preferable method because of the industries demand for accurate machine at affordable cost. Most CNC machine tools nowadays have an electronic compensation feature built in within the controller system. This feature can be used to compensate electronically the geometric errors of the machine such as the positioning and backlash errors. Errors need to be measured and

Table 2
Measurement parameters.

Axis	Parameters				
	Traverse distance (mm)	First target coordinate (mm)	Last target coordinate (mm)	Halt interval (mm)	No. of target positions per direction
X	800	0	800	20	41
Y	500	0	−500	20	26
Z	500	−500	0	20	26

Table 1
VMC800 specifications.

1.	Travel	*X*-axis	mm	800
		Y-axis	mm	500
		Z-axis	mm	500
2.	Table	Dimension	mm	950 × 500
		Max load	kg	500
		T-slot (Pitch × width × No)	mm	100 × 18 × 5
3.	Spindle	Motor power	kW	7.5
		Max. Speed	rpm	8000
		Spindle nose to table surface	mm	150–650
		Spindle centre to column surface	mm	600
		Direct drive gear ratio		1
4.	Feed	Rapid transverse	m/min	24
5.	ATC	Tool type		BT-40
		Number of tools	nos	20
		Max tool diameter (with adj tool)	mm	90
		Max tool diameter (w/o adj tool)	mm	125
		Max tool length	mm	250
		Max tool mass	kg	7
6.	Motor	*X*/*Y*/*Z*	kW	2
7.	Coolant	Tank capacity	Litre	300
8.	Accuracy	Positioning	mm	0.010
		Repeatability	mm	0.010
9.	Machine	Weight	kg	6000
		Dimension	mm	3300 × 2900 × 2700
		Power supply	kVA	30

Table 3
Laser interferometer specification.

No	Item	Specification
1.	Measurement accuracy	0.7 μ/m
2.	Power	50 W
3.	Fuse	3.15 A
4.	Resolution	0.001 μm
5.	Maximum feed	1 m/s
6.	Laser power	1 mW

Table 4
Ballbar system specifications.

No	Item	Specification
1.	Accuracy	±0.5 μm (at 20 °C)
2.	Sensor resolution	0.1 μm
3.	Calibrator accuracy (150 mm)	0.1 μm (at 20 °C)
4.	Maximum sampling rate	250 Hz
5.	Operating temperature range	0–40 °C

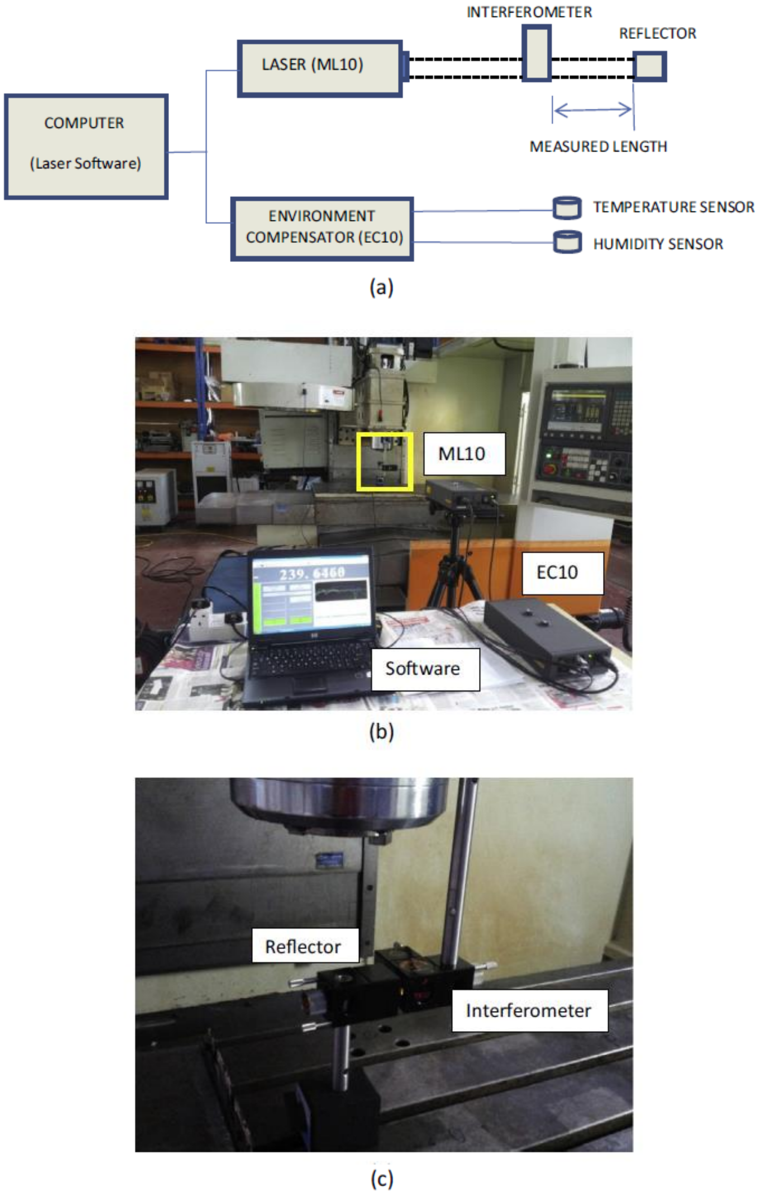

Fig. 3. Laser test scheme. (a) Laser interferometer schematic. (b) Laser interferometer setup. (c) Enlargement of (b).

analysed so that prediction can be made and this is usually done directly by the measuring system used. The predicted error value then inputted to the compensation system.

The positioning accuracy of CNC machine tools depends highly on the accuracy of the machine linear and circular axes and the machine structure dimensional stability.

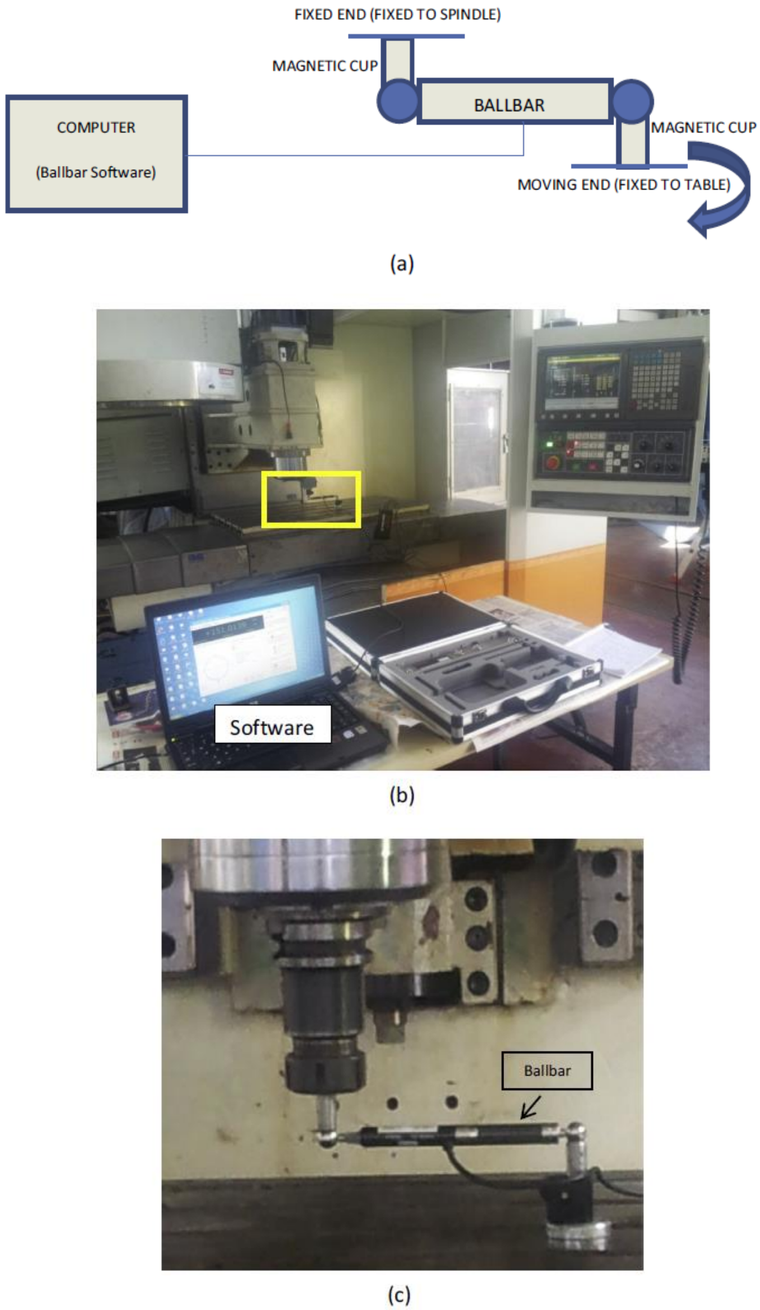

Fig. 4. Ballbar test scheme. (a) Ballbar system schematic. (b) Ballbar setup. (c) Enlargement of (b).

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