“Contouring Accuracy Improvement in VMC V-544”

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ABSTRACT

Computer numerical control (CNC) machine tools are currently broadly utilized as a part of the manufacturing business. With an expanding request on the dimensional precision of machined parts, analysts are keeping on looking for different techniques to enhance the machining accuracy of CNC machines. Contouring accuracy regarding contour error is a major sympathy toward the planners and end-clients of contouring (or continuous-path) kind of CNC machines. In this paper, a methodology for axial dynamics matching through increase tuning is proposed for enhancing the contouring accuracy in CNC machines. All the more particularly, gain tuning has a place with contouring control.

Keywords: *CNC machine tool, Contouring Accuracy, Gain Tuning, Axial Tracking Error.*

I. Introduction:

In CNC machines, a part is made by a part program which characterizes the geometrical measurements and assembling conditions, for example, feed rate and tool type. The part program can be physically composed or created by a computer-aided manufacturing (CAM) program. One class of CNC frameworks is the contouring frameworks, in which the instrument is cutting while the axes of movement are moving. A case of this is the CNC milling machine. In these frameworks, the machine axes are independently determined and controlled so they take after the reference inputs produced by an interpolator. The interpolator arranges the movement among various axes by supplying the comparing reference inputs to every pivot of movement in order to create tool paths important to machine the wanted part. In most present day CNC machines, the interpolator is equipped for interpolating linear, circular and occasionally parabolic contours. [1]

In this paper experiments are done in endeavour to show that even when individual axes tracking errors are significantly high, the overall tracking error of the machine can be lowered by tuning tracking errors (gain tuning).

II. Existing Work:

By R. Ramesh, M.A. Mannan, and A.N. Poo [2] in 2004, Investigation of Tracking and contour error control in CNC servo systems carried out. They presumed that Conventional tracking control algorithms depend on the feedback principle. Utilizing a high feedback gain has serious constraints showing as increased noise sensitivity, generation of undesirable oscillations, and so on. According to Somnath Chattopadhyay [3], the general precision of the machine instrument is chosen by the mechanical attributes of the machine and in addition the qualities if the control framework driving the individual axes. They recognized different benefactors to this contouring error, and specifically assess the error because of stick slip movement utilizing scientific methods. In 2008, Xue-Cheng Xi, Aun-Neow Poo, Geok Soon Hong [4] presented a paper on improving contouring accuracy by tuning gains for a bi-axial CNC machine. According to them, the errors due to unmatched dynamics can be largely reduced by using a simple controller so as to keep the order of axial dynamics low and by tuning appropriately the proportional gains to match the dynamics. According to Charlie A. Ernesto and Rida T. Farouki [5], CNC machines utilize input control frameworks to freely drive every machine axes keeping in mind the end goal to accomplish a given velocity of the apparatus along a given way, in respect to the workpiece. Because of the innate machine controller motion, it is difficult to react promptly to varieties in commanded path geometry and speed. They proposed a strategy as a rule connection of PID (proportional integral derivative) controllers and its executions.

III. Experimental Setup

Experimental evaluation of the proposed approach was carried out on a 3-axis CNC machine- V 544. Only the X and the Y axes were used. AC servo motors with the motor drives set in velocity control mode. Gp is a proportional controller for the position loop executed in the PC and Gv is a proportional-plus-integral controller for the inward velocity loop actualized in the equipment motor drive which goes with the motor. Position feedback was actualized through an encoder which has a determination of 10000 pulses /rev. The lead of the ball screw utilized is 4 mm giving a determination for the position criticism as 0.4 μm/ pulse of direct travel.

A Core i3 2.3 GHz computer was used with a Servo-To-Go interface card. The computer operated under the RTAI real-time operating system which was patched to Windows XP. The open source Enhanced Machine Controller (EMC) was used as the CNC control software. The hardware abstract layer (HAL), a feature in EMC, was used to implement the real-time module used in EMC. The sampling frequency used is 1 kHz. Measurements are taken by Renishaw's XL80 laser interferometer.

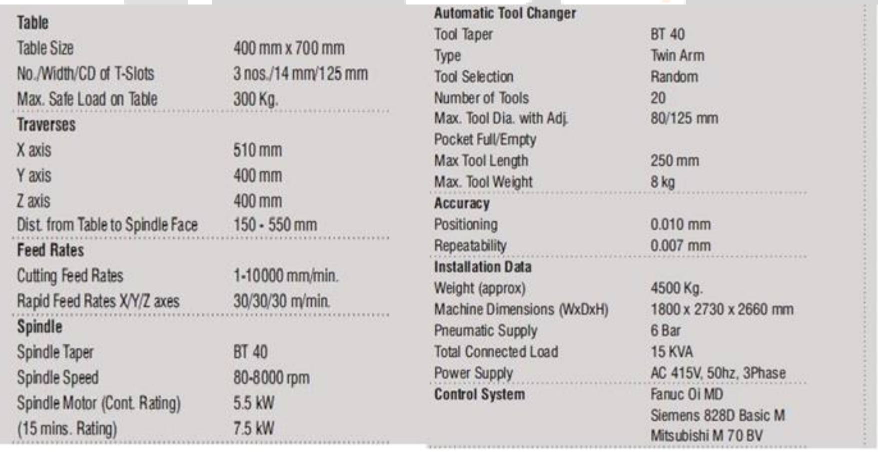


Table	
Table Size	400 mm x 700 mm
No./Width/CD of T-Slots	3 nos./14 mm/125 mm
Max. Safe Load on Table	300 Kg.
Traverses	
X axis	510 mm
Y axis	400 mm
Z axis	400 mm
Dist. from Table to Spindle Face	150 - 550 mm
Feed Rates	
Cutting Feed Rates	1-10000 mm/min.
Rapid Feed Rates X/Y/Z axes	30/30/30 m/min.
Spindle	
Spindle Taper	BT 40
Spindle Speed	80-8000 rpm
Spindle Motor (Cont. Rating)	5.5 kW
(15 mins. Rating)	7.5 kW

Automatic Tool Changer	
Tool Taper	BT 40
Type	Twin Arm
Tool Selection	Random
Number of Tools	20
Max. Tool Dia. with Adj.	80/125 mm
Pocket Full/Empty	
Max Tool Length	250 mm
Max. Tool Weight	8 kg
Accuracy	
Positioning	0.010 mm
Repeatability	0.007 mm
Installation Data	
Weight (approx)	4500 Kg.
Machine Dimensions (WxDxH)	1800 x 2730 x 2660 mm
Pneumatic Supply	6 Bar
Total Connected Load	15 KVA
Power Supply	AC 415V, 50hz, 3Phase
Control System	Fanuc Oi MD Siemens 828D Basic M Mitsubishi M 70 BV

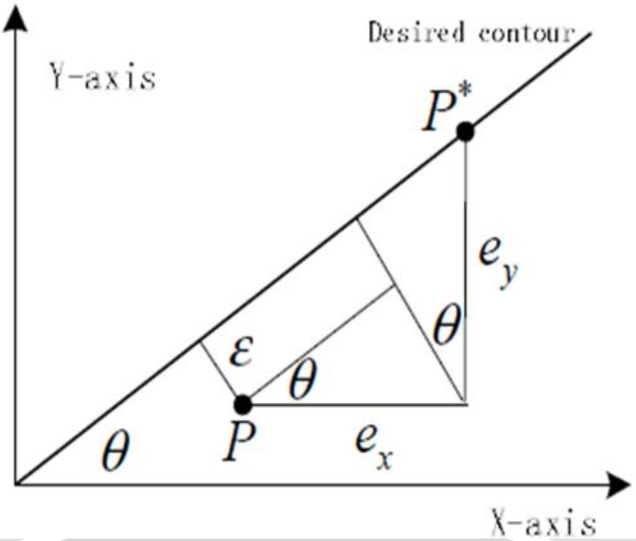
Figure1: Picture and specification of VMC V 544

IV. Errors for linear contours

To produce the coveted straight shape at an edge of θ to the X pivot and with a way speed of V, the reference inputs to the two tomahawks will be

$$R_x(s) = \frac{V\ cos\theta}{s^2} \qquad Ry(s) = \frac{V\ sin\theta}{s^2}$$

Alluding to Fig. 2 in which P* and P are the desired position and actual position respectively of the device area along the linear contour amid movement, the contour error at any given example is given by



$\varepsilon = e_y \cos\theta - e_x \sin\theta$

Figure 2: Linear contour error (P is the real position, P* is the sought position.)

Procedure of matching individual axes tracking error can be illustrated by following conditions.

1. If exss > eyss, then the gains should be changed to

Kpxnew = Kpxold

Kpynew = Kpyold (eyss/exss)

2. If exss ≤ eyss, then the gains should be changed to

Kpxnew = Kpxold (exss/eyss)

Kpynew = Kpyold

K_{pxold}	K_{pyold}	e_x	e_y	$\gamma = e_x/e_y$	K_{pxnew}	K_{pynew}	e_{xnew}	e_{ynew}
11.0	10.0	0.1581	0.1736	0.9107	10.02	10.0	0.1736	0.1737
10.02	11.0	0.1736	0.1588	1.100	10.02	10.00	0.1736	0.1737

Table 1: Tuning of axial gains

Taking after the tuning method proposed in this anticipate, the corresponding additions of the axes controllers were tuned keeping in mind the end goal to accomplish coordinating loop gains. These gains, spoke to by Kpxold and Kpyold in the principal column of Table 1, are Kpxnew = 10.02 and Kpynew = 10.00 respectively. With the new arrangement of tuned gains, the framework was made to take after the same liner contour at 45° to the X-axes. Fig. 3 demonstrates the contour errors delivered before tuning and after tuning.

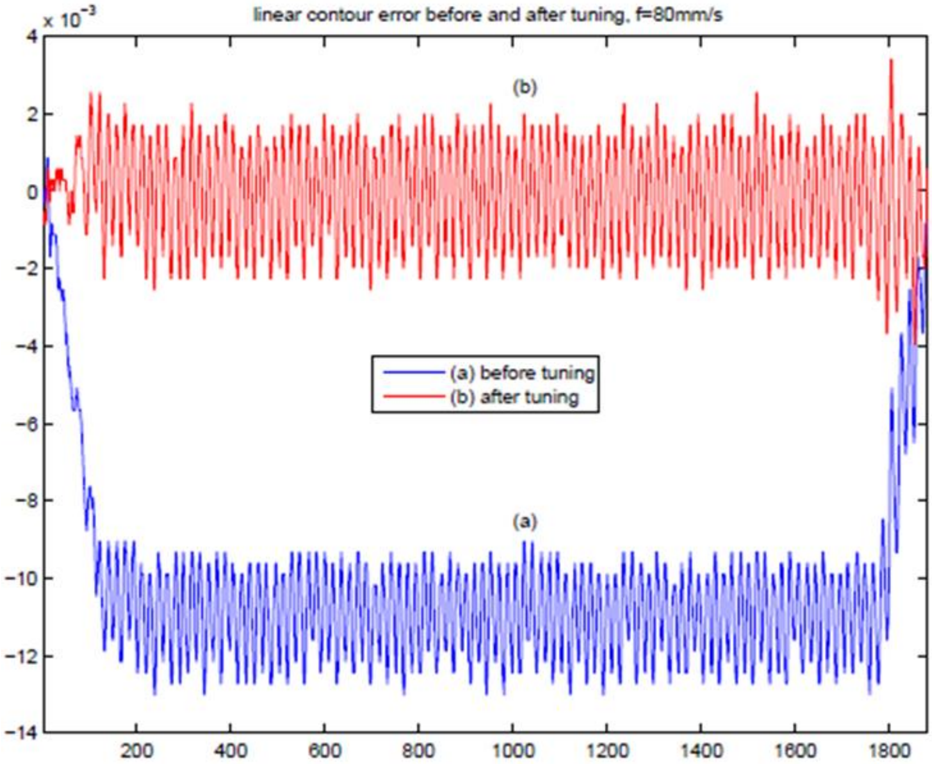


Figure 3: Linear contour errors before and after tuning

In the wake of tuning the proportional gains, three linear contours were created at three diverse points concerning the X axes, i.e. 30°, 45° and 60°. The outcomes, appeared in Fig. 5 and Table 2, show that the contour errors are inside a band of ±2µm, and the size of the mean estimation of the contour errors are all inside the determination of the encoder, which is 0.4 µm.

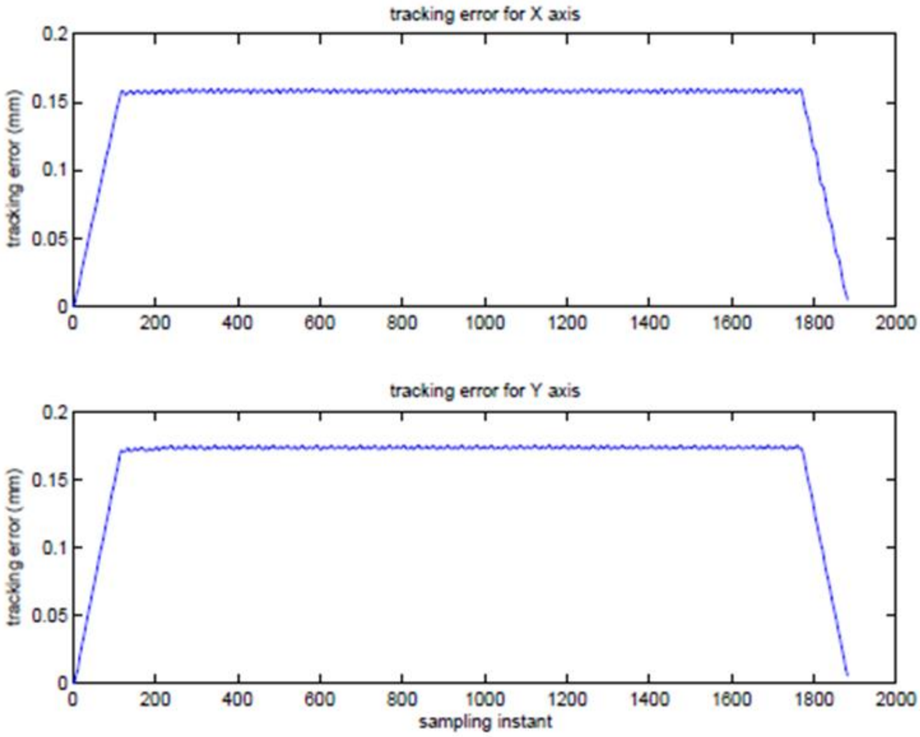


Figure 4: Tracking error for the X and the Y axes after tuning

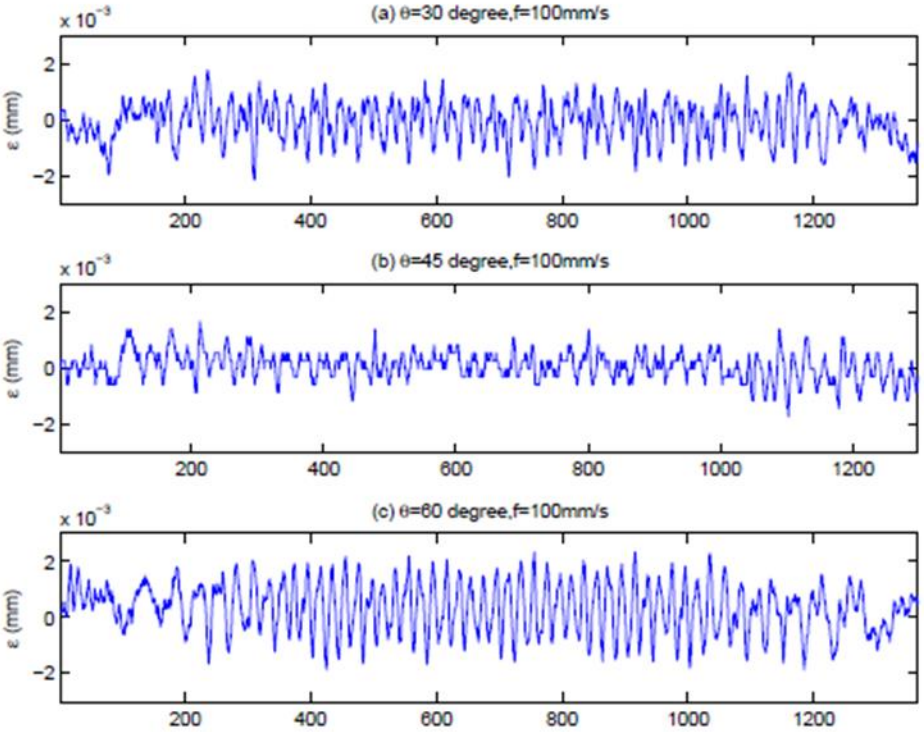
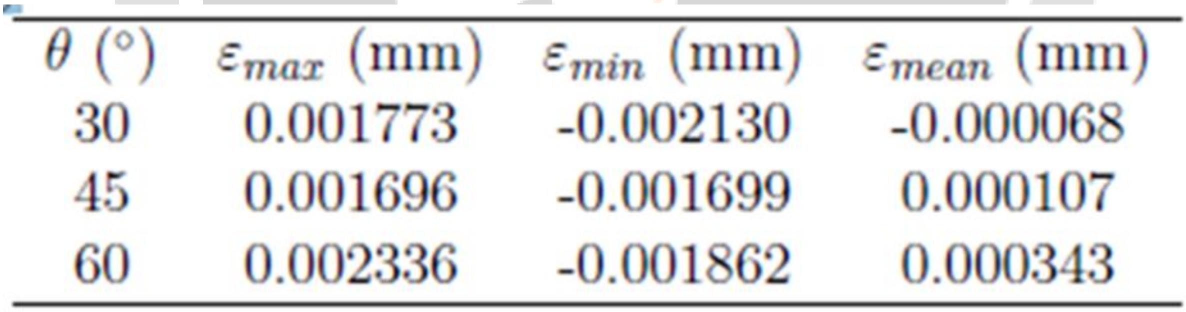


Figure 5: Linear contour errors for 3 different angle with respect to the X axis after tuning Kp: (a) 30°, (b) 45° and (c) 60°

By tuning individual axes we get the contouring error as following,

Table 2: Linear contour errors for different angles after tuning the proportional gain



θ (°)	ε_{max} (mm)	ε_{min} (mm)	ε_{mean} (mm)
30	0.001773	-0.002130	-0.000068
45	0.001696	-0.001699	0.000107
60	0.002336	-0.001862	0.000343

V. Conclusion

As shown by the experiment, even when there is significant amount of axial tracking error in x and y axes, the overall contouring error is improved from 10 µm max to 2 µm max. These results conclude the objective of the proposed analytical point, hence the experimental results show that with this simple approach, the resulting matched axial dynamics can effectively eliminate the linear contour errors.

VI. References

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