euspen's 17th International Conference & Exhibition, Hannover, DE, May 2017
www.euspen.eu

Development and performance evaluation of desktop machine tool

Satoshi IINO[1], Serenn SATO[1], Yoshitaka MORIMOTO[1], Ryo HIRONO[2], Naohiko SUZUKI[2], Yoshiyuki KANEKO[2]

[1]*Kanazawa institute of technology,* [2]*TAKAMAZ Machinery Co. Ltd.*

b6600345 @planet.kanazawa-it.ac.jp

Abstract

In recent years, the miniaturization of products and machine parts is progressing and becomes available as the practical use. However, the machine tool itself still remains the conventional size. Therefore, in order to improve production efficiency, one of the solutions is to downsize the machine tool. In our laboratory, a desktop machine tool with hollow CFRP pipe frame has been developed to realize the space saving with guaranteeing the rigidity by designing truss structure and adopting a unique feed drive mechanism with the worm gear and the helical rack. The original CNC controller based on the FPGA technique has been also developed. The feedback system can be selectable both semi-closed system (a position encoder) and full-close system (a linear encoder).

In this study, we report the positioning performance and the evaluation results of the developed desktop machine tool.

Key words: Desktop machine tool, CFRP pipe, Truss structure, Simulation, Double lead worm gear, Full close control

1. Introduction

Recently, downsizing of various products is required from the industry and become important to develop micro components for realizing the downsized machine. However, conventional machine tools are relatively large to workpiece traditionally, because the rigidity is regarded as the priority design for them [1]. The downsizing of machine tools has not been realized completely. On the other hand, the needs of machine tool, which can machine the workpiece with enough high accuracy at the limited machining space and with the improved productivity, is higher requested from the production field [2]. Therefore, we propose a unique machine tool that consist of truss structure using hollow CFRP pipes, the original NC controller for developing the desktop machine tool. This can not only save the machine space but also has the enough high rigidity. In this report, the performance of this machine tool developed are evaluated.

2. Basic configuration of desktop machine tool

The specifications of the developed desktop machine tool are described in Table 1 and shown in Fig.1. The developed machine tool is developed is enough simple that the configuration of it can be changed easily.

3. Motion simulation of X-axis feed drive mechanism

The positioning system of the X-axis feed drive mechanism is modelled and simulated the table motion to compare the table motion. The block diagram of the feed drive system for the desktop machine tool is shown in Fig. 3. As all the mechanical parameters are identified by experiments and the technical information, the table motion can be predicted by the simulation software (MATLAB Simulink).

3.1. Simulation result

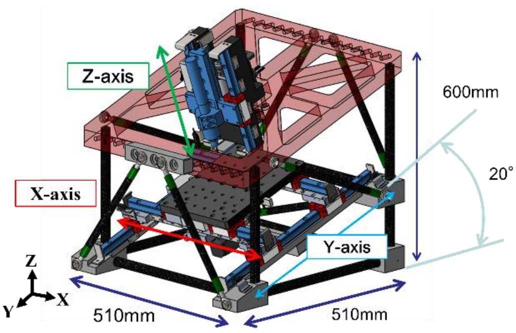

Figure 1. Desktop machine tool

Table 1 Specifications of desktop machine tool

Stroke(mm)	200×200×120
Table size(mm)	210×260
Maximum workpiece size(mm)	60
Target material	Aluminium alloy, steel
Rated spindle speed(min^{-1})	30000
Spindle power(W)	125
Resolution(μm)	Under0.2
Tool chuck system	Chuck collet
Mass(kg)	60
Power supply system(V)	DC24

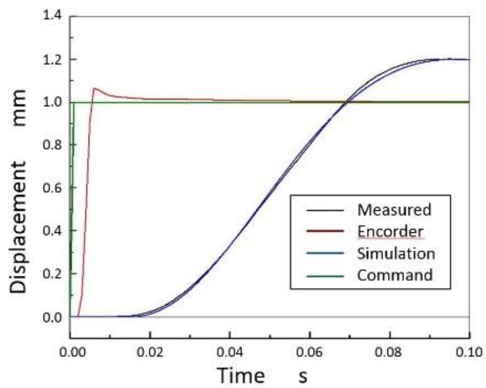

Figure 2. Motion comparison obtained by rotary encoder

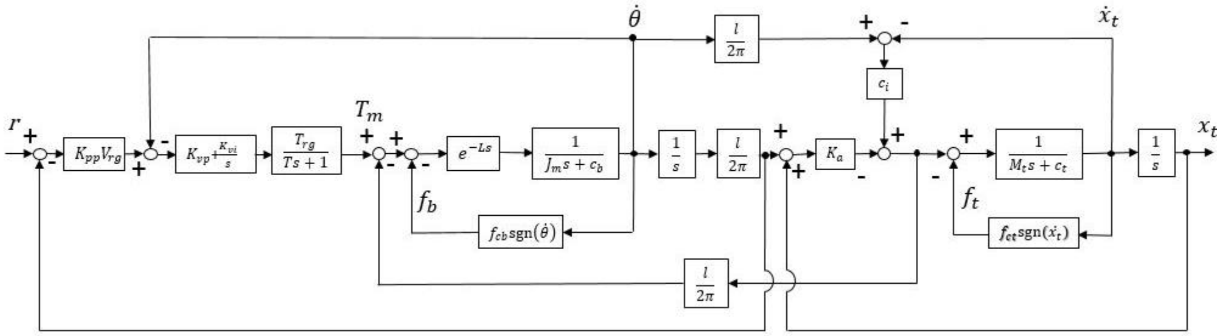

Figure 3. Block diagram of feed drive system

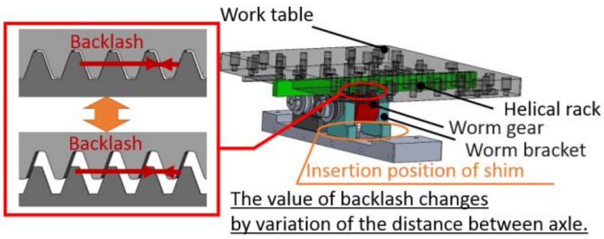

Figure 4. Mechanism of the backlash adjustment

Table 2 Tuned results of backlash by the adjustment to alignment

	Backlash value (before the adjustment of alignment) (μm)	Backlash value (after the adjustment of alignment) (μm)
X-axis	114	8.7
Y-axis	87.0	19.6
Z-axis	-	10.3

The predicted result is shown in Fig.2. The table motion is measured with a laser displacement sensor while 1mm step input. The position of encoder of the servo motor are compared simultaneously. The simulated result shows a good accordance between them. These results demonstrate that it can be used for the tuning of the feedback system of the developed table motion to cope with the high accuracy and the high speed table motion.

4. Positioning performance

4.1 Backlash adjustment

The unique feed drive system with a helical rack and a worm gear is adopted to save the space of the feed drive system. This mechanism cannot be avoided the backlash of from 50 to 100μm for the distance of the helical rack and worm gear. Therefore, we tuned the backlash by adjusting the alignment and using some thickness sheet to obtain the improvement of the positioning. The structure of the backlash adjustment is shown in Fig.4. At the same time, we changed the number of shim sheets to insert into each bracket to obtain the minimum backlash considering the parallelism of the worm gear for the helical rack.

The results of backlash adjustment are shown in table 2. The backlash settled in 8.76 μm (93.9% reduction) in the X-axis and 19.6 μm (77.4% reduction) in the Y-axis.

4.2 Positioning performance by full close control

The full close control system by a linear sensor (SCHNEEBERGER, resolution: 0.2 μm) attached to the side rail of a table guide. The positioning performance was compared with the semi closed control by the rotary encoder in the servo motor and with the full closed control. The motion trajectory

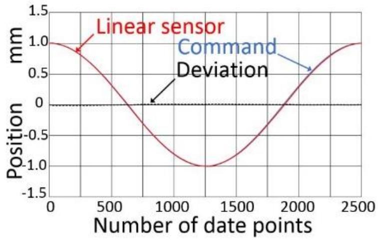

Figure 5. Motion measurement of the table (X-axis by full closed control positioning)

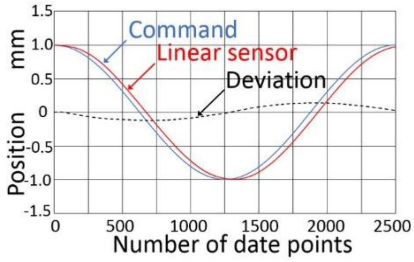

Figure 6. Motion measurement of the table (X-axis by semi closed control positioning)

when a worktable is controlled to move a circular motion on X-Y plane is shown in Fig.5 and Fig.6.

From Fig.5, the trajectory by the full-closed control shows the good accordance between the data of the linear sensor and the command. The maximum deviation was 15.04 μm. On the other hand, in Fig.6, the value of the linear sensor shows the deviation of approximately 142 μm for the command. This deviation is much larger than the backlash of 20μm in Table 2. The whole error of the driving system including the elastic displacement of the drive belt is contained in this deviation. These results demonstrate that the full-closed positioning is more precise than the semi-closed positioning and suitable for the precise machining.

6. Conclusions

The following results were obtained for the developed desktop machine tool.

1) The feed drive system of X-axis is modelled and the good accordance with the calculation and the simulation was obtained.

2) Backlash between the helical rack and the worm gear mechanism settled in 8.76 μm in the X-axis and 19.6 μm in the Y-axis by adjusting the alignment.

3) The influence of backlash can be supressed by full-closed control.

4) In future, we have a plan for machining test by full-close control and evaluating the machined accuracy of the workpiece.

References :[1] MISHIMA N, Prototyping of the Microfactory and Conceptual Design of a Miniature Machine Tool 2002 Japan. JSPE Vol. 68, No. 4. pp. 586-590

[2] SUZUKI N et.al, Development of Desktop Machine Tool with Pipe Frame Structure, 2015 Japan. IJAT Vol. 9, No. 6. pp. 720-730