euspen's 15th International Conference & Exhibition, Leuven, Belgium, June 2015
www.euspen.eu

Development of desktop machine tool

Ryo KOBASHI[1], Ryo HIRONO[1], Yoshitaka MORIMOTO[1], Naohiko SUZUKI[2], Yoshiyuki KANEKO[2]

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

b6400479@planet.kanazawa-it.ac.jp

Abstract
In recent years, the miniaturization of products and machine parts has been progressing and used as the practical parts. However, the size of machine tools has remained unchanged. It is necessary to downsize machine tools in proportion to the downsized parts because miniature size parts are currently machined using relatively large machine tools. Furthermore, the conventional NC machine tool, with its various peripheral devices, occupies a large space. Smaller machine tools will allow for increased productivity.
In the present study, we have developed a desktop-sized machine tool that can machine even steel. The developed tool is controlled using the original three-axis synchronous real-time NC controller that was developed with the LabVIEW FPGA tool. The dynamic and static performances of the machine tool and its cutting performance are reported herein.

Key words: Desktop machine tool, CFRP pipe, Original controller, Truss structure, Worm gear and helical rack

1. Introduction

In recent years, the miniaturization of products and machine parts has been progressing. However, the size of machine tools has remained unchanged. Furthermore, in many cases, a number of machines have been designed considering the rigidity of the machined workpiece. Therefore, under the present conditions, the machine operator must machine miniature size parts using a large machine tool.

In order to realize efficient production activity in a limited production space, the introduction of several small machines is effective. Conventional NC machine tools occupy a large space with various peripheral devices, even though such conventional machine tools are arranged efficiently from the viewpoint of productivity. Furthermore, the volume of the conventional NC controllers is not negligible. Desktop machine has been developed [1,2]. However, stroke is small, NC software is the general purpose.

In the present study, we have developed a desktop-sized machine tool that can machine even steel. The newly developed machine tool has pipe frame that consists of pipes, joints, and plates. The rigidity of the machine tool is guaranteed by applying truss structures that can be used to tune the rigidity by adding or removing brace bars. Although the truss structure is used for various architectural structures, there are few machines in which such a structure is applied.

Furthermore, the newly developed machine tool has a conventional three-axis synchronous real-time NC controller. Eliminating the extra features, this NC controller has sufficient performance for precise positioning of the machine tool and is sufficiently compact. In the present paper, the dynamic and static performances of the developed machine tool and the typical cutting performance are reported.

2. The basic configuration of desktop machine tool

The goal is to develop a compact desktop machine tool with three orthogonal axes. The specifications of the developed desktop machine tool are listed in Table 1, and a schematic diagram of the developed desktop machine tool is shown in Figure 1.

2.1. Machine size

The mass of the developed desktop milling machine (60 kg) is rather light compared with a conventional machine tool, the developed desktop milling machine can be placed in a convenient location.

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(rpm)		30000
Spindle power(W)		125
Resolution(μm)		Less than 0.2
Mass(kg)		60
Pipes diameter(mm)	outside	φ21 ,φ16
	inside	φ15 , φ10

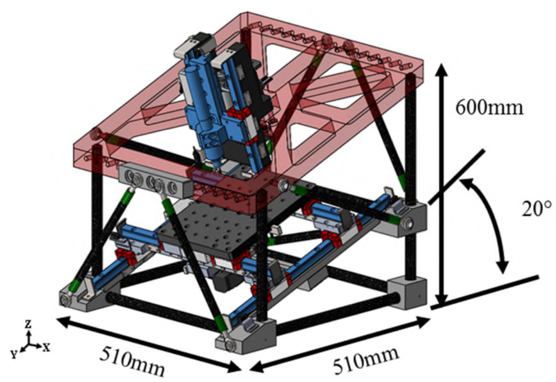

Figure 1. Developed desktop machine tool

2.2. Structure of the machine

The main frame of this desktop milling machine consists of S45C blocks and hollow CFRP pipes. The CFRP pipe is machined in two portions. One portion is used to obtain a close-tolerance (H7/g6) fit between the pipe end and the connection block. The other portion is used to achieve the required adhesion strength. This connection method can avoid the dependency on displacement by the adhesion strength. It is possible to reduce the displacement of the frame when a disturbance acts on the machine due to the cutting force. Furthermore, by applying a brace bar made from a CFRP pipe to the sides of this machine, a rigid and lightweight structure can be obtained at the same time by adjusting the connecting tension. In addition, the table is slanted 20° in order to efficiently shed the cutting chips. This alignment table uses a truss structure to achieve better rigidity. In this study, we selected CFRP pipes for the frame elements to prevent the thermal deformation compared to conventional desktop machines. The developed machine tool is so light weight that we can set on the desktop.

2.3. Drive system

A worm and a helical rack with a small backlash are adopted for the drive system of each axis (Figure 2). Since the drive system does not require a speed reduction mechanism nor hang out of driving parts from the table, Furthermore, it prevents cutting chips from entering the drive system of the table.

3. Analysis of dynamic characteristics

In order to obtain better rigidity through the addition of brace bars constructed of CFRP to the frame, accelerance transfer functions are measured and analyzed by means of an impulse hammering test. The vibration of a tool tip in an impulse hammer (Point A in Figure 3) was measured in order to determine the acceleration using an acceleration sensor fixed to the table (Point B in Figure 3).

The results for the calculated transfer functions in the X and Y directions are shown in Figures 4 and 5. In Figure 4, the resonance frequency changes from 260 Hz to 300 Hz, and the amplitude decreases by the addition of brace bars. These results demonstrate that the dynamic accelerance can be improved. The resonant frequencies of 30Hz and 80Hz shifted to 70Hz and 110Hz respectively. Although the amplitude of accelerance increased, the displacement at each resonant frequency is almost same level of that without brace bars. In Figure 5, a 40% decrease in amplitude (37 $m/s^2/N$ to 22 $m/s^2/N$) is also achieved at 340 Hz. Based on these results, we have obtained sufficient dynamic stiffness for the machine tool.

4. Control system

Three axes of the motor and spindle are controlled using the original NC controller that was developed with the LabVIEW FPGA tool. This controller can control three axes with synchronizing control, and even current control is executed by the software. The traditional NC codes are not used in this original NC controller. Only position data are acceptable. The position feedback is adopted in order to achieve simple and practical control.

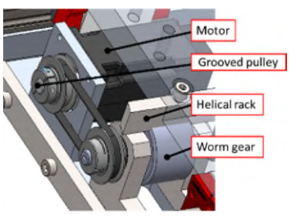

Figure 2. Gear and rack mechanism

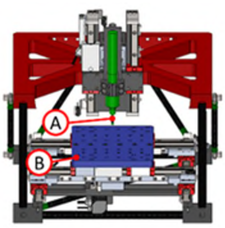

Figure3. Measurement point

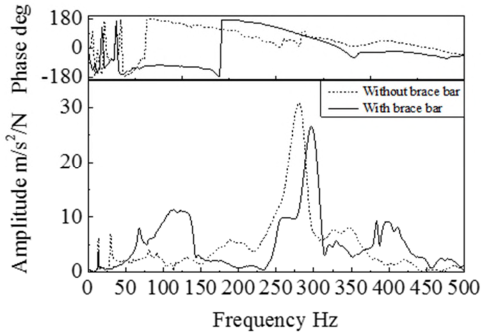

Figure 4. Measured transfer functions (X-axis)

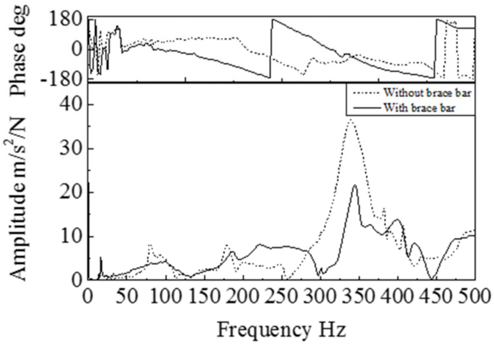

Figure 5. Measured transfer functions (Y-axis)

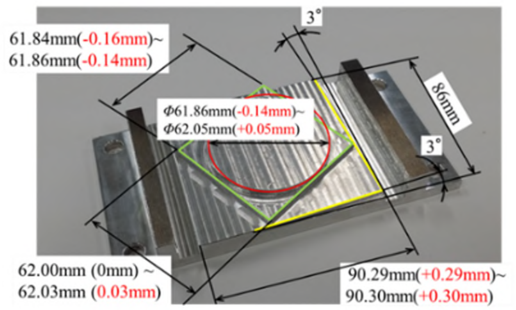

Figure 6. Machining of aluminium alloy

5. Evaluation of cutting performance

The machining performance of the developed machine tool was investigated by machining an aluminum alloy. The workpiece based on ISO10791-7 and JIS B 6336-7 was machined by the milling process. The machined workpiece is shown in Figure 6 with the measurement results of the dimensions. The machining yielded a successful surface and profile. Thereby demonstrating that the machine tool can be used for machining various materials.

6. Conclusions

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

1) A light weight of 60 kg and sufficient rigidity can be realized by applying CFRP pipes to the frame structure.

2) By placing the drive system under the table, the machine tool can realize not only space savings but also good chip evacuation.

3) A simple and sufficiently functional motion was realized using the original NC controller.

References

[1] Fujioka M, Hirogaki T, Aoyama E, Ogawa K and Iwana M 2005 the japan society of mechanical engineers 479-484

[2] Suzuki M, Hirogaki T, Aoyama E, Ogawa K and Iwama M 2009 the japan society of mechanical engineers 61-66