Proceedings of the Sixth International Symposium on Mechanics, Aerospace and Informatics Engineering 2012
Busan Exhibition & Convention Center(BEXCO), Korea, February 27 ~ 29, 2012 ISMAI06-EP-00

The experiment result of the relation between the counter weight vibration and the transient tracking error of machine head

Wan-Seok Yang[1], Hyun-Gwang Cho[1], Su-Jin Kim[1]*, Gyung-Ho Kim[2], Chun-Hong Park[2]

Abstract

The counterweight used to compensate the gravity force of the vertical table of machine tools declines dynamic characteristic. At pervious paper we have modeled vibration of vertical table simulation. In this paper vibration of counter weight was measured by acceleration sensor and the vertical table was measured by laser interferometer. And we compared simulation and experiment. So we proved the relation between vibration of counter weight and vibration of machine head. And this result will help designing vertical movement system of machine.

Key Words : Machine tools, Counterweight, Vertical table, Vibration, Tracking error, Precision

1. Introduction

In this paper, we study about the vibration of vertical movement system of machine tools. Machine has linear guide way, so the table can move smoothly. And each axis has each motor which provides power to move the table.

At the horizontal axis, weight of the table is uniformly applied to the guide way. But in the case of vertical axis, a big moment is applied to vertical guide way. And it causes deformation of guide way. (1) And at the horizontal axis motors just carry a light load compared to vertical one. But in vertical axis, motor should stand the total weight of the table. So if the machine is big, strong motor and strong linear guide are needed.

To solve this kind of problem, some machine has CW(Counter Weight). When a machine has CW, the moment on the vertical guide becomes smaller. And deformation of the guide and friction also become smaller. And CW releases the motor from the heavy weight of the table. So even though a machine is huge if it has a CW, a small motor and guide can handle the huge machine. Usually CW is used for heavy machine, because the advantages of CW is magnified with big machine.

There are many advantages from using CW. But there is side effect also. (2)(3)(4) If a machine has CW, the total weight of vertical table becomes larger twice. And vibration of the CW affect to machine head. So CW makes dynamic characteristic of vertical movement system worse. Although vertical system is assembled with CW to increase their capacity and reliability, the precision is reduced due to vibration (5)

There are three kinds of the CW. mechanical, hydraulic and pneumatic CW. (6) (7) In this case we will have an experiment about mechanical CW. We measured vibration on the CW with acceleration sensor during the vertical table moves and stop.

1) *School of Mechanical and Aerospace Engineering ,
Gyeongsang National University
900, Gajwa-dong, Jinju, Gyeongnam, 660-701
TEL: +82-55-772-1636 FAX: +82-55-772-1577
E-mail: sujinkim@gnu.ac.kr
2) Korea Institute of Machinery & Materials

And we also measured the vertical position of the machine head with laser interferometer. The experiment will show that the vibration on the CW affect to the machine head.

2. Machine tools

Fig. 1 Machine Tools

Fig. 1 shows machine tools. The machine tools usually have horizontal axis and vertical axis. The table move along x and y direction. This is a horizontal axis. The spindle moves up and down and it is called z axis or vertical axis. The vertical axis moves along the gravity direction when it moves up it should sustain gravity. And because there is offset between the center of mass and ball screw force vector, there is big moment at the machine head. So we use the CW to reduce gravity force and moment.

Fig. 2 CW and chain

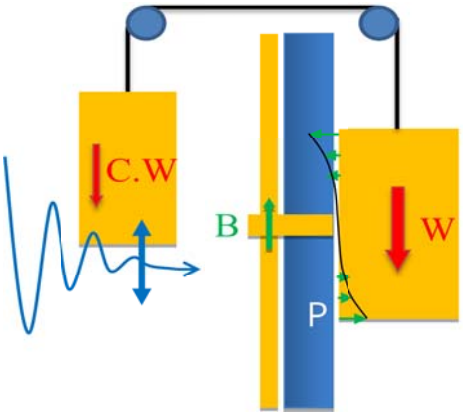

Fig. 3 Counterweight and Machine head

Fig. 2 shows chain and CW. There is behind machine tools. Usually the CW's weight is about the 70% of head's weight. The advantage of CW is compensating the gravity force of vertical guide. But the disadvantage is that the increased mass reduces the dynamic characteristic of vertical guide. Although it is effective at static balance, the vibration is increased at dynamic case. Adding component to the machine structure means dynamic problem needs to be reconsidered. So in this research we study about the dynamic characteristic of vertical guide

3. Vibration Experiment

We tell you that CW reduces the dynamics characteristic. This characteristic was studied at previous public reference (8). At the paper we modeled vertical movement system including CW and show the displacement error of head and CW. The simulation has shown CW vibration induce the vibration of machine head. But we didn't improve by experiment. So in this paper, we measured the vibration of CW and displacement error of machine head.

Fig. 3 Experiment machine

Fig. 3 is shown machine tools that we use to experiment. The model is Dosan DMB-UBS5. Because the machine has heavy and power of sub motor is not large enough to pull up the machine head. The CW compensates the weight of machine head. So, displacement of machine head is measured by laser interferometer and the vibration of CW is measured by acceleration sensor. And the experiment equipment show Fig. 4 and Table 1. The experiment condition is like that we move up the machine head about 100 mm by feed rate 4000, 6000, 8000 mm/min. During the motion, the vibration of CW and the tracking error of machine head are measured. And Table 2 shows experiment condition.

Fig. 4 Experiment equipment

Table 1 Equipment capacity

Acceleration Sensor	
Range	2g
Sensitivity	1000 mV/g
Frequency Response	0-200 Hz
Residual Noise	650 μV rms

Laser interferometer	
Range	2g
Linear measurement accuracy	±0.5 ppm
Laser frequency accuracy	±0.05 ppm
Resolution	1 nm
Maximum travel velocity	4 m/s
Dynamic capture rate	10 Hz - 50 kHz

Table 2 Experiment condition

Experiment range	
Range	±100mm
Speed	F4000, F6000, F8000

4. Experiment Result

The vibration of CW is measured by acceleration sensor. The feed rate is 4000 mm/min at the experiment. The vibration of CW is started when machine start move and the disacceleration increase the vibration. After the machine stop, the vibration of CW still remains, and it is reduced after few seconds. If the feed rate is increased to 6000 mm/min, 8000 mm/min, the vibration of CW shown same phase. When the speed of CW increased, the magnitude of acceleration is bigger than low speed. It is shown in Fig. 5. The horizontal axis is time and vertical axis is magnitude of acceleration.

a) F4000

b) F6000

c) F8000

Fig. 5 Acceleration of Counterweight

To check the nature frequency of vibration FFT(Fast Fourier Transform) of CW is done. The main frequency in FFT result is same in three different feed rate cases. Fig. 6 shows FFT result. By FFT transformation the domain was changed from time to frequency. The horizontal axis is the frequency and vertical axis is the magnitude. When feed rate is 4000 mm/min the main frequency is 9.4 Hz and when feed rate is 6000 mm/min the main frequency is 9.8 Hz and when feed rate is 8000 mm/min the main frequency is 9.6 Hz. Though the feed rate is changed, the frequency is usually about 9.6 Hz. That means that the vibration frequency is not depending on the speed. And it means that it is the nature frequency of the mass spring system of CW. In this case mass is CW and spring is the chain.

We measured the displacement of head by laser interferometer. It is shown in Fig. 7. And the horizontal axis is time and vertical axis is displacement. We enlarge the displacement graph to see displacement in detail after the stop. In the enlarged figure we able to see there is vibration of machine head. After move up, the vibration frequency of machine head is about 9.6 Hz. When the machine head move down, we also check vibration after the stop. The vibration of machine head remains after stop and the frequency is 9.4 Hz. At here since the vibration frequency of CW and vibration frequency of machine head is almost same. And it is not depend on the speed. Because the vibration frequency is same and we able to note that vibration of CW make vibration of machine head. This experiment improved that CW make the vibration of machine head. After stop or during the movement after acceleration, vibration was shown at the simulation in previous paper[8] and it was also improved at the experiment in this paper.

a) F4000

b) F6000

c) F8000

Fig. 6 Fast Fourier Transform of Counterweigh

Fig. 7 Machine Head

5. Conclusion

In this research we studied about vibration of vertical table of machine head. At pervious paper we simulated the vibration of CW and machine head. And at this paper we did experiment to improve that the simulation is right. At the experiment we measured the acceleration of CW by acceleration sensor and we measured the displacement of machine head by laser interferometer. The vibration frequency of CW was same to the vibration frequency of machine head. It means that the vibration of CW induced the vibration of machine head. So at this experiment we improved that CW vibration makes the machine head vibrate after acceleration and disacceleration. Thought CW reduces the weight effect of vertical table and reduce the moment of vertical table, it reduces dynamic characteristic of vertical table. So if you make low speed and heavy machine tool, you need use the CW. But if you design fast machine tools it is better not to use CW

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