VIBRATION ISOLATION SYSTEM WITH HIGH ACCURATE POSITIONING TECHNOLOGY OF SEMICONDUCTOR LITHOGRAPH MACHINE

Masato Takahashi¹, Shinji Wakui², and Susumu Makinouchi³
¹Design Department , Development Headquarters
Nikon Corporation
Kumagaya-city , Saitama, Japan
²Institute of Symbiotic Science and Technology
Tokyo University of Agriculture and Technology
Koganei-city , Tokyo , Japan
³Business Development Headquarters
Nikon Corporation
Sendai-city , Miyagi, Japan

INTRODUCTION
In the field of accurate positioning system, an active vibration system is generally used. Especially it is indispensable unit in the system which is required a highly accurate isolation performance from outside, such as floor vibration, in the semiconductor lithograph machine[1]. Isolation performance from floor vibration to the body is particularly called transmissibility. There are many development elements in the semiconductor lithograph machine. However, that are assumed the introduction only of the title(Incline compensation of isolated table using voice coli motor[2], Wide bandwidth by using multi VCM for isolation unit, Improvement of compensation for accelerometer and high bandwidth for isolation unit[3],etc) by limiting space.

In recent years, the progress of semiconductor is remarkable development, therefore outside vibration isolation performance become more important factor than current machine for total machine accuracy. Isolation vibration system is generally supported by air-spring[4].

In this paper, we will introduce two methods of improvement of isolation performance, that is, passive and active method.

At first, as passive method, there is one of mechanical method in order to increase vibration rejection ratio, which is reduced the stiffness of air-spring by using auxiliary tank, Helmholtz resonance is caused by using auxiliary tank, and vibration rejection ratio become worse. In usual as is introduced in the Handbook[4], we can reduce the peak of Helmholtz-resonance by adjusting the aperture with the built-in the connected pipe. Furthermore there is the best aperture as is introduced in the Handbook. However, there is no reference regarding the relationship between Helmholtz frequency and vibration rejection ratio.

Secondly, it is as to active method, there is the method by control technique using servo valve. We can achieve the same performance to passive method of auxiliary tank by means of servo valve control technique, it is called here as “pseudo auxiliary tank.”

ISOLATION DEVICE AND IMPLEMENTATION OF MAKING LOW NATURAL FREQUENCY METHOD

Structure
Figure 1 shows an active vibration unit in the semiconductor lithograph machine. The semiconductor exposure machine sets up on the installation floor that is called a pedestal which is in the base of the main body of this machine. Voice coil motor whose main body of the exposure machine is an actuator of the machine(thereafter, abbreviation as VCM)and an air-spring are mounted on the base of the main body of the machine. In addition, the projection lens, optics system of the alignment etc. are mounted on the main body of the exposure machine. Thus, this main body is isolated from the floor vibration with the air-spring , and the isolation performance greatly related to the stiffness of the air-spring, that is , the capacity of the volume of the air-spring. In general, main body is supported on the pedestal through three air-spring support legs. In each supporting legs of the machine, it provides with three sensors that measure a pedestal and a relative position.
with the main body respectively in the vertical direction. In addition, to measure the position of the main body from the floor, there are 3 (6 in total with vertical direction) positioning sensors for horizontal direction. The position sensing device of the main body from the pedestal are adjacent and arranged with three air-springs. In similarly, three accelerometers are mounted in the vertical direction, another three are mounted horizontally, and the movement of six degrees-of-freedom is measured. Moreover three VCM are horizontally and vertically arranged.

**Means of making low natural frequency**

There is a demand that it wants to decrease the natural frequency of the main body supported with the air-spring. It is easy to adjust the natural frequency of the main body to 1-3Hz equipped with the air-spring. Since specifications of the machine came to become severe, further isolation performance improvement has been imposed on the isolation machine.

In this paper, we introduce the method with a auxiliary tank as one of the making to a low natural frequency[5]. The air room of the air-spring is connected with auxiliary tank by piping, and air-spring stiffness can be decreased because of the increase of the capacity of the air room. This design requirement is written in the reference [4]. Concretely, referring to Figure 2, it is explained that the best diameter that puts out the maximum damping force exists for the squeezing diameter mounted in the model which is composed of the volume of main tank, the volume of auxiliary tank, and the piping part when the auxiliary tank is connected with the main tank by piping. In addition, it is said that the larger the squeezing attenuation is the capacity of the auxiliary tank, the more effective. However, it became clear during the study of the authors that critical relationship are actually in the piping length between the Helmholtz resonance frequency and isolation performance.

**Mechanism of Helmholtz resonance**

The modeling when two auxiliary tanks are connected with the main tank by piping is expressed as the model of Figure 2. At first, frequency $f_0$ Hz of the Helmholtz resonance is the following expression for Figure 3 where only one auxiliary tank was connected by piping.

$$f_0 = \frac{C}{2\pi} \sqrt{\frac{A_p}{L \cdot V_{\text{aux}}}}$$

(1)
Here, $C$: speed of sound m/s and $A_{p}$: piping part cross sectional area $m^{2}$ and $L$: piping part length $V_{aux}$: volume of auxiliary tank $m^{3}$. Moreover the mechanical model in Figure 3 is expressible as shown in Figure 4. In addition, the mechanical model of three inertia system is requested from the supporting leg of Figure 5 where two auxiliary tanks were connected with the main tank, it becomes Figure 6. That is, it is a mechanical coupling vibration of 1DOF. According to the reference [4], air-spring stiffness $K$ can be written as equation (2)

$$K = \frac{\partial W}{\partial z} = \frac{A}{\partial P} \frac{dP}{dZ} \frac{dA}{dZ} = \gamma \left(P + P_{a}\right) \frac{A}{V}$$

Here $P_{a}$: atmospheric pressure and $Z$: compression deformation from a neutral position of the air-spring. Using equation (2) and based on the mechanical model of Figure 6, when isolation performance $z/z_{0}$ from displacement $z_{0}$ of the floor vibration to displacement $z$ of $M$ in mass is simulated, it becomes Figure 7.

$\text{FIGURE 5. Main tank connected two auxiliary tanks}$

$\text{FIGURE 6. Mechanical model for FIGURE 5.}$

$\text{FIGURE 7. Comparison between with and without sintered metal}$

$\text{FIGURE 8. Overview of pseudo tank by using servo valve}$

The Helmholtz resonance frequency appears in the low frequency region by having connected it with the auxiliary tank by piping as understood in Figure 7. In addition, the most important things is not to achieve the effect of the auxiliary tank in the high frequency region according to this resonant frequency. Therefore, it means isolation performance can not reach the objective.

Psuedo auxiliary tank method

In the above mentioned, we explained the active method of improving the isolation
Air-spring stiffness is written as next expression,

$$K = \frac{\gamma V P}{V}$$

where $K$: stiffness of air-spring, $V$: volume of air-spring, $A$: actual effective area of air-spring, $P$: neutral pressure, $\gamma$: polytropic coefficient. To become pressure change similar to a big volume, the controller puts air in and out with a pressure sensor and servo-valve. In other words, pressure can be changed effectively in the main tank of $V_{real}$ so that the volume may become a pressure change similar to the pressure change of $V_{real}+V_{pseudo}$.

Figure 9 shows the control block, according to this figure, it is possible to achieve the objective/specification by feed back the differentiation of pressure signal.

![Figure 9](image)

**FIGURE 9. Overview of pseudo tank by using servo valve**

$$p = \frac{G_s}{\beta_0 \left( V_0 + \frac{G_s k_{vo}}{\beta_0} \right) s + c} \cdot \frac{M^2 s^2 + D s + K}{\beta_0 \left( V_0 + \frac{G_s k_{vo}}{\beta_0} \right) s + c}$$

Here, $p$ is a target pressure, and $\beta_0$: compressibility, $V_0$: volume in air tank, $G_s$: flow rate gain, $k_{vo}$: differential feed back gain, $A_0$: effective area, $M$: body mass, $D$: air-spring damping, $K$: air-spring stiffness.

Finally, we will introduce the comparison when with or without this algorithm. There is a pressure response characteristic in Figure 10.

In Figure 10, the line shown in green is original data. On the other hand, the line shown in blue shows the effect when this algorithm is applied.

**FIGURE 10. Comparison effectiveness of with/without this method**

Since it is half at the natural frequency, it can be said that the stiffness is one-quarter. that is the experimental result is proof of effective.

**CONCLUSIONS**

The effect of the auxiliary tank to increase isolation performance is a band up to Helmholtz resonance frequency. The auxiliary tank did not function as an air volume more than this frequency, and isolation performance becomes only air volume of main tank. The point of the design is an effect of damping. In a word, it is necessary to set the hole size of the porous quality that doesn’t deprave isolation performance below the Helmholtz resonance frequency and suppresses the resonance peak of the Helmholtz resonance. Furthermore, the air volume effect of the auxiliary tank is able to be pseudo produced with a servo valve in the main tank.

**REFERENCES**