Vibration control combining MR damping and pneumatic forces for LCD manufacturing : experimental approach

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Abstract

This study discusses the effects of vibration control to improve the performance of precise motion. An air mount was developed for vibration absorption and isolation in the 8th generation of LCD manufacturing. The air mount was composed of an air spring for floating heavy weight and a magneto-rheological (MR) damper for removing oscillation. The vibration control logic was derived from a 3 DOF model, including coordinate conversion and feedback control methods. The performance results of the test were -20dB for isolation, 7.4dB for absorption and 60% reduction of the settling time in micro level positioning.

1. Introduction

The glass panel of an LCD line has a large size, so a stage for this LCD manufacturing machine usually has long strokes and a heavy weight. High-end motion control techniques are applied for fast and accurate positioning of the stage. Paradoxically speaking, the motion control works as a vibration source due to high acceleration which is a kind of shock vibration and disturbances in the manufacturing.[1] As LCD processes become more sophisticated and nano techniques are applied, vibration becomes a very sensitive issue. Thus, vibration criteria have been proposed for semiconductor and LCD manufacturing.[2] External vibration from the environment can be reduced using pneumatic isolators but the problem is the internal vibration coming from the high speed motion. The stage commonly oscillates on low frequency due to the heavy weight of the machine and the low stiffness of the isolators. In this study, an air mount was proposed to improve the performance of the LCD stage in high speed and micro motion. The air mount is a combined device which has a pneumatic and damping mechanism, controlled by electric signals for the purpose of quick vibration removal.

2. An LCD stage and an air mount

A stage for the 8th generation of LCD requires XY linear motions, 2200mm*2500mm travel range, 0.5G max acceleration, ±2um accuracy and 1500mm/s max velocity. A gantry structure is required to cover the long strokes and extreme motion. The Y axis was composed of two linear mechanisms synchronized by dual servo and installed on a stone surface plate. The X axis which was installed across the mechanisms of the Y axis, has 300kg of moving mass. The mechanisms of XY axes were constructed using linear motors, optical linear encoders, current amplifiers (AMPs) and a motion controller. The weight of the stage is approximately 6200kg, which was supported using four air mounts. Figure 1 shows the stage for the 8th generation LCD and the air mounts on a base frame.

An air mount was composed of an MR damper and an air spring. The air spring has an air chamber which contains pneumatic pressure to support the heavy weight of the stage. The pressure is controlled using a proportional flow valve by means of the driving current. The air spring also contains the MR damper in the air chamber. The bottom of the MR damper is fixed to the bottom of the air chamber and the plunger of the MR damper is connected to the top of the air chamber. The plunger has an electromagnetic (EM) coil and floats on MR fluid with small clearance to the MR container. When the current is driven to the EM coil, the MR fluid responds to the magnetic flux of the EM coil and shear force is generated in the clearance. Figure 2 shows the internal structure of the air mount and its installation under the stage. The vibration of the respective air mount was detected using 4 eddy-current sensors. The sensors detect relative distance between a steel plate and a sensor coil. Four sensors were equipped in the corners of the stage and coordinate conversion was made for 3 DOF vibration of the stage. An embedded controller was constructed, based on VME bus and DSP which conducted PID feedback control logic. An accelerometer was attached to the X axis to determine control modes of isolation and absorption.

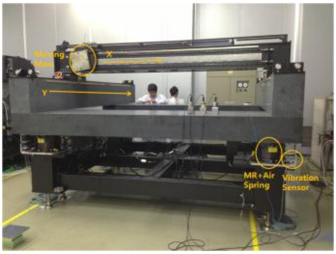

Figure 1: A stage for the 8th generation LCD manufacturing

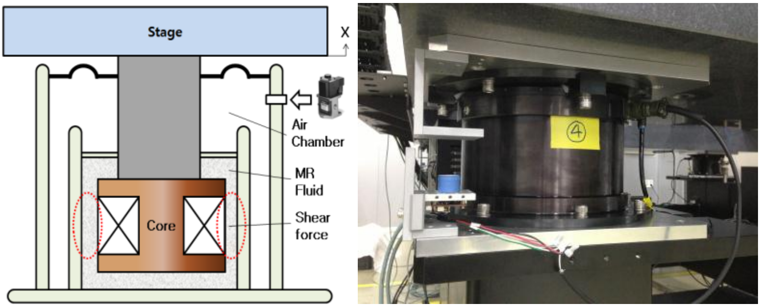

Figure 2: A stage and vibration control device for large screen LCD manufacturing

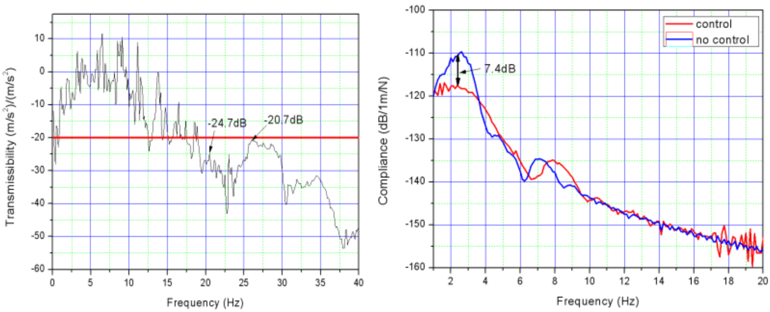

Figure 3: Performances of an air mount (a) isolation only (b) vibration control

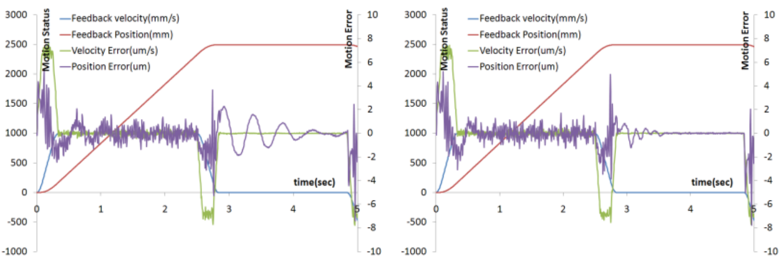

Figure 4: Positional accuracy with (a) isolation only and (b) vibration control

3. Results

The major performances of the air mount are isolation and the absorption of vibration. The isolation of the air mount can be shown through transmissibility between the stage and the base frame. The transmissibility was obtained by comparing the impact of the base frame with the acceleration on the stage, as shown in figure 3(a). The targeting frequency of the air mount in this study was above 20Hz, so the isolation was -20.7dB. Vibration absorption can be obtained with compliance comparing the impact given on the stage with the vibration response as shown in figure 3(b). The resonance frequency was formed at 2.4Hz and the magnitude decreased 7.4dB. Figure 4 shows the motion status and the motion error in the tests. The position error kept oscillating 2sec after motion stopped without vibration control. The settling time was reduced to 0.8sec and the ripple during motion also decreased with vibration control.

4. Conclusion

This study constructed and tested an air mount for the 8th generation LCD manufacturing machines. The air mount was composed of an air spring for isolation and an internal MR damper for transient response. The 3 DOF model of control logic was applied including the coordinate conversion between the sensors and the stage vibration. The result showed that the air mount can be useful for vibration isolation and absorption. It is also proven that vibration control can improve the motion performances in the micro motion of an industrial stage.

References:

[1] Heo J and Chung J 2002 Vibration and Noise Reduction of an Optical Disk Drive by Using a Vibration Absorber : *IEEE Trans. on Cons. Elec.* vol 48 p 874-878

[2] Bessason B, Madshus C, Frystein H and Kolbjrnsen H 1999 Vibration criteria for metrology laboratories: *Meas. Sci. and Tech.* vol 10 p 1009-1014.

[3] Kim H, Kim J, Ahn D, and Gwen D 2013 Development of a Nano-precision 3-DOF Vertical Positioning System With a Flexure Hinge: *IEEE Trans. on Nano.* vol 12 p 234-245