Design of a Dual Servo XYtheta Stage using double H frame

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1. Introduction

Dual servo actuator is very frequently used for ultraprecision stages requiring long travel and ultra fine resolution: from hundreds mm to nm. Especially, in recent year CMM and a high precision machine tool need it. It is composed of a coarse and a fine actuator. And, they have to carry out respectively long travel in XY and fine motion in XYtheta. In addition, a few requirements of it are decoupling mechanism between a Coarse and a Fine actuator, high speed and high power.

2. Conceptual Design of Dual Servo XYtheta Stage

A. Fine Actuator

At first, decoupling mechanism between a Coarse and a Fine comes from VCM(Voice Coil Motor) concept that a force is generated by a energized coil and magnetic field induced by magnet without contact with coil as shown in Fig. 1. [1] That is to say, as three coils of Coarse are energized in magnetic filed, Fine with three magnet pairs moves without physical contact between Coarse and Fine. And by adjusting three inputs through coils, Fine is able to have fine motions in XYtheta from millimeters to nanometers. Coils and magnets are located triangularly and respectively on frames of Coarse and Fine for symmetric structure to decrease thermal effect as shown in Fig. 2. [2] And then, Fine uses preloaded air bearings such as bearings of *New Way Machine Component. INC.* bottom magnet pairs in a frame of Fine on a granite plate with a triangular shape such like a location of three magnet pairs as a guide mechanism. So that, Fine actuator may be called as a tracking actuator.

B. Coarse Actuator

Second, Coarse actuator following Fine consists of double H-frame with four linear motors, a coil jig with three coils to drive Fine and several air bearings for guide mechanism. The advantages of Double H-frame are symmetric structure and to induce higher force. And this actuator system uses '?-bar' for composing of double H-frame to have higher rigidity, lighter, more compact. It is composed of two linear guides with rectangular granites and a window frame respectively with two linear motors, namely, that two motors are used for one axis movement with higher force. The linear motor is a moving coil type that has fixed magnet arrays and yoke bar and moves sustaining a distance on magnet arrays. In here, magnet arrays with a yoke bar are put on an optical table in a state of being able to be moved by a reaction force and coils in the window frame. Coarse actuator might be called a follower because it follows fine actuator.

C. Guide system and Dual Servo XYtheta Stage

As above mentioned, Coarse has two axis motions that a window frame moves in one axis and a coil jig in other.

The window frame slides along two rectangular granites and on a granite plate. At that time, it uses several air bearings that some is on two rectangular and others on a granite plate. Especially, four air bearings are along two rectangular granites. Two are vacuum preload types and others not preloaded but flexure system. This system uses a rectangular granite bar with three bearings with two preloaded bearings and a general flat bearing as a reference of guide system in one axis that the window frame moves along, and other granite bar with a remaining as an adjusting guide.

And the coil jig with three coils moves in window frame composed of '?bars' and on a granite plate by using force from two linear motors that are composed of magnet arrays fixed at the window frame and coils fixed at coil jig and operated as above mentioned and a guide mechanism with several air bearings using like it of the above window frame.

3. Design of Dual Servo XYtheta Stage

A. Fine actuator

(1) XYtheta Stage

As shown in Fig. 3, Actuating Forces for XYtheta motions of Fine actuator are generated from Lorentz motor with magnets(NdFe40), yoke systems(steel1010), and coils. To design Lorentz motor for fine actuator, permeance method is used. With the method, in the limit of size, power, current, and so forth, the optimal design has been carried out. Results are shown in Fig. 4. Especially, this Lorentz motor generates a force to actuate fine actuator with its acceleration above 5(m/sec^2) in 0.53(T) between magnets. This XYtheta Stage includes leveling actuator for leveling and focusing due to the tightness in depth of focus on the decrease of lateral resolution – that is the shrink of an optical source, for example DUV. The actuator force is governed by flux change between a solenoid and a permanent magnet [3][4]. That is located on the triangular such as Lorentz motor for XYtheta Stage. Fine actuator is presented in Fig. 5.

B. Coarse Actuator

(1) Linear Motor using Halbach Magnet Array

As mentioned above and shown in Fig. 6, Linear motors with Halbach magnet array are designed for actuating coarse actuator. We calculate Maxell equations to have optimal design values for linear motors – especially in coarse actuator [5].

In detail, a linear motor for x-axis has magnets(75mm*12mm*11.25mm), coils connected to a window frame, and so forth, and for y-axis magnets(45mm*12mm*12.9mm). Optimal values happen as shown in Fig. 7. So that, a force for x-axis is 220N with induced current 2A and for y-axis 150N that respectively generates above 5(m/sec^2) with a safe factor –1.5.

C. Design of Dual Servo XYtheta Stage

According to be mentioned above, we design and assembly a noble actuator. This actuator is presented in Fig. 8. The size of this system is about 600mm*600mm*100mm to have a stroke range above 150mm. And frames are made of AL7076, total mass of fine actuator about 10kg, and of coarse actuator below 30kg. At last, this actuator system may have 6inch wafers.

Conclusion

This paper presents the design of each parts and assembled double H frame stage with them for Xytheta motions. Actuator system consists of fine and coarse actuator, respectively with Lorentz motor, three preloaded air bearings and mirrors, and with linear motors, several air bearings, and guide systems. And we designed a noble actuator system with above 5(m/sec^2) and with above 150mm moving range by using SQP of MATLAB program for optimal design of this actuator system.

References

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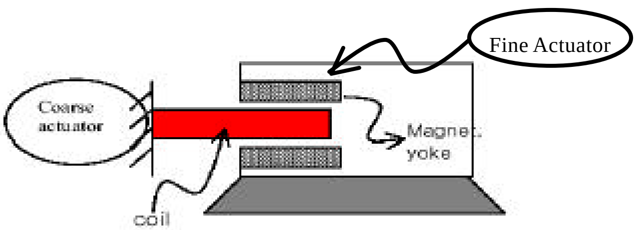


Fig. 1 Concept of Fine actuator

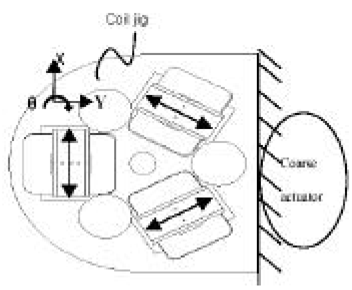
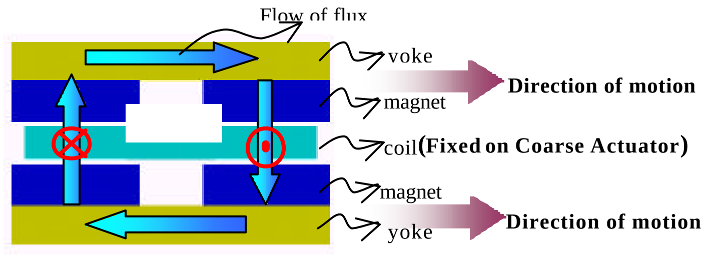
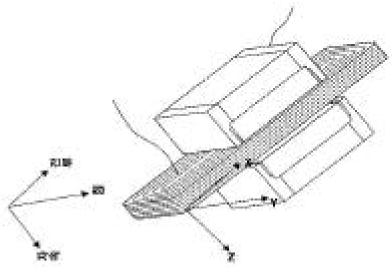


Fig. 2 Symmetric structure of fine actuator

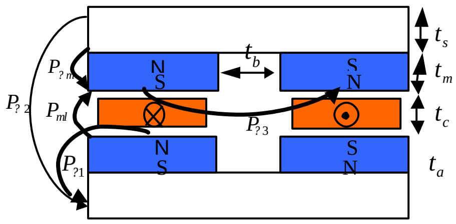


(a) Section of a Lorentz motor

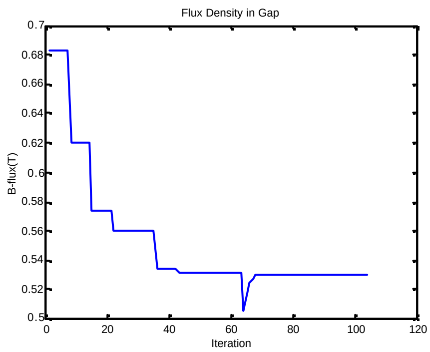


(b) Structure of a Lorentz motor in 3-D

Fig. 3 Lorentz motor for fine actuator

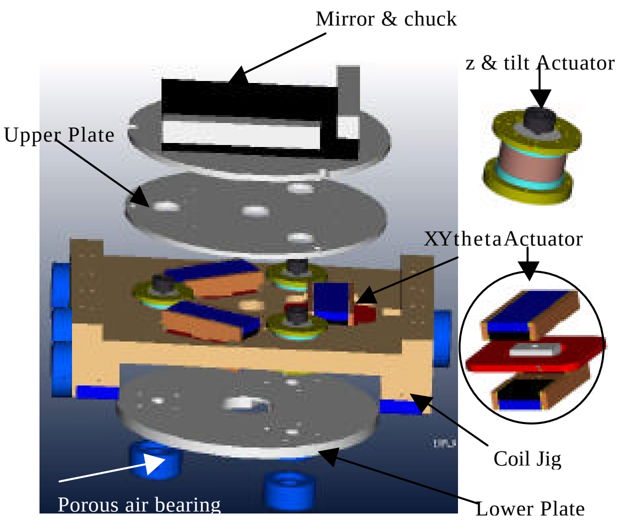


(a) Permeance method

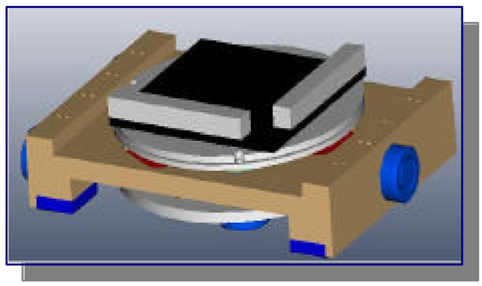


(b) Optimal Value in B-flux(0.53T)

Fig. 4 Permeance method and optimal value of B-Flux for fine actuator



(a) Exploded Fine actuator with coil jig part



(b) Assembled Fine actuator with coil jig part

Fig. 5 Fine actuator for a noble Dual servo system

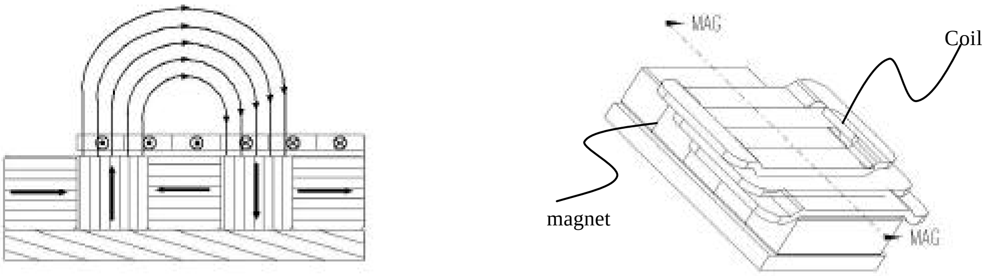
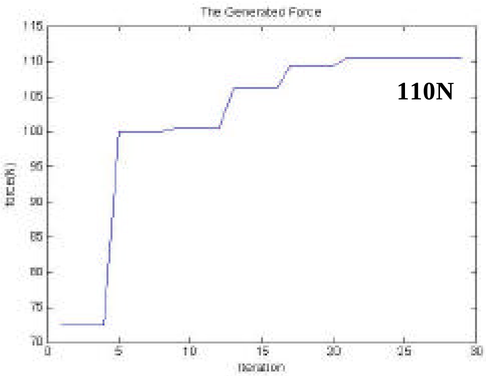
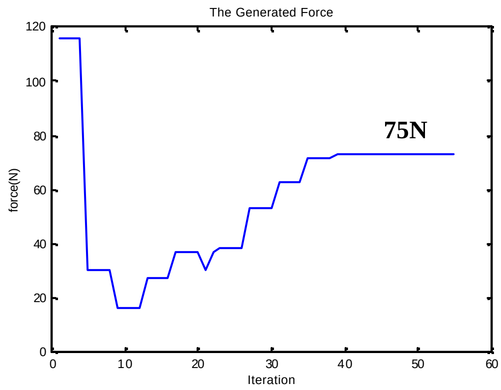


Fig. 6 Halbach Magnet Array for XY linear motors

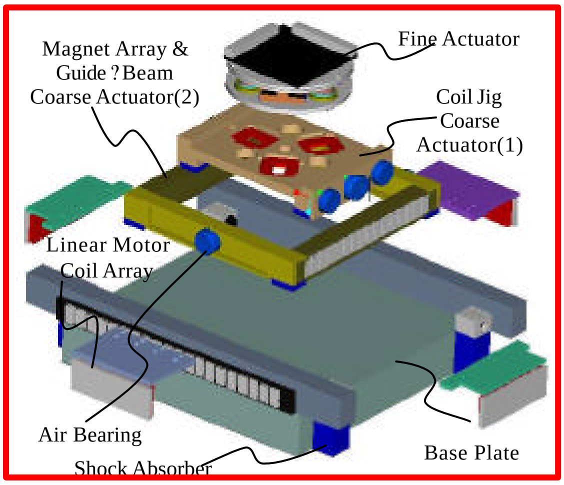


(a) Optimal Value of X-linear motor in one side

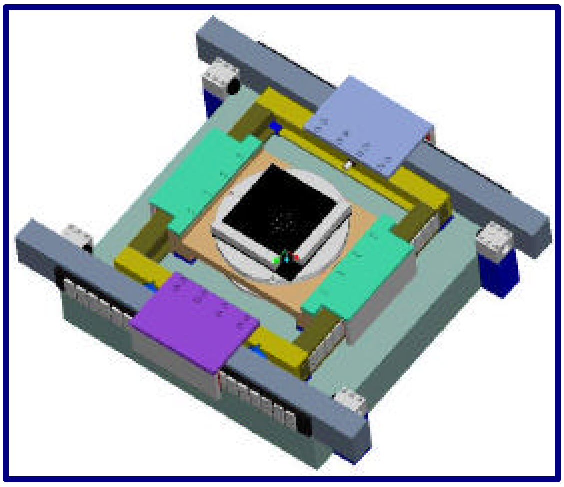


(b) Optimal Value of Y-linear motor in one side

Fig. 7 Optimal Values for XY linear motors



(a) Exploded actuator system



(b)Assembled actuator system

Fig. 8 Noble Dual Servo XYtheta Stage using Double H frame