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Flexure Tilt Adjustment Mechanism Design Based on Quasi-Kinematic Coupling

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1. Introduction

Adjust mechanisms play a very important role in optical systems, because various optical elements must be precisely combined with each other to obtain an aberration-free image. Slight variation will make the image differ in thousands of ways. To achieve all kinds of positioning accuracies, several types of adjustment mechanisms are used to the optical systems. Most of research papers covered three basic types of adjustment mechanisms, namely: linear [1], rotary [2] and tilt mechanisms [3]. No matter which types adjustment mechanisms might be consisted of five basic components, such as interface, actuator, coupling device, preloading device and locking mechanism. For each of these five components, a number of choices are available to a designer depending on the type of adjustment mechanism. In this paper, a flexure tilt adjustment mechanism is designed based on quasi-kinematic coupling. The 3D model and prototype are shown in Fig. 1.

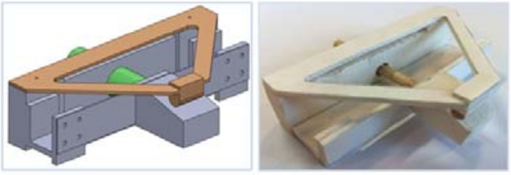
(a) (b)

Fig. 1 Flexure tilt adjustment mechanism design based on quasi-kinematic coupling (a) 3D model, (b) prototype made by plastic material

2. Tilt adjustment mechanism analysis

Tilt adjustments for optical system are designed to optimize the image quality. It can be designed to one degree of freedom adjustment about one axis or two degree of freedom about two mutually orthogonal axes. For tilt adjustment mechanism design, we will abide by the basic design principles to discuss briefly as fellow.

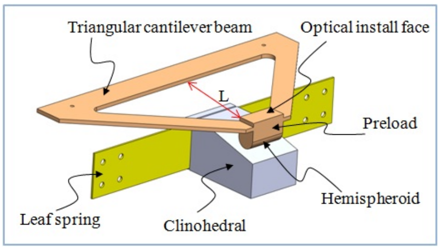

Fig. 2 Detail descriptions of the flexure tilt adjustment mechanism

The tilting component can be attached to a fixed structure through rotary bearing, flexure or a traditional kinematic interface. Flexure is suitable for backlash-free adjustment, which have low friction and hysteresis. In this paper, triangular cantilever beam is used to produce short travel ranges. The detail descriptions of tilt stage are shown in Fig. 2.

For small angles of rotation, the slope θ and deflection δ at the free end of the triangular cantilever beam are given by [4]

$$\theta = \frac{FL^2}{2EI} \qquad (1)$$

$$\delta = \frac{FL^3}{3EI} \qquad (2)$$

where E is the elastic modulus of flexure material, I is the moment of inertia of triangular cantilever beam, *F* is the applied bending force and *L* is the vertical distance from hemispheroid to bottom of triangular cantilever beam.

In order to produce the applied bending force, an actuator should be used. The screws and micrometer adjustments are used in manual mechanism. In this paper voice coil motor (VCM) is used to produce long distance and high force.

Next step for tilt adjustment mechanism design is to couple an actuator to the moving component. VCM cannot drive the triangular cantilever beam directly. Therefore, the coupling mechanism of hemispheroid and clinohedral is designed to install the VCM and produce vertical force onto the hemispheroid. Also the materials of hemispheroid and clinohedral are all rigid bodies, and have very high stiffness. After special technical process, both of contact faces are very smoothly, friction between this two parts can be neglected.

About preloading methods and locking methods for tilt mechanism, it is also considered in the design. High weight hemispheroid and leaf spring play the functions of these two parts.

3. Static and dynamic analysis

The schematic representation of the tilt adjustment mechanism is shown as Fig. 3. As VCM produce the displacement along the *x* axis, the clinohedral will move along the *y* axis. The symmetric relationship of displacements of $\bar{x}$ and $\bar{y}$ can be described as fellow.

$$\bar{y} = \tan\alpha \times \bar{x} \qquad (3)$$

where $\tan\alpha$ is constant value, which can be called as output scale. We can change the output scale through change the slope angle.

And the relationship of input force *Fin* and the deflection δ or *y* can be described as fellow.

$$F_{in} = (K_{if} \times \mathrm{ctan}\alpha - \frac{3EI}{L^3}\tan\alpha)\bar{y} - M\tan\alpha \qquad (4)$$

where M is preload, K_{if} is the stiffness of leaf spring.

The slope θ can be calculated as

$$\theta = \frac{3(F_{in} + M\tan\alpha)}{2\left(K_{if} \times \mathrm{ctan}\alpha - \frac{3EI}{L^3}\tan\alpha\right)L} \qquad (5)$$

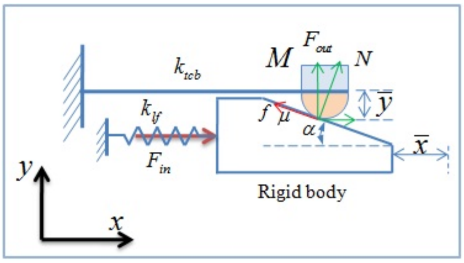

Fig. 3 The schematic representation of the tilt adjustment mechanism

4. Conclusions

In this paper, main purpose is to design a tilt adjustment mechanism. However, in order to decrease the backlash, produce sub-micron accuracy and increase the dynamics performance, the tilt adjustment mechanism is added some flexure elements, such as leaf spring, triangular cantilever beam. At the same time, the dynamics equations of input force with the slope θ and deflection δ at the free end of the triangular cantilever beam are derived.

Future work

In the future, simulation of static should be made based on parameters. Because this paper just give some concept design of flexure tilt adjustment mechanism, the structure of mechanism have some problems, we need modify and improve this structure. For example, we can use double leaf spring instead of single leaf spring to improve the stability of the system.

Reference

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