Journal of Engineering Science and Technology
Vol. 16, No. 2 (2021) 1416 - 1425

DESIGN AND EXPERIMENTAL TESTING OF XY FLEXURE MECHANISM

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Abstract

This paper presents a model reference of position estimator controller for controlling XY stage Flexure Mechanism. The mechanical testing and design of XY stage mechanism with the tracing of the built Simulink model. The different type of topology is discussed first. To get the high frequency symmetrical stage developed. The experimental platform is set to the test of tracking performance. The experimentally obtained trajectory is agreed with reference trajectory with different inputs. A reference circle of diameter 1mm was resulted of same amplitudes and frequency. Very close agreement in between reference input and developed algorithm output. The model tested accepts the algorithm built with novel position.

Keywords: Amplitude, Flexure mechanism, Frequency, Topology.

1. Introduction

In the previous decades, different flexure-based consistent stages have been produced. Awtar and Slocum [1] introduced a parallel XY flexure system plans in light of precise requirement designs. The benefits of the parallel flexure structure were examined, and the imperative course of action was given specifically. Qin et al. [2] composed a 2-level of opportunity (DOF) decoupled flexure-based system which was made out of statically uncertain symmetric flexure structures in parallel. The symmetric outline wiped out the warm blunder and acquires decoupled property. The try comes about exhibited that the proposed component had great decoupled capacity and load ability, and wide possibilities in exactness situating applications. Yong et al. [3] presented a flexure-based XY arrange for quick nano scale situating. The plan of the flexure-construct nano positioning stage was situated in light of the idea of adaptable systems. The stage was formed of two fundamental parts: the external segment that comprised of intensification levers and roundabout flexures, and the inward area that incorporated a phase and bar flexures. Li and Xu [4] composed a completely decoupled flexure-based XY parallel micromanipulator. Flexure-based consistent components have numerous focal points, for example, no clearance, no contact friction, and no requirement for oil, minimization, and simplicity of manufacture [5-7]. Thinking about these focal points, they have been broadly utilized as a part of numerous modern applications, for example, scanning microscopy, smaller scale grippers and biological science equipment [8-10].

The rest of the segments of this paper are sorted out as takes after. In Section 2, the mechanical outline of the organize is inferred. In Section 3, a model of the stage is produced an experimental stage is set up. The circular performance execution is in this manner tried under various frequencies.

2. Mechanical Design

Planar mechanism consists of rigid stages of four, one ground or fixed stage and remaining two intermediate stages and one is motion stage. It is a multistage development of the high precision mechanisms. [11-13].

Outline of planar flexural mechanism accentuates more on decreasing a portion of its constraints. For example, high stiffness along degrees of compels, parasitic errors, helplessness to temperature impacts and parasitic coupling actuator cross affectability [14, 15]. The comparisons with high-precision actuators based on stiffness and induced vibrations of high-speed flexure [16, 17]. Various building blocks of flexure mechanism with different parameters is carried out [18, 19]. Experimentation is carried out with mechatronic integration and results are validated [20]. It gives complete knowledge and various building blocks available both planar and hinge type [21]. Static and dynamic analysis is carried out and experimentally validated for high precision applications [22].

Motion has portability of two with translational movement with reference to fixed stage. Motion stages are required to isolate the two axes movement and confine the actuators. Flexural units A, B, C, D have an alternate stiffness in various axes as shown in Fig. 1. Flexural units A and C have high stiffness in Y-direction and B and D have high stiffness in X-direction. Median stage 1 befits extreme position for utilization of the activation constrain in X plane and stage 2 for exciting in Y plane. For any distort shape, median stage 1 has displacement in X plane while Median stage 2 has a pure displacement in Y plane. This key standard is utilized for planning two pivot planar flexural mechanisms. Advance these essential building squares of flexure instruments are talked about and instruments created utilizing these building blocks are clarified with their benefits and disadvantages according to concerned present application.

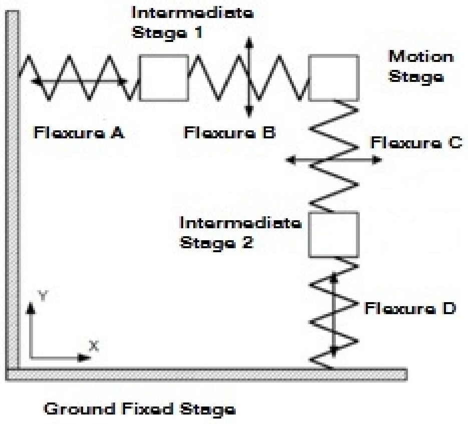

Fig. 1. Topology of flexure mechanism.

2.1. Single cantilever beam

At the point when cantilever beam is loaded with end point stack it will be deflected Fig. 2 delineates the bending of the cantilever beam under single point load. Cantilever beam is critical building block component element in flexural mechanism. For beam bending investigation, beam tip interprets in Y-direction δ as well as rotates θ under the point load. A parasitic error displays due to bending in the X plane € along with motion in Y plane δ.

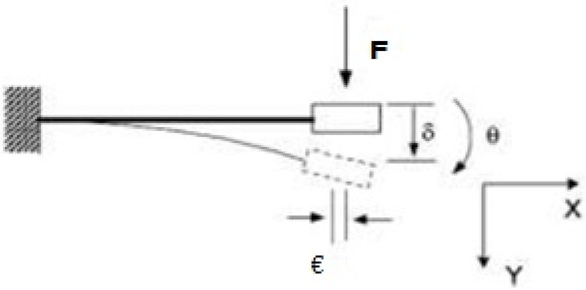

Fig. 2. Cantilever beam with end point load.

Theoretical calculation such as, deflection, angular rotation and parasitic motion are calculated by using Eq. (1).

$$\delta = \frac{FL^3}{3EI}, \theta = \frac{FL^2}{2EI}, \varepsilon = \frac{\delta^2}{L} \quad (1)$$

where: L is length of the beam in mm, E is Young's modulus of the material in MPa, and I is second moment of the area of the beam cross-section in mm^4.

2.2. Building blocks of parallelogram flexure

Figure 3 shows parallelogram flexure, it provides small resistance to Y direction motion and it provides very rigid motion and rotation in X direction.

$$\delta = \frac{FL^3}{24EL}, \theta = 2\left[\frac{t}{b}\right]^2 \frac{\delta}{L}, \varepsilon = \frac{3\delta^2}{5L} \quad (2)$$

This unit experiences unfriendly parasitic error in *x*-direction as for above expressed expository articulation. The two axes planer flexure system with Flexure Units A, B, C and D is appeared in Fig. 4.

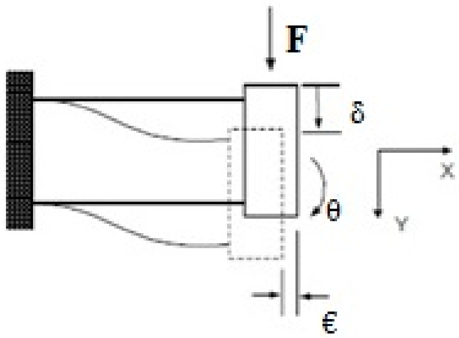

Fig. 3. Parallelogram flexure.

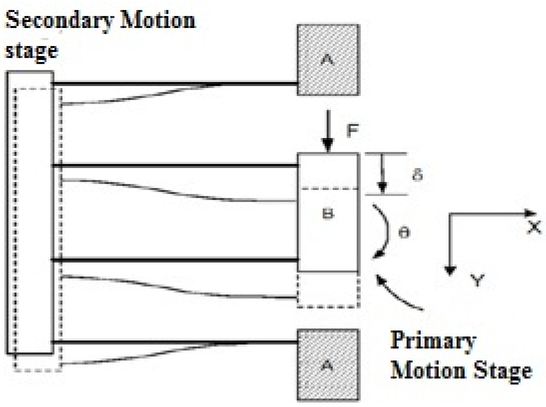

Fig. 4. Double parallelogram flexure.

2.3. Building Blocks of Double Parallelogram Flexure

Double parallelogram flexure is typically referred to as a compound, folded beam or crab-leg flexure as appeared in Fig. 4. Investigation of the structure demonstrated that displacement and rotation in X direction is generally stiff, yet it permits relative translational movement in Y direction between A and B. Length constriction because of deformation of beam is consumed by an auxiliary motion stage.

Subsequently the parasitic blunder along X direction was seen to be extensively smaller. The rotational parasitic motion might be disposed of by Y direction force in appropriate location. Subsequently, body A creates translation movement in Y direction as for body B on the utilization of force in Y direction. This is true just without X directions forces. The double parallelogram structure used to build XY systems as appeared in Fig. 4. In these cases, cross pivot coupling, and motion organize yaw is small and actuator detachment is moreover being superior to previous designs.

$$\delta = \frac{FL^3}{12EL}, \theta = t^2\left[\frac{1}{b_1^2} + \frac{1}{b_2^2}\right]\frac{\delta}{L}, \varepsilon = 0 \tag{3}$$

Double parallelogram flexure is all the more near the perfect one when compared with other flexural units. Investigative condition demonstrates that it has zero parasitic error motion. Henceforth double parallelogram flexural unit can be utilized for precision positioning for XY mechanism. Figure 5 S outlines the planar flexural mechanism utilizing double parallelogram flexural unit. Henceforth it is the best suitable for opto-mechanical scanning system framework in smaller scale stereo-lithography.

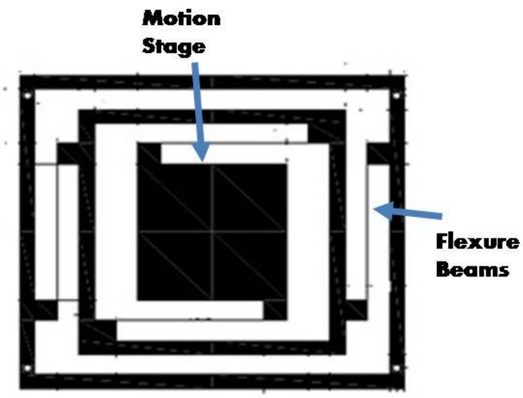

Fig. 5. XY mechanism.

Plan of flexural mechanism system depends on fundamental beam bending calculation. Different flexural components are utilized for XY mechanism System and exhibited here. The survey indicates obviously that double parallelogram flexure has zero parasitic error motion and small measure of pivot of arrange. Proper position of actuator can dispense with revolution of stage. XY Flexural mechanism is further planned utilizing double parallelogram flexure and appeared in Fig. 5. Here two or four double parallelogram flexures are utilized for one direction and they act as parallel springs.

Flexure beams undergo deflection at molecular lever which are responsible for their bending mechanism without the need of any roller or bearings. In our proposed model, the flexural beam is attached to the motion head on one side and hangs with supporting structure on the other side. Therefore, this system acts like a cantilever beam with a hanging mass. Figure 5 shows the XY mechanism. Comparison of the XY blocks is shown in Table 1.

Table 1. Comparison of the blocks of XY Mechanism using the dimensions length *L*=100 mm, Width *b* = 10 mm thickness *t* = 1mm.

Parameters	Comparison of XY Mechanism		
	Single Beam	Parallel Flexure	XY Mechanism
Deformation δ	7.599	0.6184	1.83
Parasitic Error ϵ	0.3464	0.00299	0.0200
Angular Rotation θ	0.0015	0.000123	0.000360

3. Experimentation

An experimental platform is set up as shown in Fig. 6. It includes a dSPACE-DS1104 board. The setup is ready for experimentation as shown in Fig. 7.

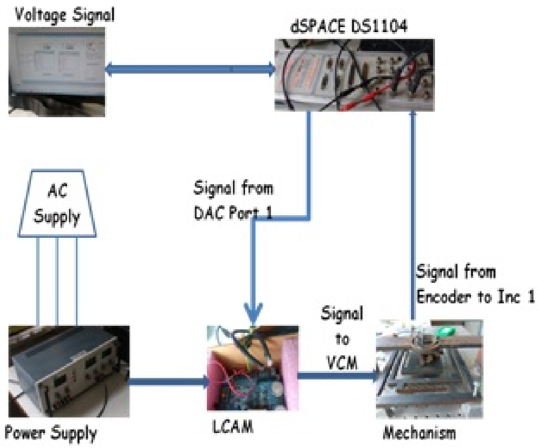

Fig. 6. Experimental setup with integration of XY mechanism with dSPACE DS1104.

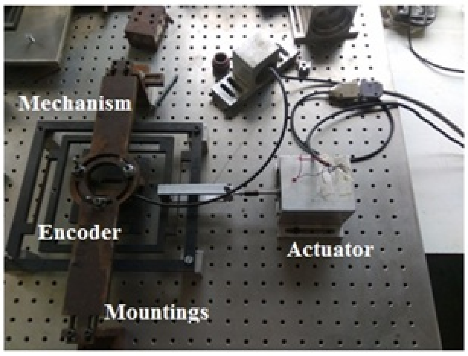

Fig. 7. The Experimental platform.

Figure 8 represents the Simulink model of the circle tracing. Building of the control logic in SIMULINK MATLAB and generating the signal in Voice coil motor to actuate the actuator connected to the mechanism by C clamp and downloaded into the dSPACE to run in real time with the hardware in loop, in the voltage range of 0-

30V. The software Control Desk is used to supervise the experimental process and upload the experimental data instantaneously. The output platform is measured by Renishaw encoder reads motion stage positing. To reduce the vibration optical board is used to mount the mechanism structure of aluminium honeycomb. The linear encoder signal is displayed on the control desk.

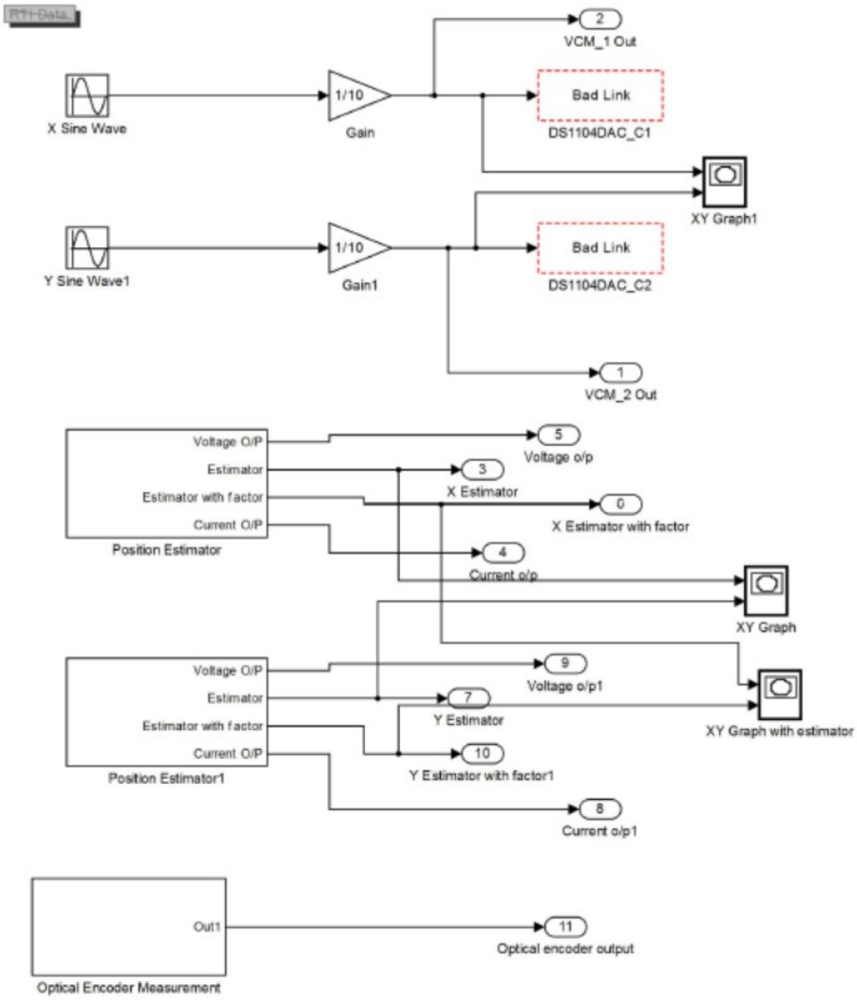

Fig. 8. The Simulink model for running under real-time work environment in dSPACE.

The dSPACE is used for receiving the displacement feedback from the optical encoder and them sending signal to drive the amplifier and actuator. The analog voltage positional signal to digital signals is translated by using the analog to digital convertor of 16-bit. The LCAM amplifies the current and actuator is actuated.

The proposed mechanical design of XY mechanism is tested for cooperative tracking performance. The circular trajectory test is performed. Figures 9 and 10 are the reference and actual signals in X and Y direction. As shown in Fig. 11, a reference circle of diameter 1 mm was resulted as an outcome of same amplitudes and frequencies provided to both X and Y direction in voice coil motor. As seen from above result, we find a very close agreement in between reference input and developed algorithm output.

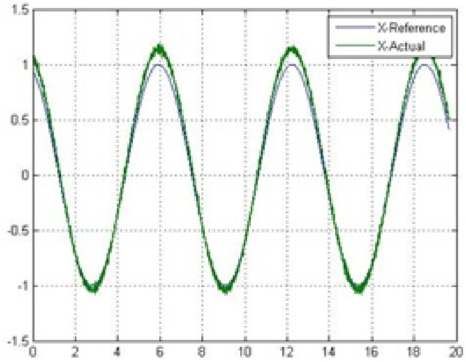

Fig. 9. Reference and response in x-direction when tracking a circle.

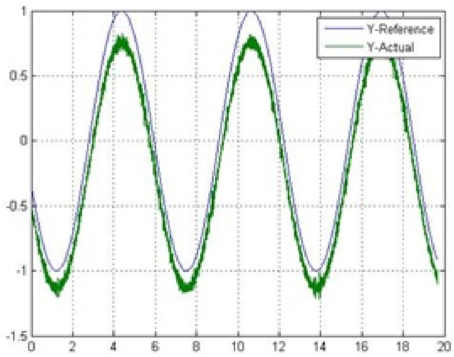

Fig. 10. Reference and response in y-direction when tracking a circle.

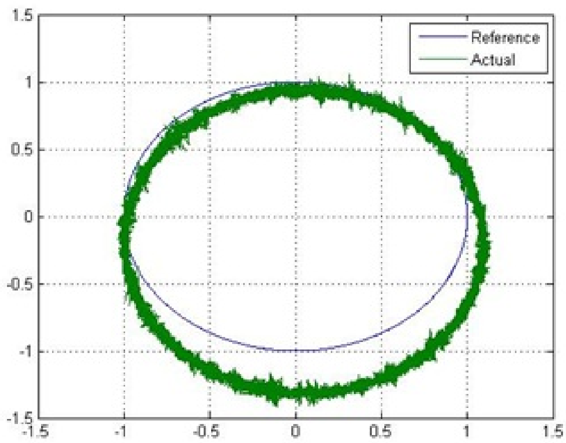

Fig. 11. Performance of the system when tracking a circle.

4. Conclusion

A position estimator flexures-based XY mechanism stage is designed and manufactured. The proposed stage will be used for positioning using high-performance displacement sensors with high resolution. Analytical, simulation and experimental studies series were considered to design the system, identification of the model and verification of the controller. In this tracing of the built mechanism was carried out and it followed the same. It is SISO Single input and single output control system is sufficient for the XY stage. The controller is developed in real-time work environment and executed in control desk of the dSPACE for running. The built algorithm estimator for the positioning with the combination of PID gives the better result as seen in the discussion and verified with experiments. The integration of the system with various elements and building of the control model for the mechanism with accuracy is achieved. The developed algorithm is used for XY mechanism for the scanning range and validates the same. The tracing of circle also has a close match with reference input.

Nomenclatures

Greek Symbols

δ	Deflection of the mechanism
θ	Rotation .
€	Parasitic Error.

Abbreviations

LCAM	Linear Current Amplifier
SISO	Single Input and Single Output
VCM	Voice Coil Motor

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