Design and Validation of XY Flexure Mechanism

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***Abstract* - This paper gives design of jointless mechanisms with distributed compliance and fabricated for MEMS application. Flexure mechanisms have massive range in various industrial application required for high precision and frictionless motion. There are many study on concept to make precision manipulators, but only some of them can achieved to satisfy the high speed with precision Pro-e software is used for modeling of flexure mechanism and ANSYS is used for Static analysis and dynamic analysis. Deflection of motion is concluded by static analysis with force. The Deformation of XY mechanism is equivalent to S-shaped cantilever beam deformation. The results are compared with experimental and FEA results.**

***Index Terms* - Flexure mechanism, MEMS, Precision, FEA, Ansys**

I. INTRODUCTION

When flexure mechanisms uses as bearing to provide smoothen motion. A flexure mechanism is a single-piece mechanism that transfers movement without any relative motion between joints or linkages, thus motion is wear free, energy efficient, higher resolution, and high speed device. Flexures are structure that depends on Material elasticity for their functionality. Motion is generated due to deformation at molecular level, which results in primary characteristic in flexures- smooth and precision motion for example in camera lens cap, laser scanning machine.

Flexure Mechanism is a recent development in the field of MEMS designing. It is a single-piece mechanism that transfers motion without any relative motion between joints or linkages, thus causing no friction or hysteresis loss. The design of a mechanism having flexural bending at the linkages methods for modeling and designing compliant mechanisms has spurred their use in a variety of products, ranging from macro-scale products such as clutches, guides, and switches, to micro-electromechanical systems (MEMS). This mechanisms offer a number of advantages, such as increased precision, reduced friction and wear, simple construction, and reduced assembly. In many ways this mechanisms have developed.Similar functionality to rigid mechanisms. Compliant mechanisms have the potential to completely eliminate relative motion between linkages, and thus eliminate friction.

Traditionally, designs are strong but not necessarily stiff—they are compliant. Compliance in design leads to creation of jointless, no-assembly, Monolithic mechanical device. Nature has realized the pivotal role that compliance plays at the realm of microorganisms, the level at which MEMS fit. [1]

Mathematical modeling of simple XY manipulator is carried out XY manipulator uses typical Double Flexural configurations. Static and dynamic analysis is carried out using MATLAB. Static analysis is carried out to determine static deflection of motion stage with force. Dynamic analysis is carried out to determine frequencies and mode shapes of flexural manipulator. ANSYS is used to carry out static and dynamic analysis of basic DFM configuration and few XY mechanisms.[2]

The modeling of XY flexure mechanism is based on characteristics of building blocks used to build it. Comparison of linear and non-linear closed form analysis is presented. At last analytical results are compared with results of FEA and experiment. [3]

For the design of a large displacement precision XY positioning stage, a cross strip flexure joints were used. [4]

The analysis and design of general platform type parallel mechanisms containing flexure joints. They established the key difference between flexure mechanism and parallel mechanism with conventional joints and is that kinematic stability is no longer a design consideration. [5]

Design and analysis of a flexure based on XY micro positioning stage. Compliance and stiffness analysis based on matrix method. Both mechanical structure and electromagnetic model are validated by finite element analysis (FEA) via ANSYS. [6]

II. DESIGN OF FLEXURE MECHANISM

By studying many designs, we found out that all the flexure mechanisms were based on flexural motion. An elastic strip is made to bend or twist causing distortion in its original dimensions and producing the desired motion. After studying various existing mechanisms, we tried designing our own mechanism based on Flexural Force Transmission.

To eliminate the mounting difficulties we decided to take Single piece mechanism in which whole mechanism is cut from the single block using laser and wire cut machining processes. It provides ease in mounting and avoids unnecessary displacement of the strips, which provides good stability and accuracy. The stress developing in this design is maximum. It contains the angular motion of the beams because of its design and this mechanism provides linear motion. The Geometrical Modelling of this mechanism is essential for numerical analysis and graphical representation of the model. This is done on CAD software which in this case is Pro-E Wildfire 5.0.

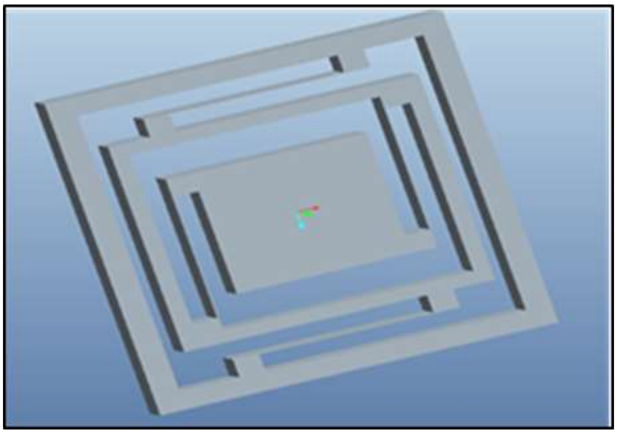


Fig.1: CAD Model of the flexure mechanism on Pro-E Wildfire 5.0

II. EXPERIMENTAL SET-UP OF FLEXURE MECHANISM

The experimental setup consists of a mechanism, Graph paper, Pencil, C clamp, string, weight pan, vibration free base (i.e. Optical Bread Board), 4 metal mounting blocks. The manufactured mechanism needed to be mounted on a fixed adjustable and vibration free base. Also the input force provided to the mechanism is given through a weight pan. Hence the weight pan shall also demand a stable and vibration free base. Lastly, the base should be adjustable to accommodate the variation in experimental setup and fix the components is different configurations.

Thus in order to fulfill the above mentioned demands, an “Optical Board” is necessary to be used for the mounting of the mechanism and assembly. Also arrangements must be made to accommodate the stylus pencil required for calibration of the output results. In order to mount the setup on the Optical Board we use the mounting block so as to lift the model. In order to fix the Fixed Base on the board, M6 bolt is used.

The model is actuated by the weights which are clamped by C-clamp that is properly positioned. Thus this setup is used to actuate the mechanism and measure the output with the help of a stylus pencil fixed at the output link.

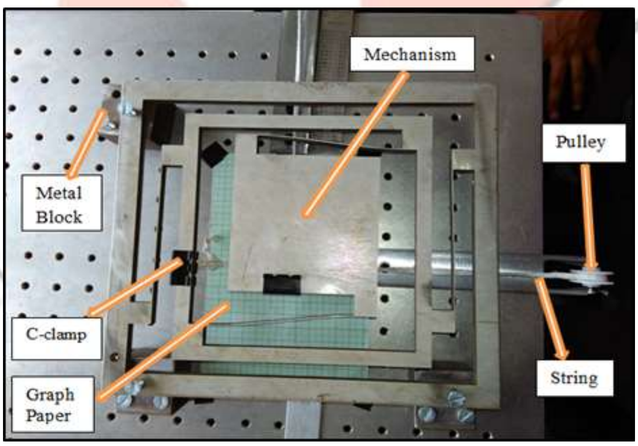


Fig. 2: Experimental Setup of Flexure Mechanism

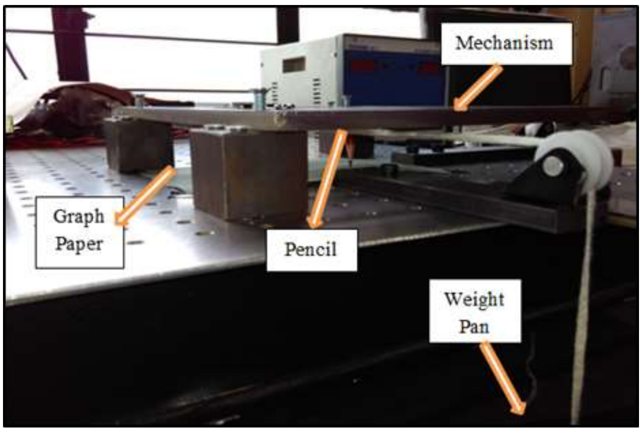


Fig. 3: Experimental Setup of Flexure Mechanism

After experimental testing the observations are shown in following table.

TABLE I: Experimental results of X and Y direction

Sr. No.	***Force*** *(N)*	***Experimental Output*** *(mm)*	
		X-direction	***Y- direction***
1	5	1.89	1.98
2	10	3.81	4.09
3	15	5.76	6.01
4	20	7.81	8.56

IV. FEA ANALYSIS

When we apply the maximum force of 20 N in X-direction and in Y-direction in Ansys software then we get the maximum deformation in X and Y direction, also the maximum stresses occurs in X and Y direction respectively.

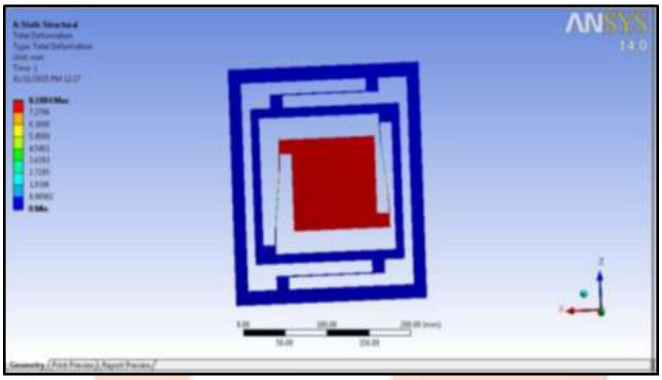


Fig.4: Deformation in X-Axis

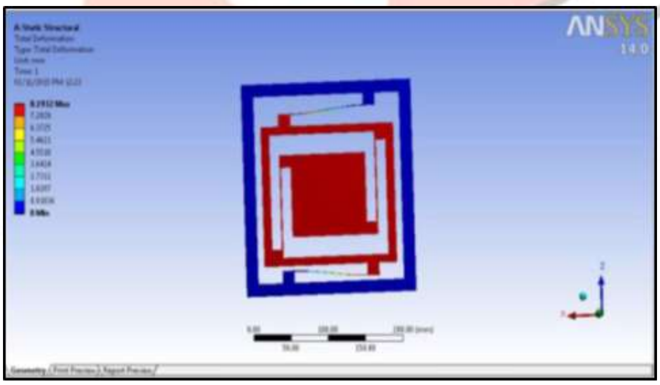


Fig.5: Deformation in Y-Axis

After experimental testing the results are shown in following table,

TABLE II: Analytical results of X and Y direction

Sr. No.	***Force*** *(N)*	***Analytical Output*** *(mm)*	
		X-direction	***Y- direction***
1	5	2.01	2.16
2	10	4.30	4.60
3	15	6.11	6.77
4	20	8.29	9.11

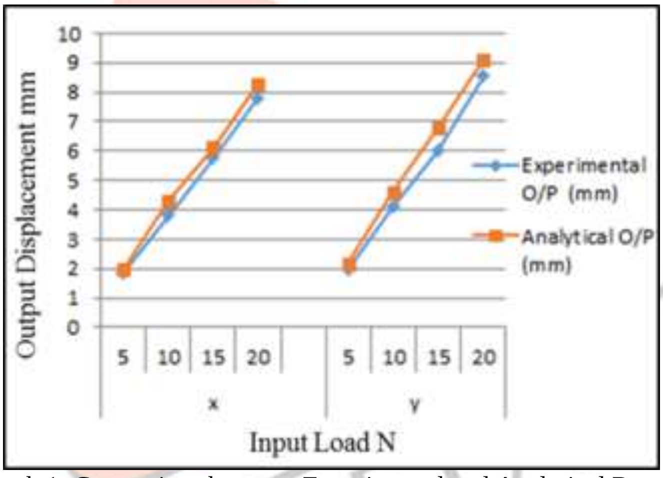
V. RESULT AND DISSCUSSION

Now we can compare the experimental output results and Numerical output results of mechanism for X & Y direction.

TABLE III: Results of comparison for Experimental and Analytical Directional Deformation in X &Y- Direction

Sr. No	***Input Load*** *(N)*	***Experimental Output*** *(mm)*	***Analytical Output Results*** *(mm)*
X			
1	5	1.89	2.01
2	10	3.81	4.30
3	15	5.76	6.11
4	20	7.81	8.29
Y			
1	5	1.98	2.16
2	10	4.09	4.60
3	15	6.01	6.77
4	20	8.56	9.12

From above comparison table we can draw a graph,



Graph 1: Comparison between Experimental and Analytical Results

VI. CONCLUSIONS

After analyzing the results we can observe that the Input Displacement vs. Output Displacement characteristics for the Experimental and numerical calculations remain the same. As well as stress are in permissible limit. The mechanism fully satisfies the Flexure mechanism characteristics like linearity, no hysteresis losses, zero error, sensitivity, etc. as it is clear from the testing results mentioned above. These characteristics are the primary factors in the feasibility and applicability of the mechanism.

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