International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Finite Element Analysis of High Flexure XY Mechanism Using Parametric Modeling

Prasanna Raut [a]*, A S Rao [a], Devakant Baviskar [a]

[a] *Department of Mechanical Engineering, Veermata Jijabai Technological Institute, Matunga, Mumbai 400019, Maharashtra, India*

DOI: https://doi.org/10.55248/gengpi.4.1223.123436

A B S T R A C T

The current article discusses the parametric demonstration of an XY flexural system that is used. The Double Parallelogram Mechanism (DFM) is used to construct squares. The Double Flexure Mechanism provides a zero parasitic error movement with a little amount of revolution of movement arrangement. DFM is used as a building block in the design of an XY flexural system. Outline Modeller ANSYS is used to create a metric model of the DFM and XY instrument. The FEA analysis is done to determine the stiffness, parasitic movement, and pivot of movement arrangement. The effect of parametric variation is considered, and a relapse display is produced. The created display is also used to improve the XY component. The purpose of this work is to investigate the execution characteristics of the two proposed designs (using DFM) of the XY instrument, using ANSYS as a FEA device. It is observed that the final plan provides greater exactness due to its symmetric requirement design.

Keywords: Double Flexural Mechanism, Parametric, Finite Element Analysis, ANSYS 15

1. Introduction

Conservative XY flexure arrangements with a wide range of movement are appealing in a variety of applications, including semiconductor cover and wafer arrangements, checking interferometry and nuclear power microscopy, micromanipulation and small scale assembly, high-thickness memory stockpiling, and MEMS sensors and actuators [1-3]. A micropositioning stage is a framework that may naturally move an end-effector with particular degrees of freedom (DOF) in its work space while maintaining a submicron positioning determination. It is appealing to have a large work space, high determination, high transmission capacity, and a small size for micropositioning stages [4-7]. Over the preceding several years, a significant amount of effort has been focused on improving the performance of such gadgets [8-10].

A flexure system organise powered by a piezoelectric actuator is a good example of an exact scanner, and its determination is small enough to be used as part of an exactness magnifying lens. However, the operating range of this scanner is limited to a few micrometres, limiting the estimate range of any magnifying lens that uses it. It is difficult to get reasonably priced conservative scanners that meet the requirements of both high resolution and a large operating range [11-13].Micropositioning apparatus is a critical and fundamental breakthrough in various domains, including scanning electron microscopy (SEM), X-beam lithography, veil arrangement, and micromachining. Recently, there has been a lot of focus on the analysis and design of small-scale locating systems using flexure pivots [12-16] Introduced a Double Hub Long-Voyaging Nano-locating Stage (DALTNPS). With the purpose of expanding travel and increasing accuracy, two types of stages were created: a standard ball-screw organise and a three-degrees-of-opportunity (3-DOF) piezo-organize. The traditional ball-screw arrangement, which consists of two guideways and a ball-screw at each hub, is a long-travel arrangement, whereas the 3-DOF piezo-arrange, which consists of three piezoelectric actuators and four translation- pivot components, is a high exactness arrangement.

Article [9] depicts and discusses the most commonly used savvy materials used for activation in miniaturised scale instruments: thermomechanical actuators (shape memory compound, warm dilatation of solids, warm extension of gas), magnetomechanical actuators, liquid mechanical actuators and furt mechanical actuators. Parametric modelling of the mechanism's shifting length, breadth, and thickness[17-18].The paper [19-22] describes the design and control of a single hub positioning stage with a total movement of 50mm.The single-hub structure includes a long-run slide route that runs on ultra-high subatomic weight polyethylene (UHMWPE) heading and a short-run positioning stage that includes a PZT driven flexure. The article examines several flexure mechanism designs utilising DFM. The XY Mechanism comprises of an actuator (VCM), an optical encoder, and a DAQ d SPACE DS1104 R & D Controller Board. [12]. Recently, piezoelectric (PZT) actuators have been widely used as a part of ultra precision positioning gadgets, with applications discovered in optical gadgets; semiconductor associated manufacturing offices, ultra precise machining tools, and other nanotechnology magnifying lenses. In contrast to conventional servo-engines or straight engines, PZT actuators are popular due to their rapid response, small size, and cost-effectiveness [13,23-25].

As a result, consistent component with a few advantages, for example, frictionless movement, absence of kickback and wear, clean component with no requirement for oil, reduced commotion, smooth geometry adjustments, and a lighter plan delivers a wide range of movement. Flexural instruments are primarily made up of pivots and flexure bars. Shorya Awatar demonstrated the layout of planar components using many key building squares, for example, single bar flexure, parallelogram flexure, and twofold parallelogram flexure unit in his study [26-28].

This study describes the design of an XY flexural instrument that employs a twofold flexural controller (DFM). Parametric analysis of the XY component is performed to obtain advanced measurements of DFM used as for length, breadth, and thickness to obtain the appealing operating range of relocation 10 mm to 15mm with a power up to 30N (due to VCM actuator specifics). This sketch may be used to accurately filter movement instruments.

2. Double Flexural Mechanism

2.1 Double Flexural Mechanism Design

Flexural instruments provide precision movement by allowing relative mobility between fixed help and movement arrangement. The interface component causes relative movement. An interface component, for example, ball heading, sliders, and fluid/air films used in standard systems cause rubbing, backfire, and don't give high exactness and repeatability. When these interface components are replaced by adaptable components, for example, pivots, adaptable pillars eliminate grinding and backslash and give high exactness checking with a high need for repeatability. According to this basic norm, XY, XY, and so on. Flexible systems are developed. The article [24,29-30] examines these flexural system building squares. It is apparent that DFM provides superior execution in terms of parasitic movement and range.

2.2 Analysis of Flexural Mechanism

The twofold parallelogram flexure unit serves as the building block for Double Parallelogram Flexure (Fig.1), also known as Twofold Flexural Component (DFM).

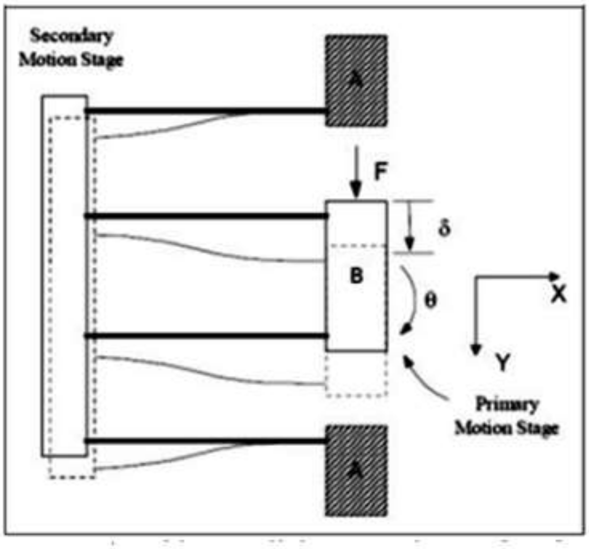

Fig. 1 - DFM[24]

The deflection,

$$\delta = \frac{FL^3}{12EI} \qquad (1)$$

Rotation,

$$\theta = t^2\left[\frac{1}{b_1^2}+\frac{1}{b_2^2}\right]\times\frac{\delta}{L} \qquad (2)$$

Parasitic error,

$$\varepsilon = 0 \qquad (3)$$

This flexure permits relative Y translation between bodies A and B, but it is stiff in terms of relative X displacement and rotation, but not as stiff as the parallelogram flexure. The parasitic error is much reduced in the X direction because any length contraction caused by beam distortion is absorbed by a secondary motion stage. Double parallelogram flexure provides a wide range of motion, strong rotational stiffness, no purely kinematic parasitic faults, and great thermal stability. Awatar [1] develops multiple XY planar flexural methods using the conventional double parallelogram flexure module as a building block. The main goal of the design is to provide great ranges of mobility along the X and Y axes. It is necessary in design to ensure high rigidity and negligible error movements in out-of-plane directions. The mechanism is constructed in such a way that the rotation of the motion stage, which is a parasitic error motion, is intrinsically restricted.

3. FEA Analysis

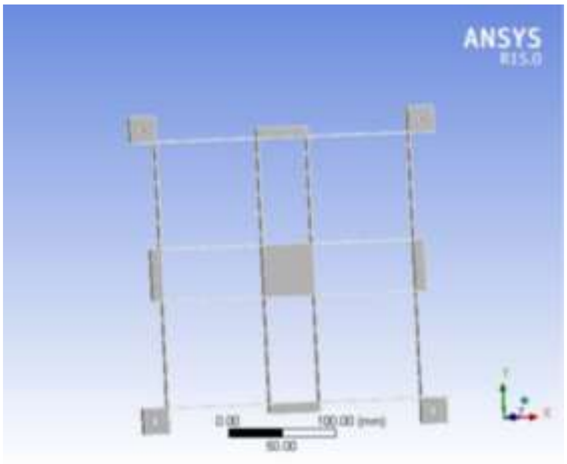

Fig. 2 - XY Flexural Mechanism

The component was exhibited on Genius E, and the investigation was carried out with the help of ANSYS. The model XY is symmetric as shown in figure 2, and it specifies criteria for both bearings. The purpose of the FEA analysis is to determine the solidness, diversion, stresses, and parasitic blunder movement. Steel is treated (Young's Modulus: 2.1 X 10^5 N/m^2, Poisson's proportion: 0.33). Figure 3(a) depicts limit conditions related to computer-aided design display, Figure 3(b) depicts disfigurement of movement organisation in X-direction under 25 N power, Figure 3(c) depicts parasitic movement (i.e. movement in Y-direction) for 25N power, and Figure 3(d) depicts comparable anxieties created. The stresses (187 N/mm^2) generated in the two sections are not identical to the yield concerns of treated steel (250 N/mm^2). As of now, a twisting in the entire instrument is inside the flexible breaking point and will be restored by expelling a linked heap of 25 N. Furthermore, the instrument shows a misshapening of 8.556 mm in the X bearing, and the solidness in the X-heading is 4.43837 N/mm, which is in close agreement with the hypothetical computations displayed in the previous region. Figure 3(c) depicts a parasitic blunder movement, and FEA investigation reveals an incredibly unimportant measure of disfigurement in Y course when movement arrange moves in X-course. In comparison, FEA investigation is transmitted in Y-heading, and FEA investigation outcomes are shown in Figure 4 (a), (b), (c), and (d). An exploratory setup is established, and experiment results are discussed.

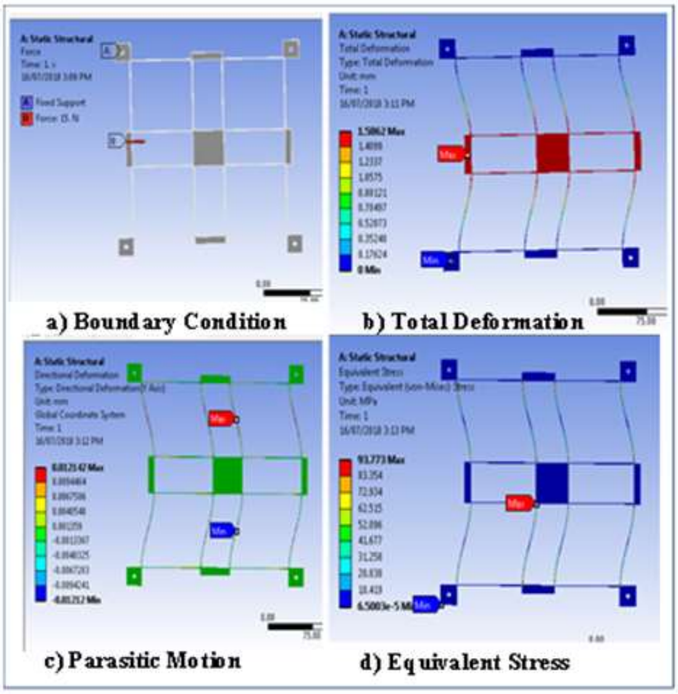

Fig. 3 - Static Analysis of XY Flexural Mechanism 1

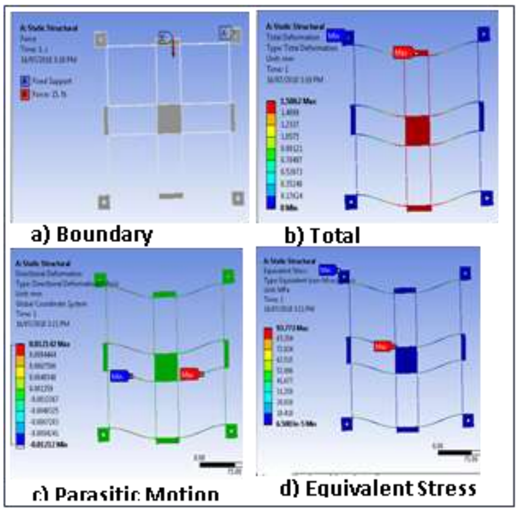

Fig. 4 - Y Directional Deformation of XY Flexural Mechanism 1

3.1 Experimental Setup

The typical Wire EDM (Electrical Release Machining) procedure is used to create the XY flexural system. Using an electric start as a cutting instrument, the work item is sliced to give a finished piece of the desired shape in this operation. This electric start creates heated temperatures ranging from 8000 to 12000 degrees Celsius, capable of liquefying almost everything. Through the cathode, a throbbing electric charge with a high repetition current is linked to the work piece. The wire cut EDM is a type of release machine that uses a continuous voyaging vertical wire under pressure as the anode. The PC programme directs its path in order to construct the desired form. The commencement is likewise methodically regulated, with the purpose of just influencing the material's surface. The EDM process frequently has little effect on the heat treatment beneath the surface. With wire EDM, the start is always in the dielectric of deionized water, which creates an incredible environment for EDM to process. The water acts as a cooler and reliably cleanses the garbage, maintaining surface quality. Figure 5 depicts a completed XY Flexural device. Because to assembly constraints, the thickness of each flexural pillar is limited to 1 mm.

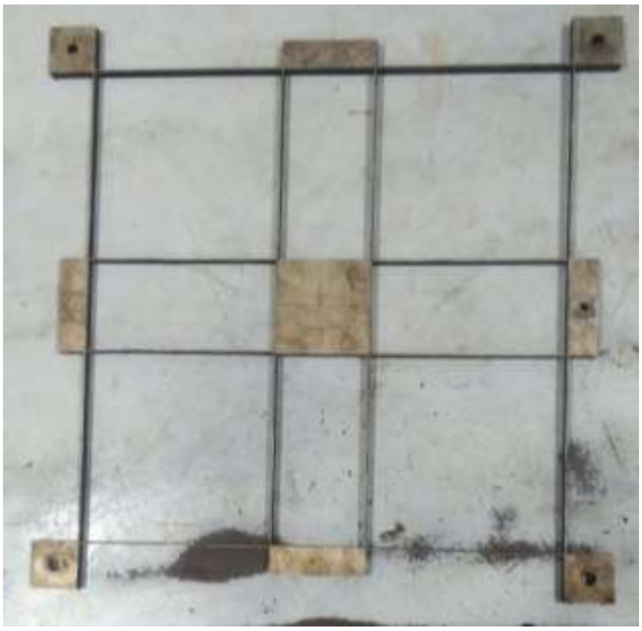

Fig. 5 - Manufactured XY Flexural Mechanism 1

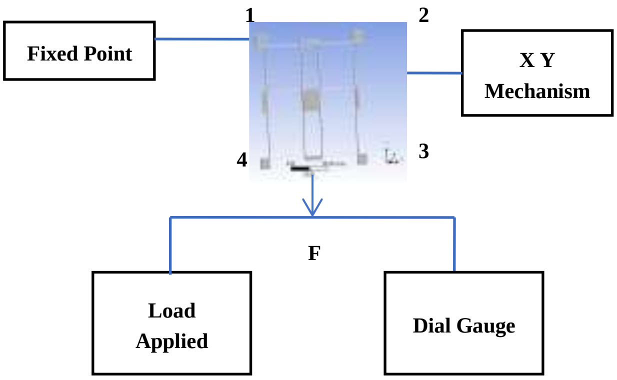

Fig. 6 - Experimental Setup for Measurement of X & Y Direction motion and parasitic motion

Figure 6 depicts a game plan for placing an XY flexural instrument on an optical table and setting up dial checks to capture X and Y course movements. Figure 7 shows a test setup that includes dial tests that assess dislodging of movement organize in X and Y directions individually. These dial checks feature a 5mm measurement and a maximum range of estimate of 10 mm. Adaptable wires are attached at the actuator region to provide appropriate activation in the X and Y directions. Load is attached using a weight container with a 100-gram increase. Every increase in load redirection of movement organize is noted. Load in weight pan (greatest 25 N) is given to such an extent that greatest of 5 mm uprooting is accomplished. Figure 8 demonstrates an examination amongst exploratory and FEA comes about for X-heading movement.

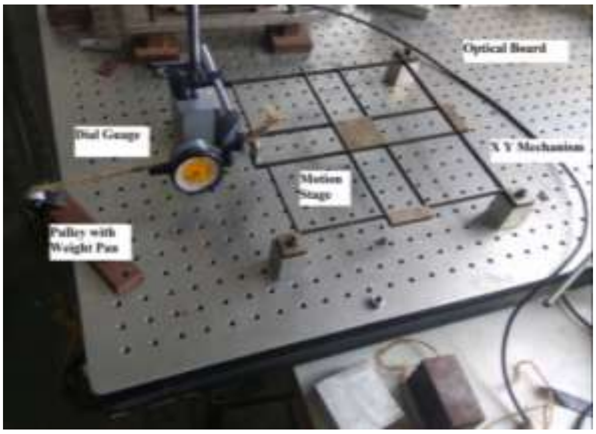

Fig. 7 - Experimental Setup for Measurement of X & Y Direction motion and parasitic motion

The comparison indicates that the experimental and FEA findings are almost identical. Other dial gauges continually record displacements in the Y-direction. Figure 9 depicts the results of Y-direction deflection. It has a maximum deflection of 2.5 mm and the variance seen is attributable only to surface defects. As a result, when the stage moves in the X-direction, there is no parasitic motion in the Y-direction.

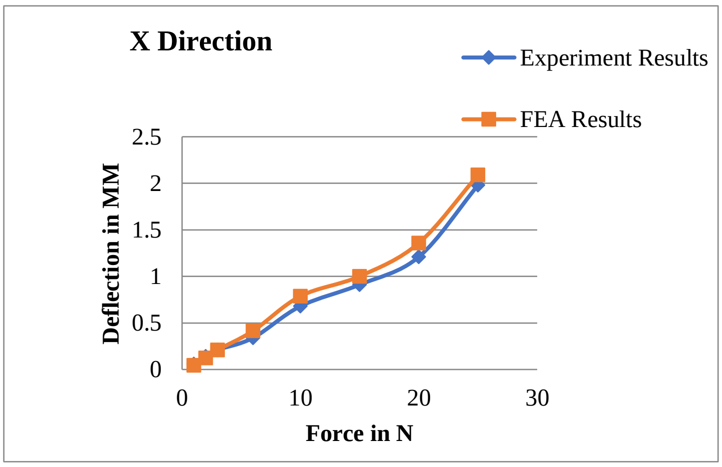

Fig. 8 - Comparison of experimental and FEA for results for X-direction.

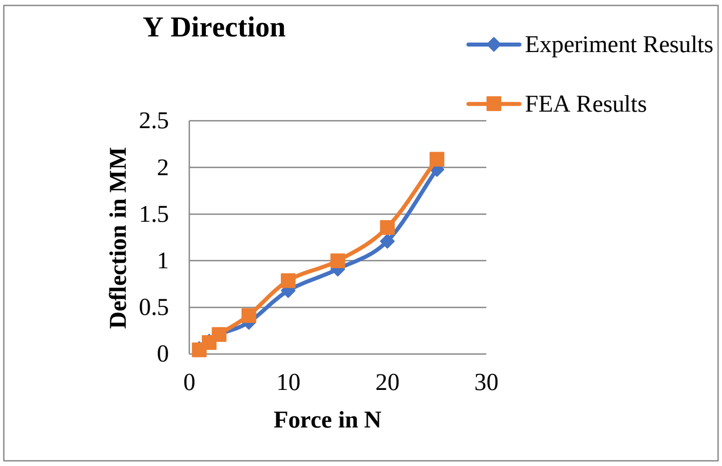

Fig. 9 - Comparison of Experimental and FEA results Y-direction

4. DFM Parametric Analysis

In this section, a planar flexural instrument is dissected using the FEA software ANSYS. The ANSYS component-based parametric presenting technique (shown in Fig. 10) is used. Essentially, a Flexural system is made up of multiple DFM flexures. DFM measurements are parameterized (parameters: pillar length, bar width, and bar thickness) and used to create various geometries. Table 1 displays the factors evaluated for study as well as their reaches.

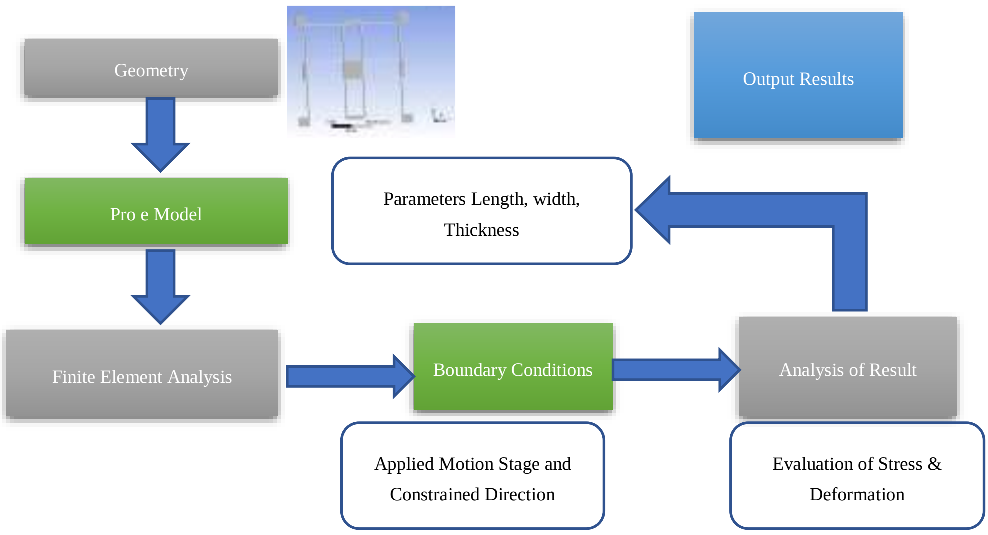

Fig. 10 - FEA Analysis Procedure

FEA Examination is completed to have a variety long, thickness and width of flexural light emission DFM. Scope of these parameters are recorded in Table-1 underneath,

Table 1 - Range of Parameters for FEA Analysis.

Sl no	Parameters in mm	Range
1	Model Length	100-125
2	Model Width	8-10
3	Model Thickness	1.0-1.5-2.0

These characteristics are utilised in the development of CAD models for the XY flexural mechanism. Creo2.0 CAD software is used to create a total of 64 models. These models are then transformed into a non-proprietary file format.iges, and then loaded into ANSYS Workbench for FEA analysis.

These various CAD models are analysed using the FEA tool ANSYS. Each model's stiffness is estimated and compared to the theoretical stiffness value. Figure 11 depicts a comparison of theoretical and FEA findings that are almost identical.

Table 2 - Design requirements for mechanism

Sl no	Parameters	Range
1	Mechanism Range	10-15
2	Force in N	35N
3	Stress	400N/mm^2

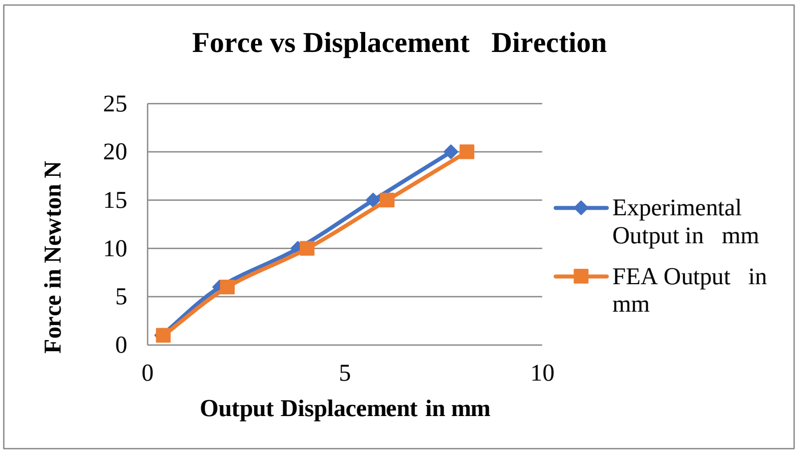

Fig . 11 - Theoretical and FEA Comparisons

5. Conclusion

XY flexural component is especially valuable in exactness applications, for example, laser checking, microscopy, small scale nano creation frameworks. Flexural system has favorable position of zero backlash also, erosion and offers better control on position. System 1 the range of the system is less as compared to the other system 2. System 2 is symmetrically upheld also, gave a lesser or zero vertical movement. Henceforth system 2 gives better execution and need to be built and tested for the same.

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