RESEARCH ARTICLE

Evaluation of Stiffness and Parametric Modelling of XY Flexure Mechanism for Precision Applications

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ABSTRACT

In miniaturized scale electro-mechanical framework (MEMS) flexural instruments are generally utilized in light of their preferences, frictionless and wear less movement and high accuracy. Flexures rely upon material versatility for their usefulness. In flexure component, movement is created because of flexibility of the shaft from which it is made. One of the run of the mill favorable circumstances of flexural system is to increase exact twisting and adaptability to acquire movement wanted way. This paper manages outline, examination and displaying of XY flexure instrument which depends on twofold parallelogram flexure (DFM). The XY system exhibited has solid structure and it depends on twofold parallelogram flexure. Limited component model and investigation is completed in ANSYS 15. Static examination is done to discover constrain avoidance attributes of instrument. Parametric examination is utilized to improve outline parameters of flexure shaft. Limited component examination (FEA) result approves investigative outcomes of component.

Keywords: FEA, Flexural mechanism, parasitic, dSPACE DS1104, DFM

1   Introduction

XY Flexure Mechanism builds motion between fixed stage and motion stage. These provide accurate scanning with large scanning range and high speed. Smooth and repeatability are obtained with Flexure Mechanism [1]. Flexure mechanism is extensively utilized as a part of microelectro- mechanical frameworks. The working of flexure system depends on material flexibility. Because of distortion at atomic level movement is created; thus, the movement created is free from contact and wear [2]. A flexural instrument is a solitary piece adaptable structure, where the auxiliary twisting is used to transmit drive or convey movement [3]. It fills in as a transmission that is intended to have the attractive connection between the info activation and the yield to nature; critical deformation happens around the flexural pillars. The advantages of a flexural system are recorded as beneath:

- Lessened kickback and no contact,
- Ceaseless and smooth dislodging, and
- Vast determination.

Flexural components accomplish their movement due to versatility of material and distortion of their parts rather than unbending joint (bearing and so forth.) utilized as a part of customary components. One of the unavoidable uses of flexures is in the arrangement of development stages. Relocation arrange more often than excludes a few fundamental components: application organize, payload bearing system, sensors, actuator too as a control calculation [4]. Right when incredibly correct development is important, every one of these components must be chosen and again arranged purposely. In spite of the reality that flexures give broad payload bearing properties to the extent correct development is concerned, the layout of the movement organize is not simply obliged to the format of the flexure bearing, in any case it needs to fuse different components [5]. Different single DOF and multi DOF flexure mechanisms have been presented

till the date. It is normally less tumultuous to layout a solitary DOF dislodging stage in light of the fact that one does not have to worry over the participation between the parts of the distinctive tomahawks. Dislodging, utilization of power and position detecting, all happen in one course as it were [6]. To achieve huge movement, extend with high precision, the usage of coarse fine estimate system is summed up. One can use a coarse-fine bearing stage, a coarse-fine activation structure, mechanical movement enhancers and even a coarse-fine sensor format [7]. The design of multi DOF uprooting frameworks ends up being extremely contending, in light of the way that the collaboration between the components of the distinctive tomahawks in the system brings about conflicting necessities being constrained on the flexure bearing format, and also on the choice of actuators and sensors [8]. In this examination article, an exertion has been made to outline and examine a novel XY situating instrument utilizing twofold flexural controller (DFM). Parametric advancement was completed utilizing ANSYS programming; and hypothetical and in addition FEA firmness esteems were dictated by utilizing power avoidance attributes of the component. The advantage of using the flexure is the single monolith in nature compact in design and eliminates the joints and friction [9].

2   Design Methodology

Parasitic blunder is one of the execution measures in flexural component and other one is rakish revolution. Parasitic mistake is the undesirable, unwanted movements of movement organize. Precise pivot is bit of movement organize. Both, parasitic mistake and rakish turn influences exactness of movement arrange. Parasitic mistake can be eliminated by utilizing double parallelogram flexure module (DFM).

3   Double Parallelogram Flexure

Different kinds of flexure building squares, for example, cantilever bar, parallelogram flexure, twofold parallelogram flexure, single hub pivot, multi hub pivot are utilized to plan flexure component [2], [10]. Here, the twofold parallelogram flexure is utilized to plan of XY flexural component. Figure 1 demonstrates the double parallelogram flexure. It is likewise called a compound parallelogram flexure, collapsed pillar flexure. It permits Y direction deformation however it is extremely firm in X-direction. The parasitic mistake in X direction is unimportant in light of the fact that auxiliary movement organize assimilates any adjustment in pillar length because of deformation. Deformation of primary motion stage is given by:

Figure 1: *Double Parallelogram Flexure* [9]

$$\delta = \frac{FL^3}{12EI}$$

Where, δ = deflection, mm;
F = Force applied, mm;
L = Length of flexure beam, mm;
E = Young's Modulus, N/mm$_2$; and
I = second moment of area of beam, mm$_4$.
Stiffness of flexure module is:

$$K = \frac{F}{\delta} = \frac{12EI}{L^3}$$
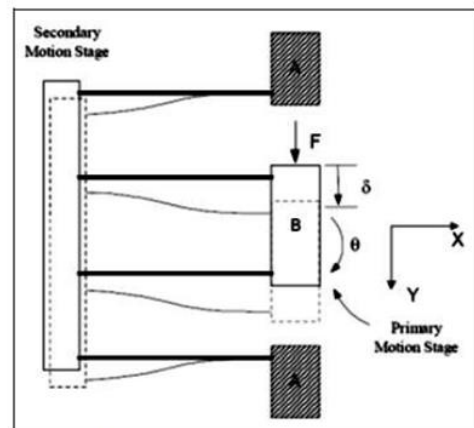
Where, K= Stiffness of flexure module, N/mm.

4   X Y Positioning Stage

Figure 2 Outline the XY flexural mechanism. XY flexural mechanism depends on two fold parallelogram flexure module [11]. There are two double parallelogram flexures in X and Y directions. These flexures go about as springs joined parallel. Subsequently, the aggregate stiffness is expansion of stiffness of two flexures ascertained as given below

Stiffness in X- Direction:

$K_x=K_{Flexure1}+ K_{Flexure2}$

Stiffness in Y- Direction:

$K_y=K_{Flexure3}+ K_{Flexure4}$

XY Flexure Mechanism deformation for motion stage
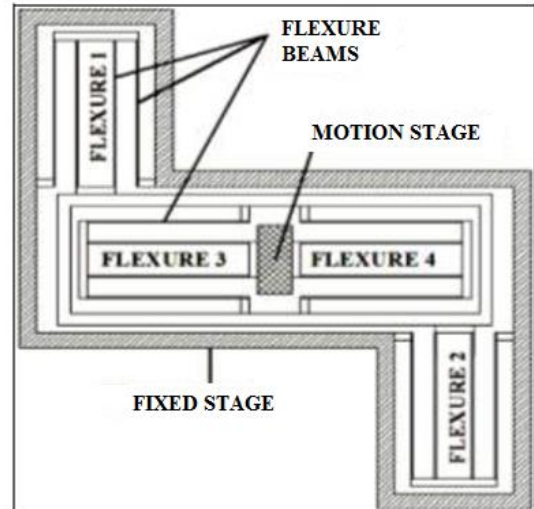
Figure 2: *XY Flexural Mechanism*

$$\delta_x = \frac{F}{K_x} \quad \delta_y = \frac{F}{K_y}$$

For the length of L=95mm, thickness t=1mm and width=10mm

Moment of Inertia

$$I = \frac{b \times t^3}{12} = \frac{10 \times 1^3}{12} = 0.83333 mm^3$$

Stiffness for single Double Flexure Mechanism:

$$K = \frac{12 \times E \times I}{L^3} = \frac{12 \times 2.1 \times 10^5 \times 0.83333}{95^3} = 2.4582 N/mm$$

Stiffness in X Direction;

$$K_x=2.4582+2.4582=4.9164N/mm$$

Deflection in X-direction:

$$\delta_x = \frac{F}{K_x} = \frac{25}{4.9164} = 5.080 mm$$

5   Parametric Optimization of XY Positioning Stage

After outline of XY flexural component systematically, the limited component investigation of same model is completed in ANSYS programming for correlation of hypothetical and FEA comes about. In FEA, static auxiliary investigation and parametric investigation is improved the situation advancement reason. The system is displayed in CREO 2.0 and investigated in ANSYS 15. The measurements of flexure pillar used to make display are; l=95 mm, b=10 mm and t=1 mm. Material utilized is stainless steel ($\mu = 0.3$, E=2.1×105 N/m²) connected power is 25 N. Fine type coinciding is chosen. Figure 3 shows the boundary conditions for XY flexural mechanism in Ansys15. Figure 4 demonstrates deformation of component in X-direction. Total extreme estimation of deformation is =4.9785 mm. Figure 5 indicates comparable Von-Mises stresses and greatest estimation of stress happens in component is 183.7 N/mm². Figure 6 the most extreme estimation of parasitic mistake at movement arranges was observed to be 0.0030335 mm.
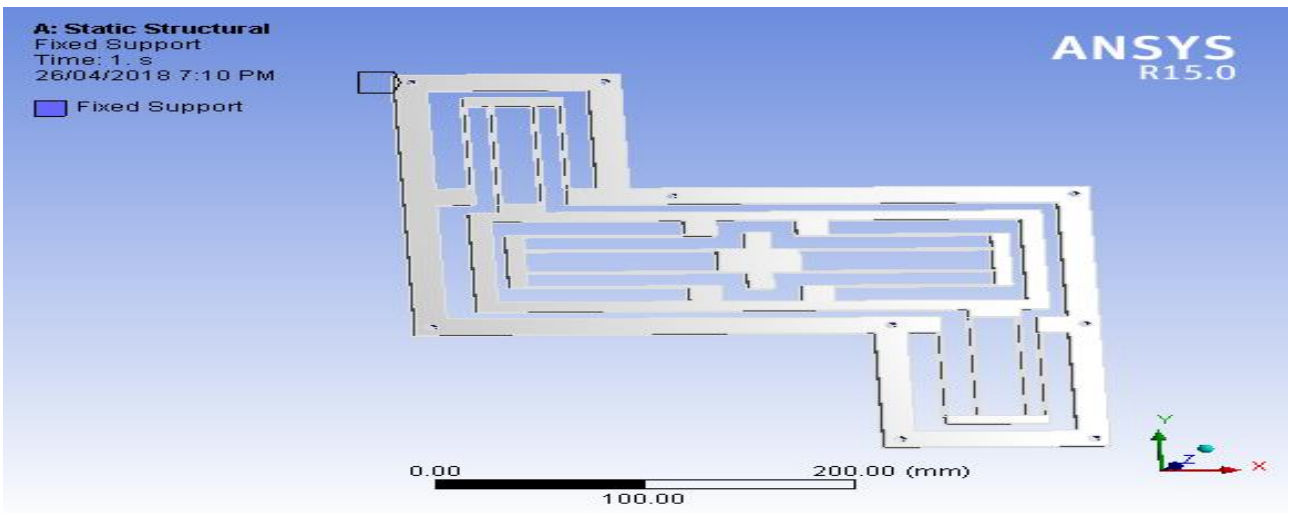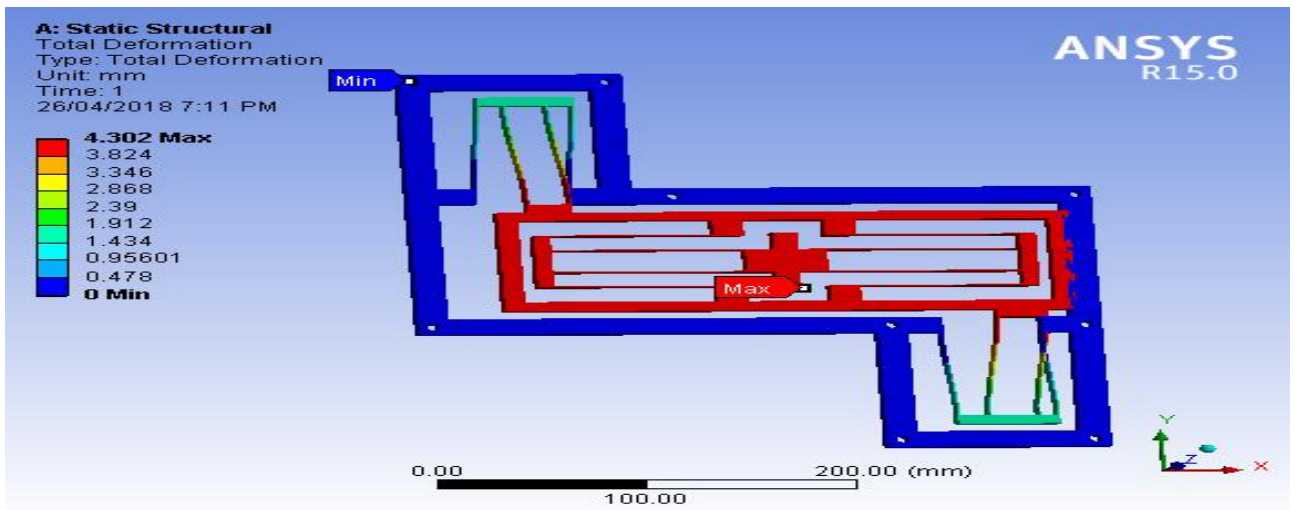
Figure 3: *Model Boundary Condition*

Figure 4: *Total Deformation in X Direction*
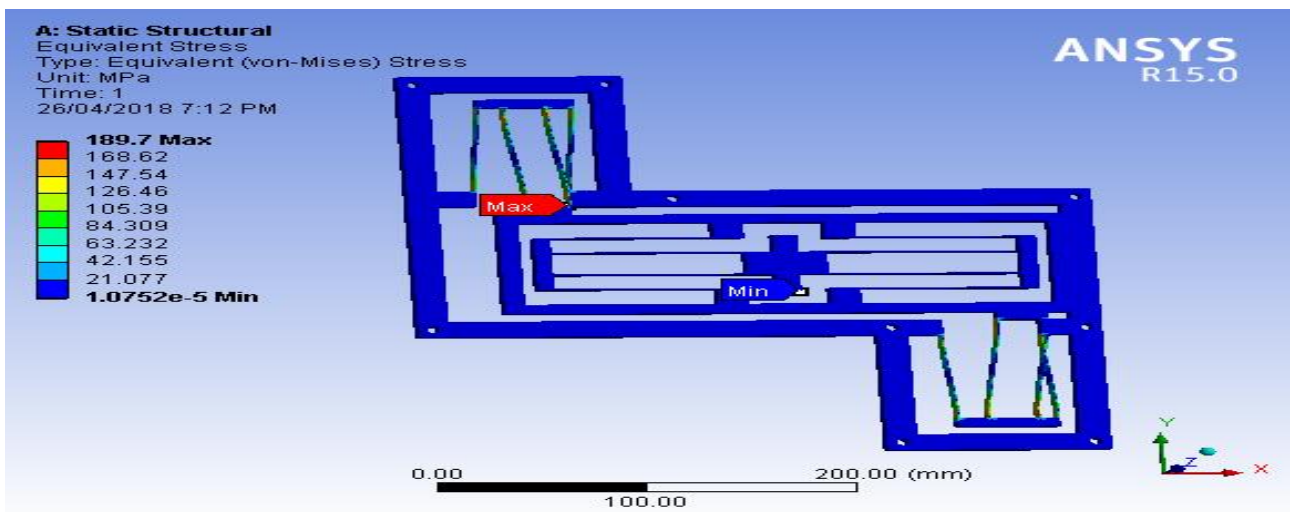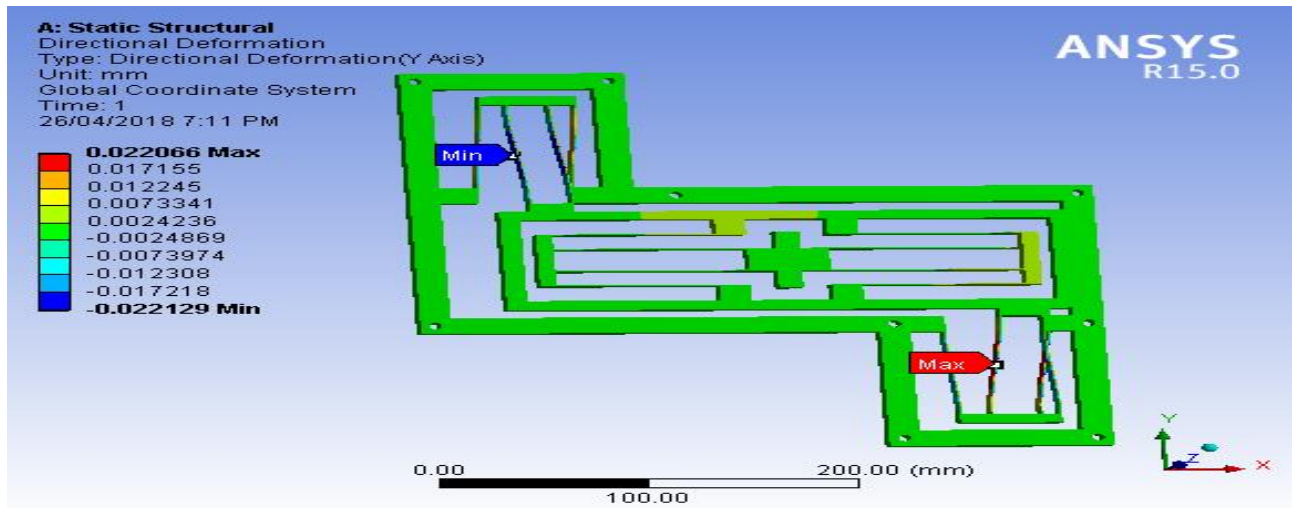

Figure 5: *Von-Mises Stress*

Figure 6: *Parasitic Motion*

5.1 Parametric Analysis

In parametric examination, right off the bat input outline parameters, for example, length, width and thickness are chosen. At that point, these plan parameters are characterized while making geometry and limited component show is created. Next, limit conditions (settled help and power) are connected to this model. After this, comes about are created and yield parameters like aggregate twisting and comparable pressure are characterized. At last estimations of input parameters are differed and comes about are translated as for these qualities. Figure 7 shows the flow chart for parametric investigation using finite element analysis. Parametric examination is conveyed for enhancement of plan parameters of flexure bar, for example, length of flexure bars 'l', width 'b' and thickness 't'. Range taken for length 80, 85, 90 and 95 mm, for width is 7, 8, 9 and 10 mm. Furthermore, for thickness 0.7, 0.8, 0.9 and 1 mm three plots are being evaluated and represented in Figure 8. It is seen that deflection increase with increase in length and decreases with increase in width and thickness.
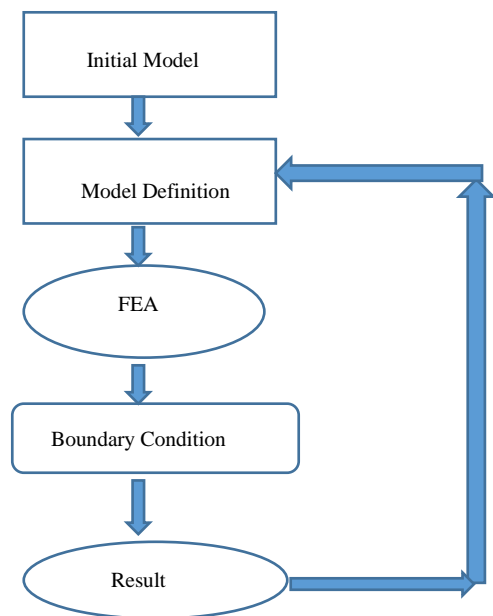

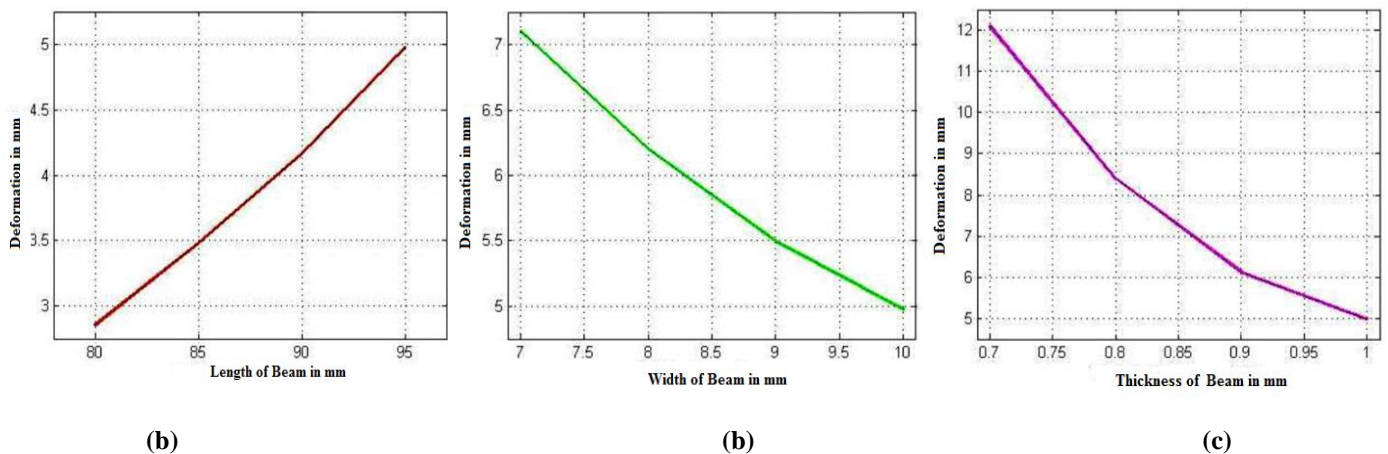**Figure 7:** *FEA Analysis Flow Chart*

| (b) | (b) | (c) |

Figure 8: *Plot of* **(a)** *Length vs Deflection* **(b)** *Width vs Deflection* **(c)** *Thickness vs Deflection*

6   Experimental Layout

Figure 9 is the experimental setup for the experimentation of the flexure mechanism. To work the framework with PC introduced graphical user interface programming control work area combination of framework is required. Component is associated with dSPACE controller. Voltage is provided to voice loop engine in the wake of changing over it to comparing current. This current has low esteem, so it is expected to open up it, and it is done by utilizing straight current enhancer (LCAM). Voice loop engine creates drive and it is connected to system. Voice curl engine has pick up of 22.6 N/Amp. Because of utilization of power, movement is produced. This created movement is identified by utilizing optical encoder. Optical encoder utilized is Renishaw's RGH22 made by Renishaw's. It has determination of 50 nm. Next, the flag from encoder is given to dSPACE. This flag is at that point contrasted and reference motion by utilizing MATLAB simulink and mistake flag is ascertained which goes about as inciting power. At last, yields of the considerable number of gadgets will be shown utilizing control work area. Control work area acts as interface amongst framework and client.
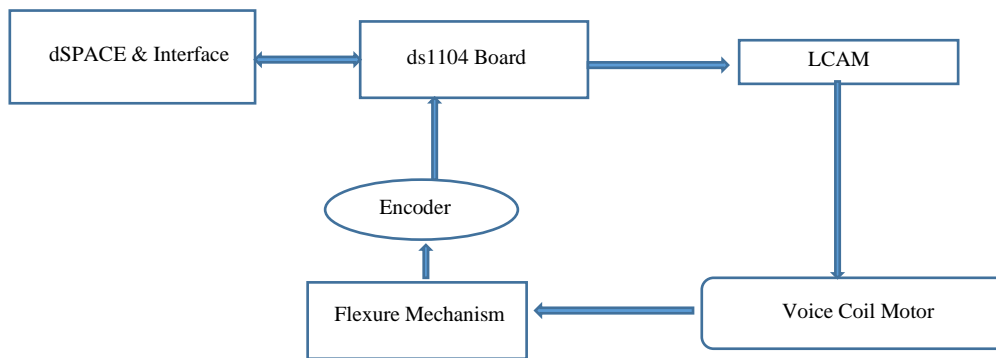

Figure 9: *Experimental setup of the Mechanism*

7   Result and Discussion

Table 1 shows the comparison of theoretical and FEA results and percentage error between theoretical and FEA results for X-direction. Table 2 shows comparison of theoretical and FEA results with percentage error between theoretical and FEA results for Y direction.

Table 1: *Analytical and FEA Results in X Direction*

Sl no	Force in N	Deflection in mm		Stiffness in N/mm	
		Analytical	FEA	Analytical	FEA
1	2	0.406801	0.344163358	4.91640876	5.811194
2	5	1.017004	0.86040838	4.91640151	5.811194
3	8	1.627206	1.576653432	4.91640272	5.074038
4	10	2.034006	1.92081676	4.91640634	5.206119
5	12	2.44081	2.364979969	4.9164007	5.074039
6	15	3.051012	2.98122514	4.91640151	5.031488
7	18	3.661215	3.597470073	4.9164007	5.811194
8	20	4.068017	3.94163352	4.9164003	5.074038
9	22	4.474818	4.285796729	4.91640107	5.133235
10	25	5.085021	4.902041901	4.91640054	5.099916
11	28	5.695224	5.581828683	4.91640013	5.016277
12	30	6.001202	5.962450281	4.99899853	5.031488

Table 2: *Analytical and FEA Results in Y Direction*

| Sl no	Force in N	Deflection in mm		Stiffness in N/mm	
		Analytical	FEA	Analytical	FEA
1	2	0.406801	0.34576668	4.9164088	5.784247
2	5	1.0170043	0.86441671	4.9164001	5.784247
3	8	1.627206	1.38306671	4.9164027	5.784247
4	10	2.0340008	1.72883342	4.9164189	5.784247
5	12	2.4408103	2.07460001	4.9164001	5.784248
6	15	3.051012	2.59325013	4.9164015	5.784247
7	18	3.6612155	3.11190025	4.9164	5.784247
8	20	4.0680172	3.45766684	4.9164001	5.784247
9	22	4.4700481	3.80343343	4.9216473	5.784247
10	25	5.085021	4.32208355	4.9164005	5.784247
11	28	5.695224	4.84073367	4.9164001	5.784247
12	30	6.100202	5.18650026	4.9178699	5.784247
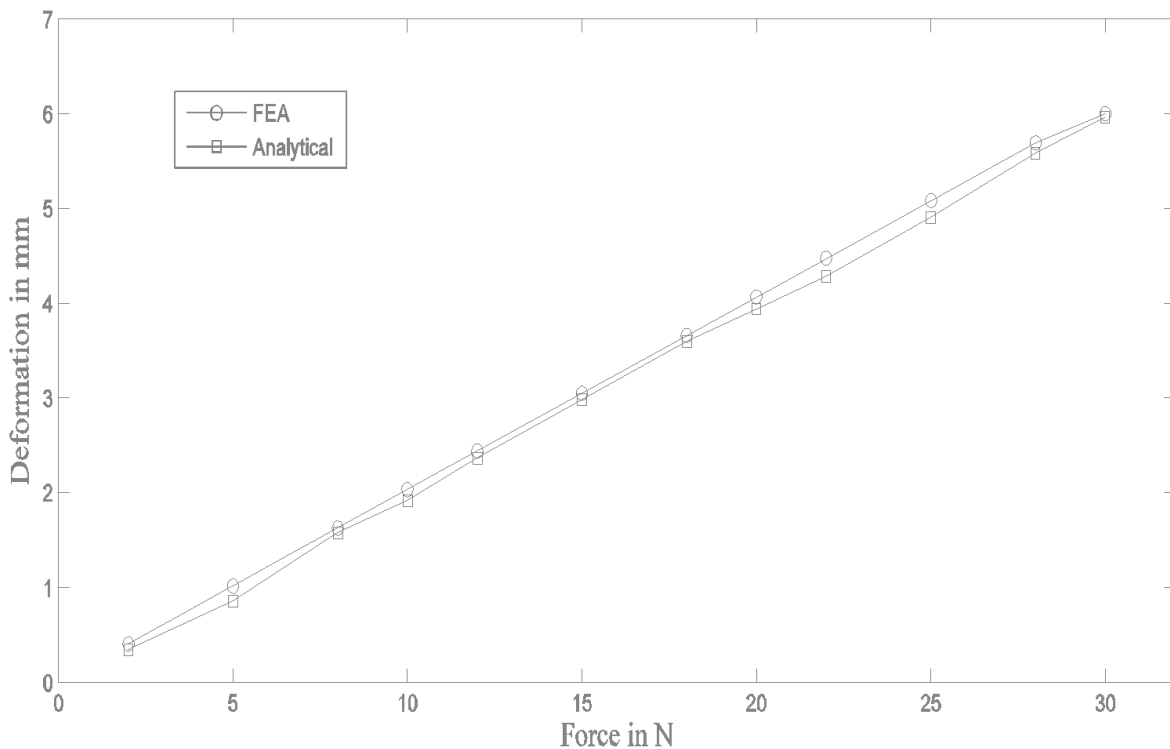
Figure 10: *Force vs Deflection Plot*

Figure 10 shows the force displacement bend is linear for both, X-and Y-direction. Tables 1 and 2 demonstrate the examination of hypothetical and FEA firmness with % mistake for X-and Y-course separately. The mistakes between hypothetical what's more, FEA comes about is 1.8125 and 0.90% for X and Y-course individually which are inside satisfactory point of confinement.

8   Conclusion

The XY flexural component for relocation has been created utilizing twofold parallelogram flexure module. The hypothetical comes about are confirmed utilizing FEA comes about. The constrain avoidance bend is straight. The incline of this bend demonstrates solidness which is consistent. It is watched that mistake amongst FEA and hypothetical outcomes is under 3%. Instrument has firmness of 4.91640 N/mm. The instrument has scope of ± 5 mm for a power of 25 N. The outline parameters are enhanced by utilizing

parametric investigation. Component exhibited in this paper can be utilized as a part of different accuracy applications, for example, nuclear power magnifying instrument (AFM), laser cutting, laser surgery and examining test magnifying instrument.

9   How to Cite this Article

10   References

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