International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-3 Issue-5, November 2014

Static & Modal Analysis of X-Y-Flexural Mechanism

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***Abstract:** This paper is an attempt to study the effect of thickness, length & width variation of flexural member on static & Dynamic behavior of flexural mechanism. ANSYS Software is used to create parametric model of flexural mechanism and do both static & modal analysis. Due to parametric modeling once we created model of mechanism in ANSYS & apply all constrain & load conditions. By varying dimensions of flexural member we can plot graphs of Thickness VS Deflection, stress etc. Above graphs will allow us to optimize flexural member. As both static & Modal analysis is done. The results will be more effective & realistic for comparision.*

***Index Terms:** Flexural member, Modal analysis of flexural mechanism, Deflection of flexural member.*

I. INTRODUCTION

Several publications talk about the pros and cons of flexure mechanisms and highlight the significance of their use in technology required to provide energy efficient, wear free, higher resolution and high speed devices. Flexures have been used as bearings to provide smooth and guided motion, for example in precision motion stages; as springs to provide preload, for example in a camera lens cap. Flexures are compliant structures that rely on material elasticity for their functionality. Motion is generated due to deformation at the molecular level, which results in two primary characteristics of flexures – smooth motion and small range of motion. From the perspective of precision machine design, one may think of flexures as being means for providing constraints. It is this capability of providing constraints that make flexures a specific subset of springs. In fact, all the applications listed above may be resolved in terms of constraint design. A historical background of flexures is presented in several texts. While flexure design has been traditionally based on creative thinking and engineering intuition, analytical tools can aid the design conception, evaluation and optimization process. Consequently, a systematic study and modeling of these devices has been an active area of research. Some of the existing literature deals with precision mechanisms that use flexures as replacements for conventional hinges, thus eliminating friction and backlash. Analysis and synthesis of these mechanisms is simply an extension of the theory that has already been developed for rigid link mechanisms, except that in this case the range of motion is typically small. The key aspect of these mechanisms is flexure hinge design. Unlike these cases where compliance in the system is limited to the hinges, other flexure mechanisms exist in which compliance is distributed over a larger part of the entire topology. Both these kinds of mechanisms offer a rich mine of innovative and elegant design solutions for a wide range of applications

MOTIVATION:-

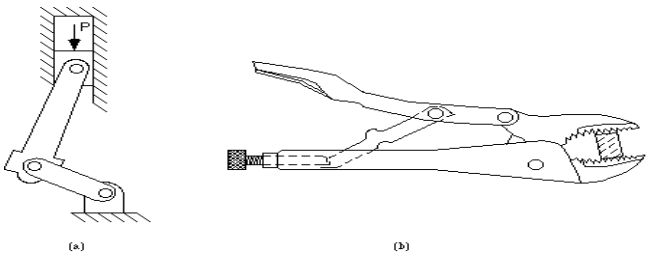
Any systematic flexure design exercise has to be based on performance measures. While detailed performance measures can be laid out depending on specific applications, a general set of measures are highlighted here. These measures are based on the deviation of flexures from ideal constraints.

One of the primary applications of flexures is in the design of motion stages. This thesis strives to bridge the gap between intuition and mathematical analysis in flexure mechanism design. Accordingly, the following list highlights the specific contributions of this thesis.

1. Dynamic Modeling of double flexural manipulator is carried to determine its natural modes and mode shapes using assumed modes method
2. Modal analysis and frequency response is determined for DFM considering actuator dynamics
3. Static analysis is carried for DFM
4. FEM analysis of DFM is carried out and comparison of results of assumed modes method and ANSYS results is done
5. Two different mechanisms are analyzed (from Shorya Awatar thesis) to determined its natural modes

II. FLEXURAL MECHANISM

A mechanism is a mechanical device used to transfer or transform motion, force, or energy. Traditional rigid-body mechanisms consist of rigid links connected at movable joints. The portion of a reciprocating engine shown in Figure is an example. The linear input is transformed to an output rotation, and the input force is transformed to an output torque. As another example, consider the vice grips shown in Figure 1.b. This mechanism transfers energy from the input to the output.



Conventional Mechanism

Revised Manuscript Received on 30 November 2014.
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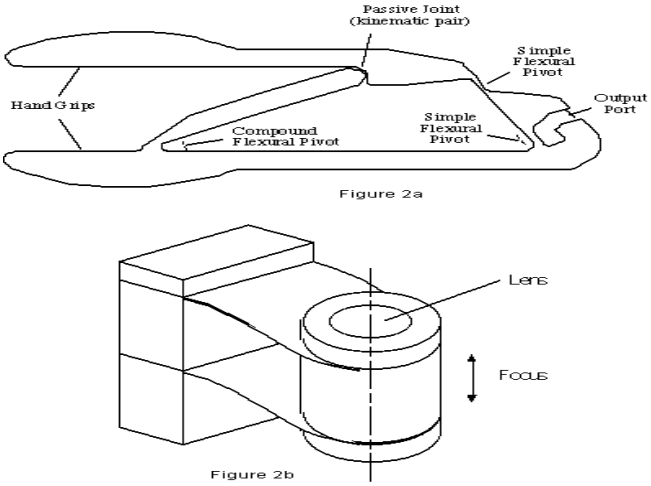
A compliant mechanism also transfers or transforms motion, force, or energy. Unlike rigid-link mechanisms, however, compliant mechanisms gain at least some of their mobility from the deflection of flexible members rather than from movable joints only. An example of a compliant crimping mechanism is shown in Figure 2a. The input force is transferred to the output port, much like the vice grips mechanism, only now some energy is stored in the form of strain energy in the flexible members. Note that if the entire device were rigid, it would have no mobility and it would be a structure. Figure 2b shows a device that is used to focus a lens, and it also requires compliant members to perform its function.



Flexural Mechanism

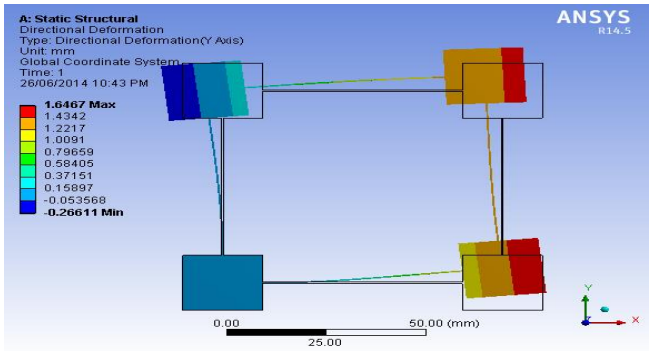
III. FEM OF FLEXURAL MECHANISM

STATIC ANALYSIS:-

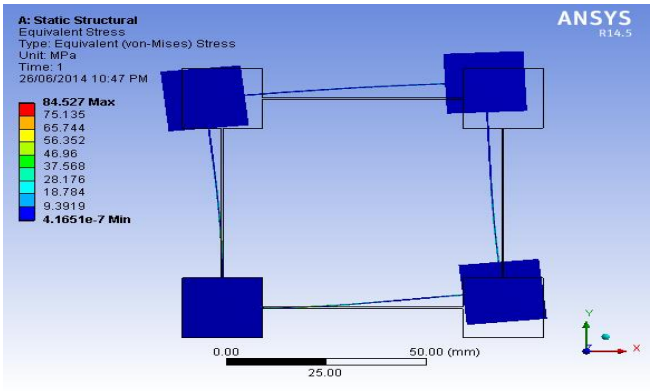
Static Analysis of different Flexural Mechanisms is done to compare the total deformations obtained using FEA. Following figures shows different flexural mechanisms. First mechanism is developed using simple beam flexure, second mechanism is developed using Parallelogram Flexure unit. Graphs are plotted as

1)Max. Deflection Vs Thickness
2)Max. Equivalent stress Vs Thickness
3)Max. Shear stress Vs Thickness

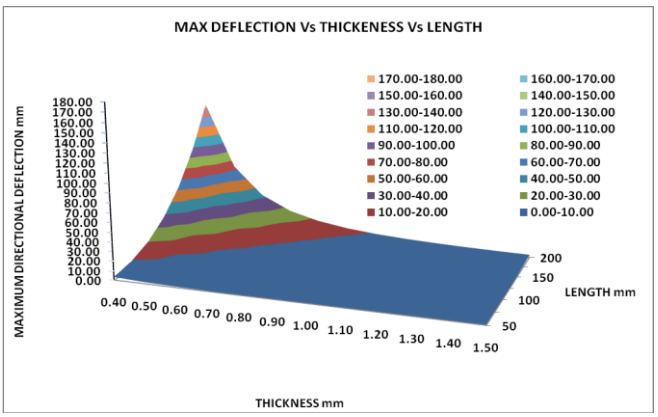
MECHANISM 1:-



Directional Deformation

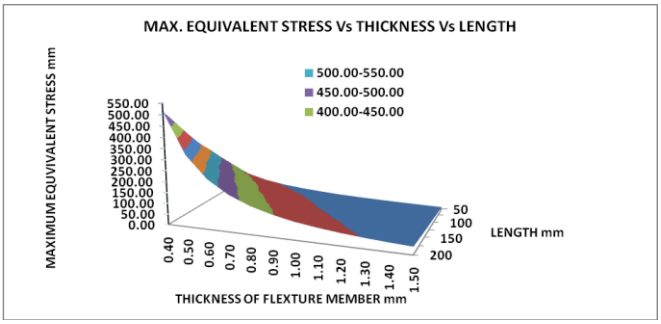


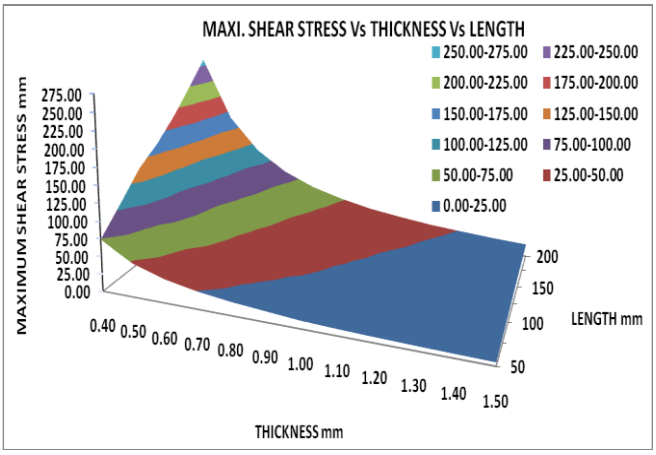
Max. Equivalent Stress



Max. Shear Stress

RESULTING GRAPHS:-





MECHANISM 2:-

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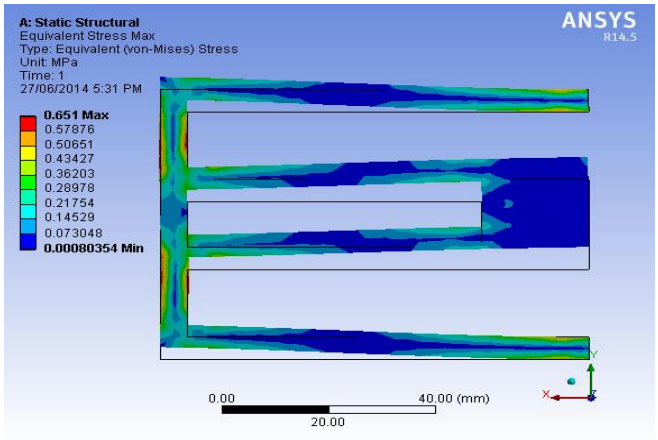
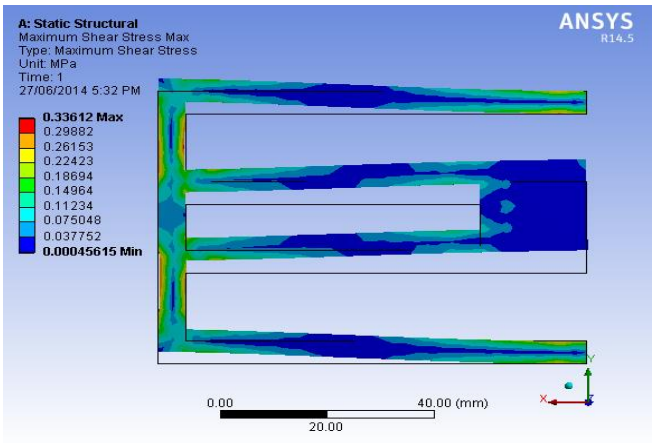
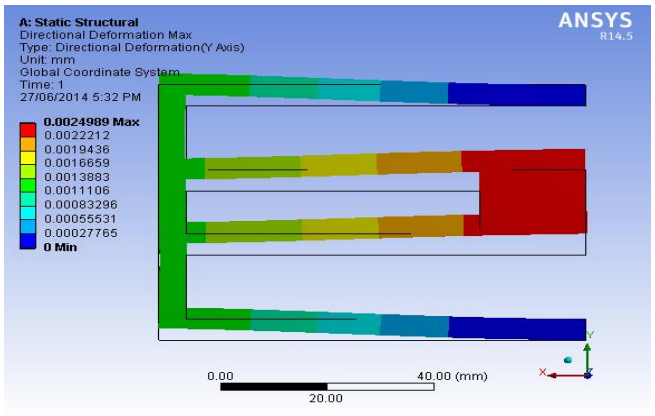


Max. Equivalent Stress

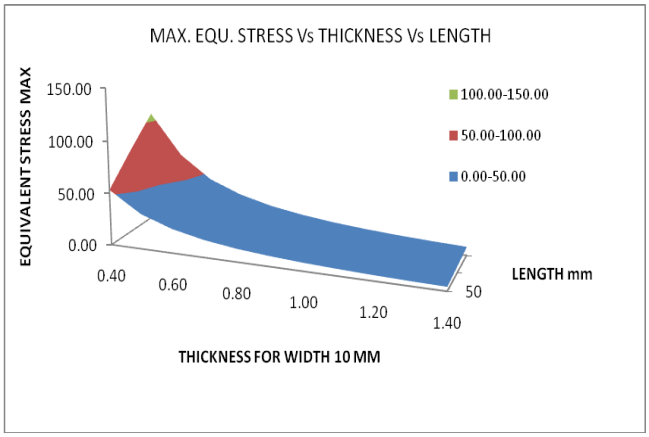


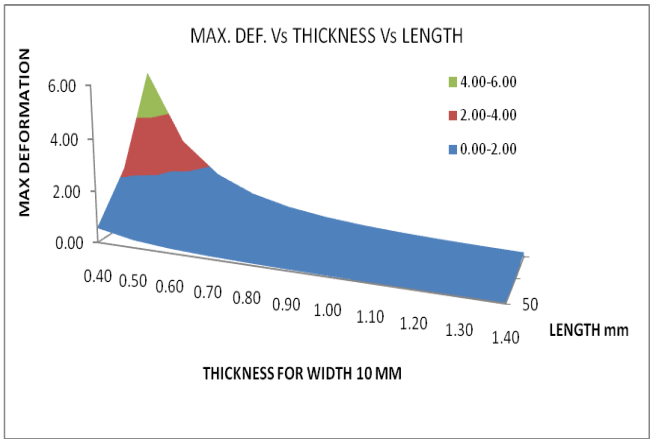
Max. Shear Stress

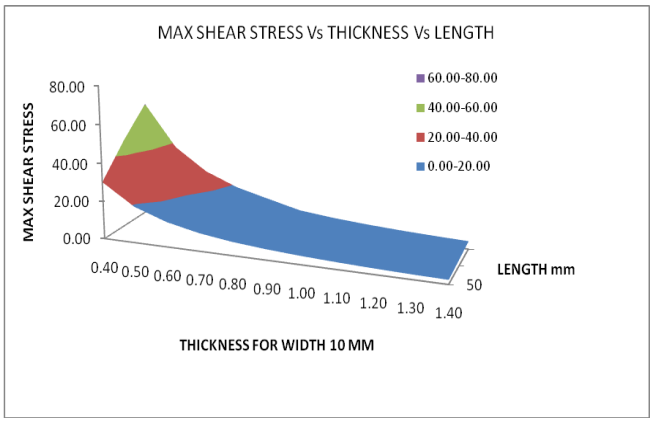


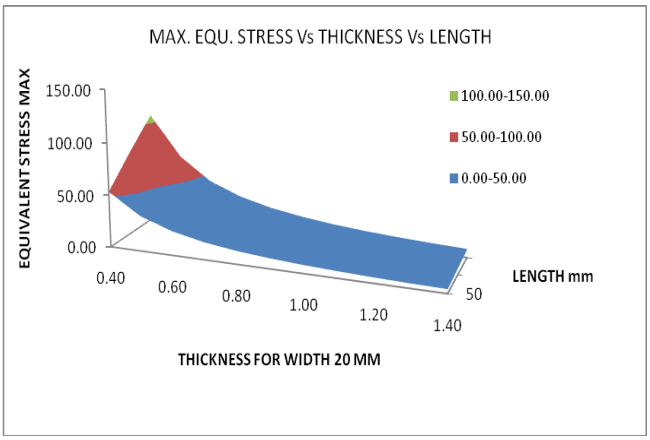
Directional Deformation

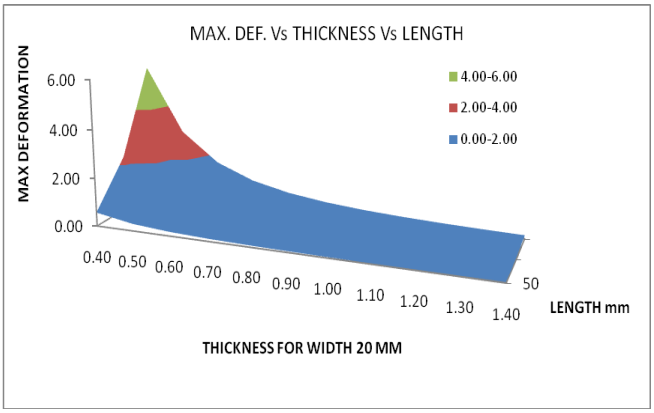
RESULTING GRAPHS:-











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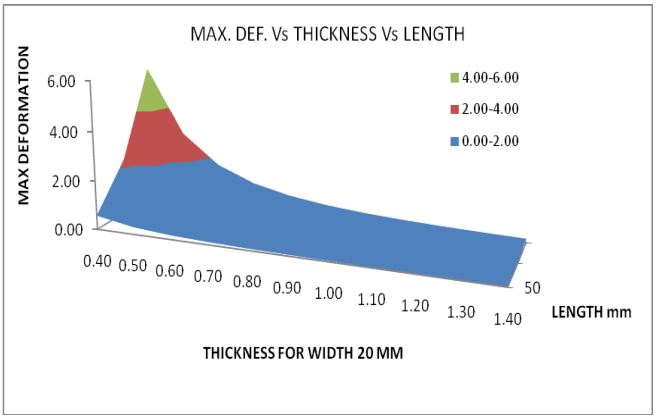
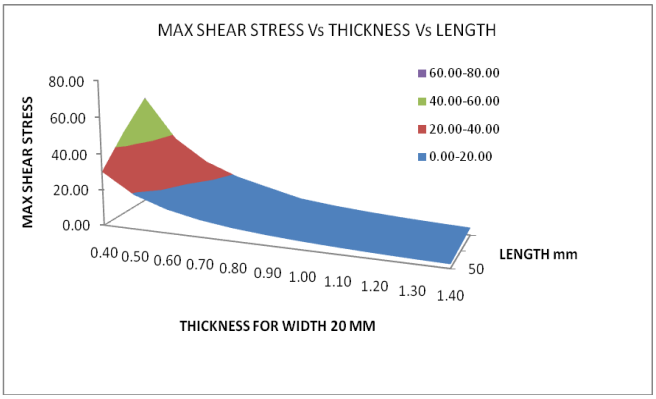


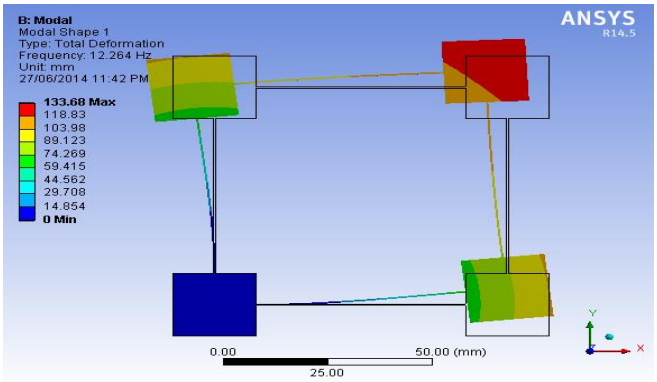


MODAL ANALYSIS:-

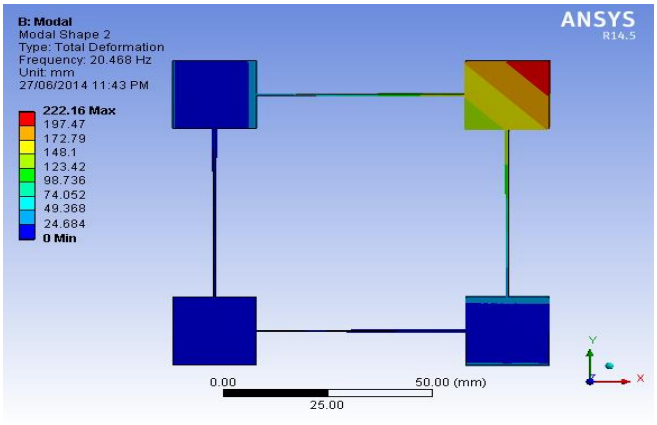
Modal Analysis is carried out to determine modal frequencies & mode shapes for XY mechanism

MECHANISM 1:-

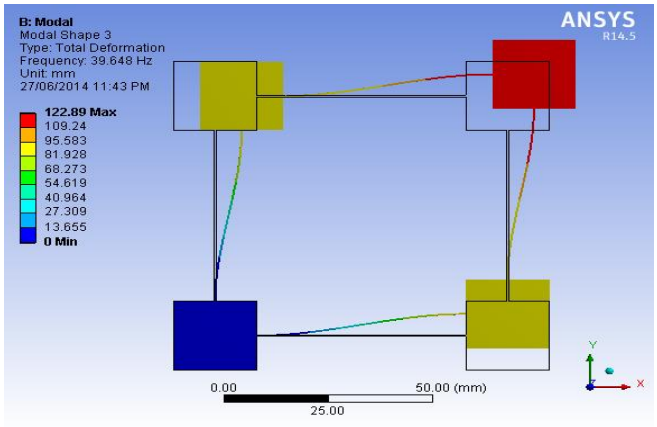
MODAL FREQUENCY 1



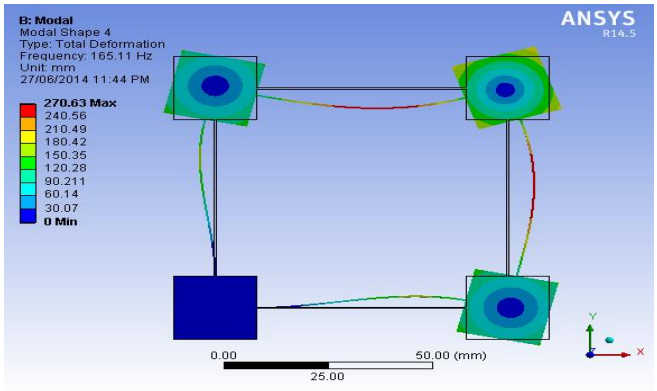
MODAL FREQUENCY 2



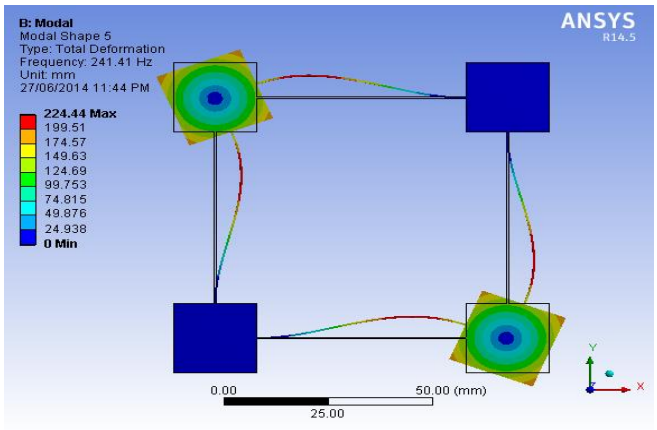
MODAL FREQUENCY 3



MODAL FREQUENCY 4



MODAL FREQUENCY 5



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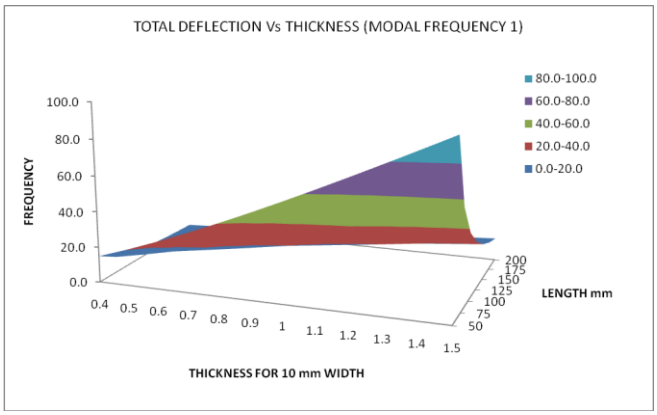

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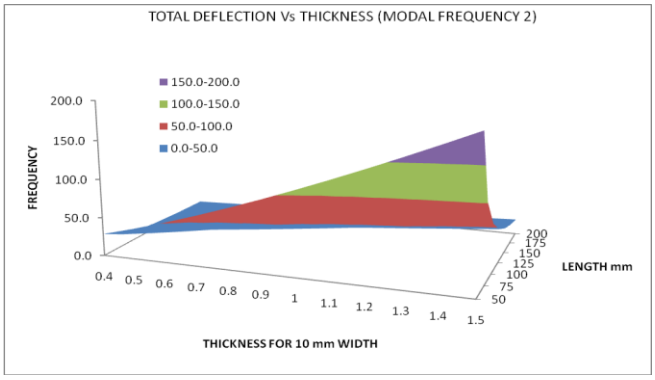
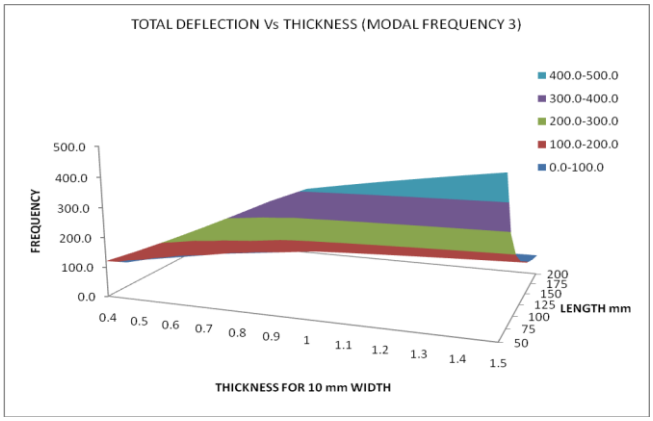
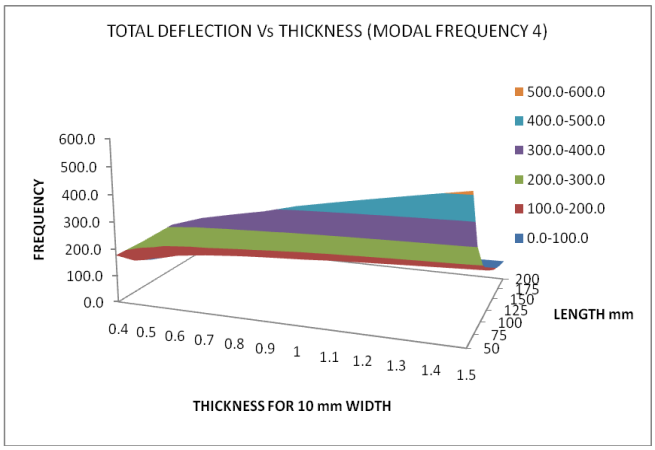
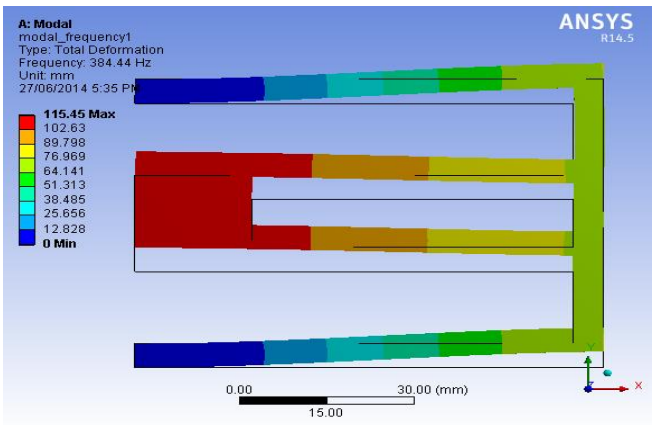




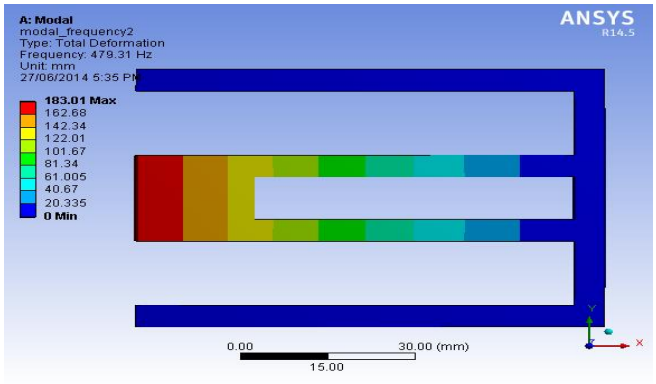


MECHANISM 2:-

MODAL FREQUENCY 1



MODAL FREQUENCY 2



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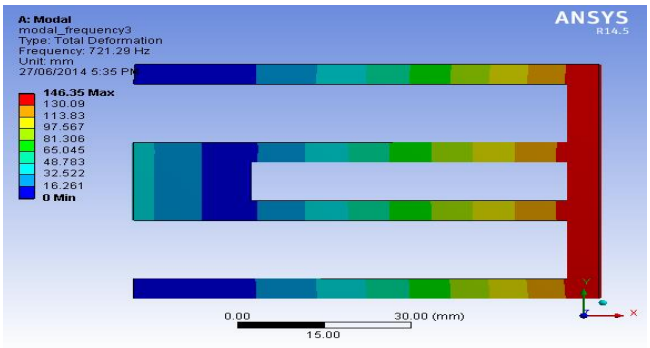

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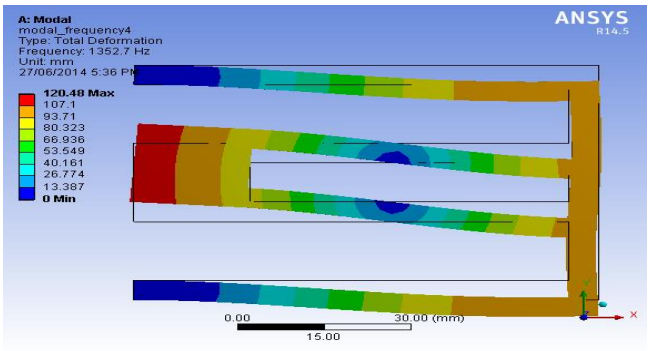

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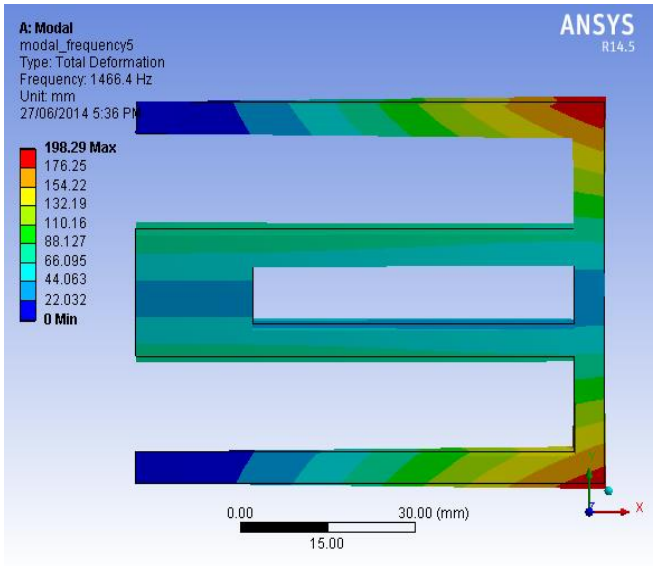

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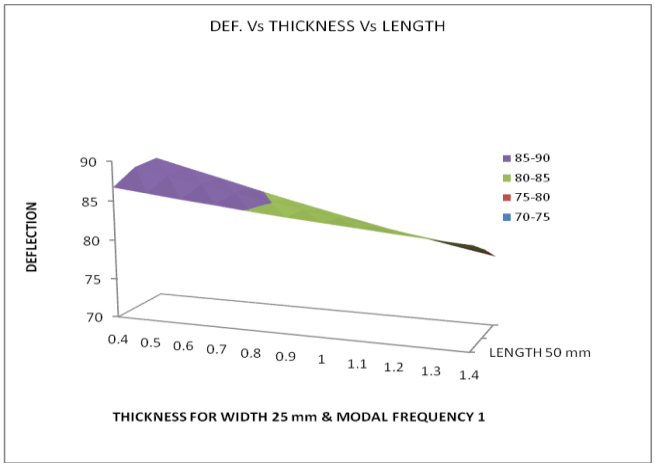

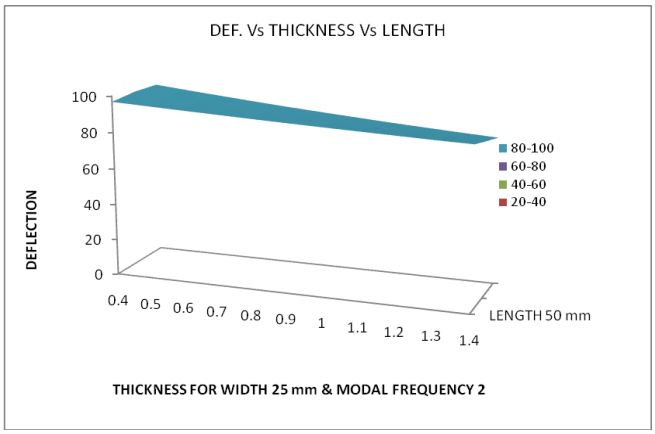

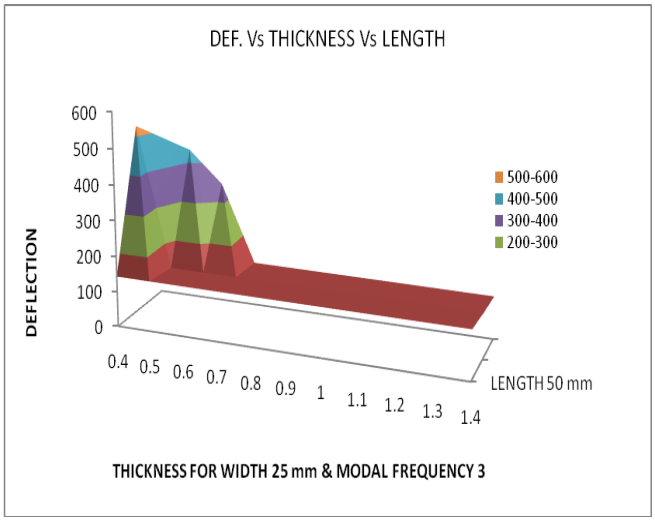

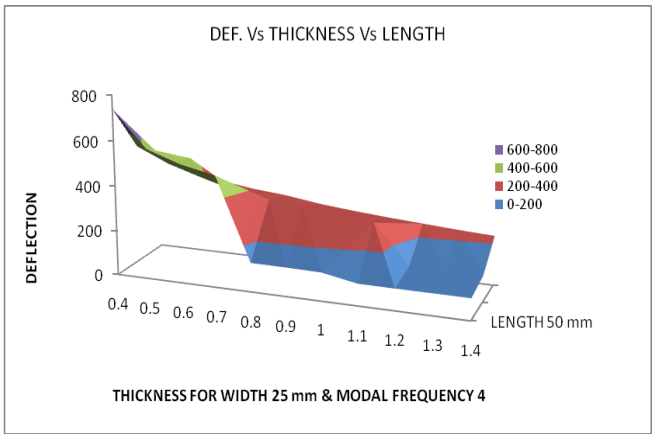

IV. TESTING OF FLEXURAL MECHANISM

Now Experimental setup consist of Flexural member-2 having Dimensions,100 mm length & 25 mm width & 0.5 mm thickness. So this test specimen is tested for same constrain & applied for as applied in CAE & results are evaluated. From test we can calculate deflection of member in direction of applied force. This deflection measured from test is compared with FEM results as shown in below table. It is found that both value from FEM & Testing are almost matching.

	Dim. Of flexural member in mm			Directional Deformation (mm)
Description	Thickness	Length	Width	
FEM Results	0.50	100.00	25.00	1.14
Test Results	0.50	100.00	25.00	1.20

So from Test results, We can conclude, prepared Parametric FEM model, applied constraints & force are accurately simulate actual condition. Thus we can have insurance about Accuracy of Results of Modal analysis down in FEM software by following same process.

V. CONCLUSION

There exist many two-axes planer flexural mechanisms that allow for small translations within the plane of the flexure. Most of these designs incorporate a stacked assembly where one linear stage in mounted perpendicular on a second linear stage resulting in a relatively bulky design. Nevertheless, in this arrangement the two axes are entirely decoupled and the actuation of one axis has no effect on the other. Such an assembly is commonly referred to as a 'serial design' in robotics terminology. In some clever serial designs, the above-mentioned stacking is achieved within a plane. The disadvantage of serial designs is that the actuator for the second stage has to be mounted on the moving member of the first stage. This not only makes the design unnecessarily complex but also limits the system dynamic performance, for example, speed of response. Ideally, it is desirable to mount the actuators for both the axes on ground, i.e., the fixed base. In this disclosure we have present a group of flexural mechanisms that are based on parallel elasto-kinematics. It is worthwhile to mention here that the motion of compliant mechanisms is not completely characterized by kinematics; it is strongly dependent on elastic deformations as well. Hence, the study of motion of flexural mechanisms is commonly referred to as elasto-kinematics. Mechanisms presented here make unique use of known flexural units and novel geometric symmetry to minimize or even completely eliminate actuator cross-sensitivity, and parasitic coupling between the two axes. In Static analysis many graph are plotted, these graph shows effect of thickness, length & width on deflection-stress characteristic. While Modal analysis section shows different mode shapes & mode frequency. And effect of thickness, length & width on deflection while flexural member executes vibrations. Thus it helps for design of Flexural member.

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