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Research Article

Dynamic Analysis of XY Flexural Mechanism

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Abstract

Flexure mechanisms are a designer delight except for the limit of elasticity, flexure represent few other boundaries as far as application concerned. Flexure have been used as bearing to provide smooth and guided motion .For example in precision stage as spring to provide preload flexural joint are used as a spring in precision motion stage . Flexural mechanism have immense scope in their use for application involving high precision motion .There are many concept to build high speed or high precision manipulator. In this work Dynamic analysis of XY mechanism is carried out to determine frequency and mode shape.

Keywords: *Flexural Mechanism, FEA Analysis*

1. Introduction

Flexure jointed mechanism have been widely utilized in precision instruments such as watches & clocks for hundreds of years, and continued to be used today in applications such as optical systems, micro robots, and clean room equipment. Flexural mechanisms are colossal structures which provide desired motion with the help of flexural hinges. Due to their smooth operation flexural joints have little friction losses and also does not require lubrication. They generate smooth and continuous displacement without backlash. XY planar scanning mechanism employing elliptical flexure is designed to have a long travel range up to 5 mm in both X- and Y-directions, while having a size of 300mm × 300mm × 3 mm. In the proposed stage system, the stage would be driven by PZT (Piezo-Electric Amplifier) at amplifier legs considering the driving force in the range of 20 to 35 N. The experimental measurements validate the large travel range of the mechanism (D. M. Bhoge, 2015). The mechanism considered here was developed using 1 DOF displacement Amplifier using Aluminium Alloy having Yield strength of 270 MPa, Poisson ratio of 0.33,Youngs modulus of 71000 MPa and density of 2700 Kg/m^3. Geometry of mechanism consist of two pairs of the amplifier legs assembled at right angles by means of two arms connecting the motion stage .when the stage plate is driven by the driving amplifier A in X-direction by means of PZT actuator, the vertical arm can guide the stage in Y direction while the Leg B does that in the X direction motion. This paper attempts at finding the mode shapes and natural frequencies of the mechanism to know the feasibility of mechanism for application in vibrating environments.

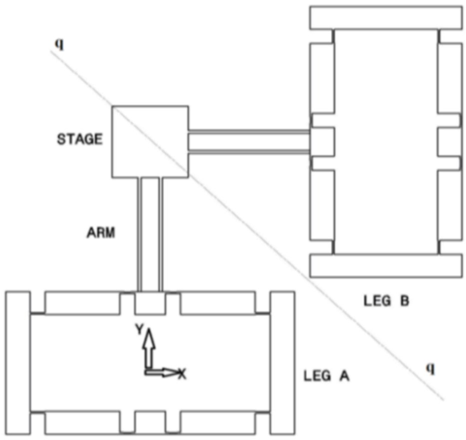

Fig.1 Geometry of XY Planar Mechanism

2. Literature review

Mathematical modelling of simple XY manipulator is carried out on XY manipulator using typical Double Flexural configurations. Static and dynamic analysis is carried out using MATLAB to determine static deflection of motion stage. Dynamic analysis is carried out to determine frequencies and mode shapes of flexural manipulator. Finite Element software ANSYS is used to carry out static and dynamic analysis of basic DFM configuration and few XY mechanisms. It is observed that close matching of FEM results with model developed (Sollapur Shrishail, *et al,* 2014).A concept of totally decoupling is proposed for the design of a flexure parallel micromanipulator with both input

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and output decoupling. Based on flexure hinges, the design procedure for an XY totally decoupled parallel stage (TDPS) is presented, which is featured with decoupled actuation and decoupled output motion as well. By employing (double) compound parallelogram flexures and a compact displacement amplifier, a class of novel XY TDPS with simple and symmetric structures are enumerated, and one example is chosen for further analysis. The kinematic and dynamic modelling of the manipulator is conducted by resorting to compliance and stiffness analysis based on the matrix method, which are validated by finite-element analysis (FEA).

Y Tina December, (2009) Investigated the inverse dynamics of the proposed mechanism established by simplifying flexure hinges into ideal revolute joints with constant torsional stiffness. Finite element analysis is used to validate the performance of the proposed 3-DOF flexure-based parallel mechanism. The interaction between the actuators and the flexure-based mechanism is extensively investigated based on the established model (Yangmin li quigang, 2009). In order to reduce the displacement loss, the modelling and analysis of bending motion of the levers are conducted; thereafter, compliance and stiffness modelling by employing the matrix method are established. Furthermore, the dynamics modelling and analysis via Lagrange equations are performed to improve the dynamic properties of the mechanism. The simulation results of finite element analysis indicate that the cross-coupling between the two axes is kept to 1.2%; meanwhile, the natural frequency of the mechanism is about 700 Hz, and the amplifier ratio is approximately 2.32. Both theoretical analysis and finite element analysis results well validate the performance of the proposed mechanism (Hui Tan, 2010).

3. Dynamic Analysis of XY Mechanism

Dynamic analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or machine component while it is being designed. It can be also served as starting point for another, more as basic building blocks of XY planar flexural mechanism. Dynamic simulations were run on the mechanism to determine natural frequencies and corresponding mode shapes. In this mechanism different deformations at different frequencies are obtained. It is observed that maximum deformation occurs at frequency 42.0722 Hz and minimum at 23.773 Hz. Therefore mechanism has to run with in a limit in order to run it successfully .This concept can be applied to industrial or maintenance environment to reduce maintenance cost and equipment down time by detecting equipment fault .It is used to detect fault in rotating equipment. Analysis settings for mechanism are shown in Fig. 2 below.

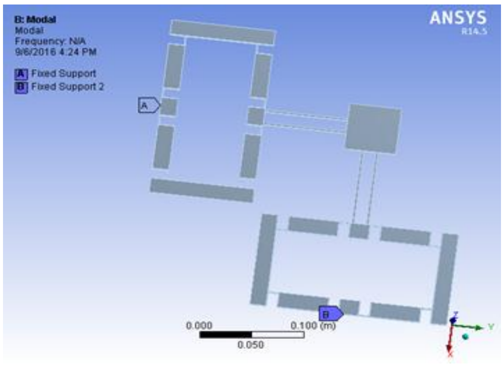

Fig. 2 Analysis settings of XY planar mechanism

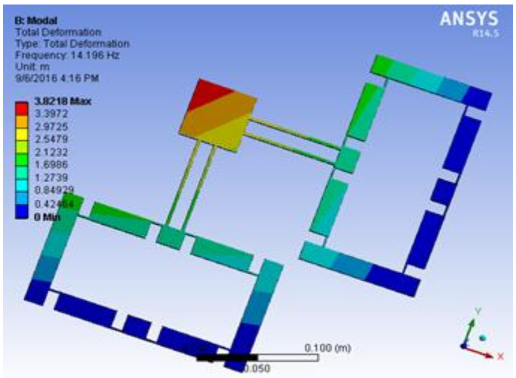

Fig. 3(a) Mode shape 1

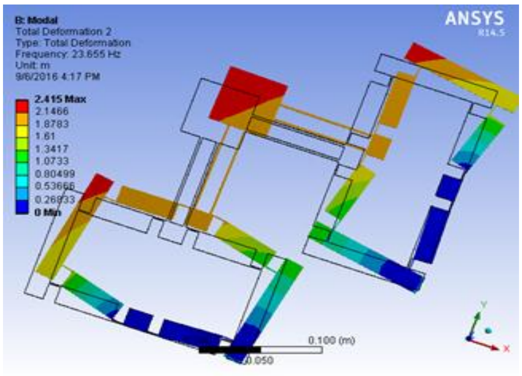

Fig. 3(b) Mode shape 2

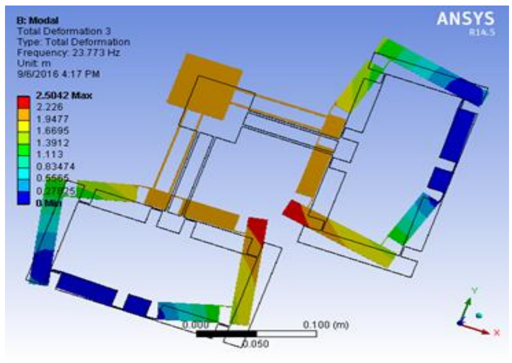

Fig. 3(c) Mode shape 3

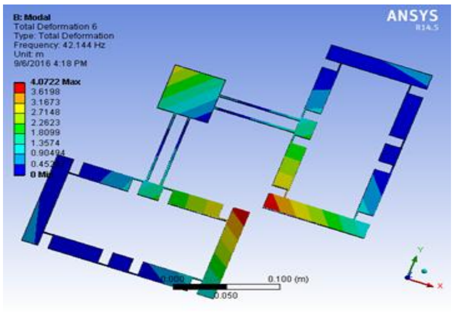

Fig. 3(d) Mode shape 4

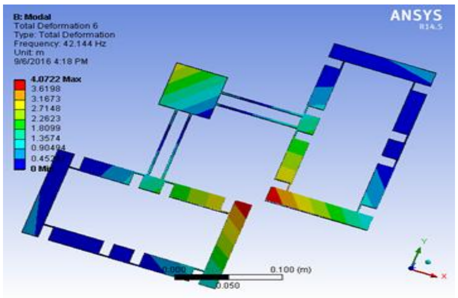

Fig. 3(e) Mode shape 5

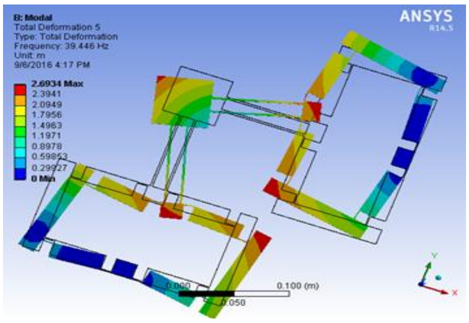

Fig. 3(e) Mode shape 6

Table 1 Results of dynamic analysis

Object Name	Total Deformation		
Mode	1	2	3
Maximum mm	3.821	2.415	2.504
Frequency Hz	14.19	23.66	23.77
Mode	4	5	6
Maximum mm	3.856	2.693	4.077
Frequency Hz	37.57	39.44	42.14

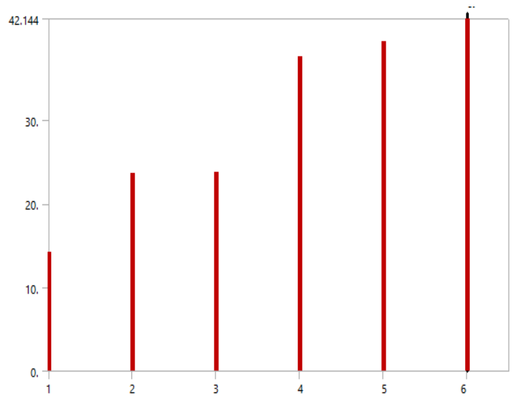

Fig.4 Frequency vs Mode Shape

Conclusions

Different types of mode shapes are obtained at different frequencies. And maximum deformation is observed at 44.144 Hz and minimum deformation at 23.655 Hz. To run this mechanism successfully, it should be operated within the obtained limits of natural frequencies. Future scope aims at transient analysis and thermal analysis of the mechanism to check its feasibility for applications in related environments.

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