Design and Analysis of Flexural Mechanism-A Short Review

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Abstract- *Flexure mechanisms are a designer's delight. Except for the limits of elasticity, flexures present few other boundaries as far as applications are concerned. 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 the brushes of a DC motor or a camera lens cap etc. Flexural joints are widely used in precision motion stages and micro robotic mechanisms due to their monolithic construction. It is difficult and expensive to make such compact mechanism using traditional machining methods. In addition, the traditional mechanisms machining methods are limited to simple design. To reduce the cost of fabrication and also to allow more complex designs, object i.e. a rapid prototyping machine is proposed to be used to build the mechanism. Traditional motors, gears, and revolute joints are not able to meet the requirements due to existence of backlash between moving parts. Hence, the flexure joints are more popularly used. One of the primary applications of flexures is in the design of motion stages. It strives to bridge the gap between intuition and mathematical analysis in flexure mechanism design. This paper presents design and analysis of flexure mechanism.*

Keywords- Flexure hinges, compliant mechanisms, backlash, actuator-cross sensitivity, parasitic coupling, precision motion

I. 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.

The importance of properly constrained design is well known to the engineering community. The objective of an ideal constraining element, mechanism, or device is to provide infinite stiffness and zero displacements along certain directions, and allow infinite motion and zero stiffness along all other directions. The directions that are constrained are known as *Degrees of Constraint* (DOC), whereas the directions that are unconstrained are referred to as *Degrees of Freedom* (DOF). While designing a machine or a mechanism so that it has appropriate constraints, the designer faces a choice between various kinds of constraining elements, two of which are considered for comparison: ball bearings and flexures. Clearly, ball bearings meet the definition of a constraint quite well, since they are very stiff in one direction, and provide very low resistance to motion in other directions. Nevertheless, motion in the direction of DOF is associated with undesirable effects such as friction, stiction and backlash that typically arise at the interface of two surfaces. These effects are non-deterministic in nature, and limit the motion quality.

Flexures, on the other hand, allow for very clean and precise motion. Since the displacement in flexures is an averaged consequence of molecular level deformations, the phenomena of friction, stiction and backlash are entirely eliminated.

II. LITERATRE SERVEY

Byounge Hun Kang et al.[1] carried out the analysis and design of general platform type parallel mechanisms containing flexure joints. They considered static performance measures such as task space stiffness and manipulability. Based on these performance measures they obtained the multi-objective optimization approach. Firstly they obtained Pareto-frontier. Lumped approximation of flexure joints in the pseudo rigid body are considered for simplification. 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. Instead of that, important design parameter is task space stiffness which needs to be carefully designed to avoid undesired motion in the presence of external loads.

Yeonge- jun Choi et al.[2] worked on kinematic design of large displacement precision X-Y positioning stage by using cross strip flexure joints and over constrained mechanism. For the design of a large displacement precision

XY positioning stage, a cross strip flexure joints were used. And to achieve a good kinematic design advanced kinematic techniques such screw system theory are used. The weight support mechanism of the motion stage was made of links and flexure joints, and a linear motor was used as the actuator. Crossed strip type flexure joints that provide large rotation were used. To eliminate the effects of center shifting in large-motion flexures an over-constrained mechanism was used to incorporate symmetry.

Yangmin Li et al.[3] represented the modeling and evaluation of a nearly uncoupled XY micromanipulator designed for micro-positioning uses. The manipulator features are monolithic parallel-kinematic architecture, flexure hinge-based joints, and piezoelectric actuation. The evaluation is carried out analytically in terms of parasitic motion, cross-talk, lost motion, workspace, and resonant frequency. The mathematical models for the kinematics and dynamics of the XY stage are derived in closed-forms, which are verified by resorting to finite element analysis (FEA) based on pseudo rigid-body (PRB) simplification and lumped model methods. They established a nonlinear kinematics model, which is based on the deformation of the entiremanipulator since the above simplified models fail to predict its kinematic performances. And the validation of effectiveness of non linear model is done by both FEA and experimental studies on the prototype. Results obtained from validation shows that the nonlinear model can predict the manipulator kinematics accurately, and the reason why simplified models fail is discovered.

B.Zettle et.al.[4] worked on equivalent beam methodology. In this paper they presented a methodology which is accurate and efficient finite elements method (FEM) simulations of planar compliant mechanisms with flexure hinges. In this method one-eighth of a single hinge is simulated to determine its true stress/stiffness characteristics by using symmetry/antisymmetry boundary conditions and 3D elements. A set of fictitious beams is derived, which have the identical characteristics. This set is used in conjunction with other beams that model relatively stiff links to generate an equivalent model of an entire mechanism consisting of the beam elements only. The research work shows that the static and dynamic characteristics of the whole 3RRR mechanism can be simulated with high precision with a model that has a very small number of DOF. The numerical efficiency of the EBM model is very high. Therefore it becomes conceivable to apply it for other purposes such as mathematical optimization, simulating complex dynamic responses, or even for real time applications to control and handling of compliance mechanisms.

Y.Tianet. Al.[5] presented the mechanical design and dynamics of a 3-DOF (degree of freedom) flexure-based parallel mechanism. They utilized three piezoelectric actuators to drive active links of the flexure-based mechanism. The inverse dynamics of the proposed mechanism is established by simplifying flexure hinges into ideal revolute joints with constant torsional stiffness. For the validation of the performance of the proposed 3-DOF flexure-based parallel mechanism he used finite element analysis. The interaction between the actuators and the flexure-based mechanism is extensively investigated based on the established model. He carried out experiments to verify the dynamic performance of the 3-DOF flexure-based mechanism.

Shunli Xiao et. Al. [6] has worked out the design and analysis of a novel compliant flexure-based totally decoupled XY micropositioning stage which is driven by electromagnetic actuators. They constructed the stage with a very simple structure by employing double parallelogram flexures and four contactless electromagnetic force actuators. Compliance and stiffness analysis based on matrix method, and analytical models for electromagnetic forces is done by using the kinematics and dynamic modeling of the mechanical system of the stage. Both mechanical structure and electromagnetic model are validated by finite element analysis(FEA) via ANSYS. The stage designed possesses a totally XY decoupled character, simple symmetrical structure, easy controlling strategy, and large range of motion. The kinematics and dynamics modeling of the mechanical structure is done by using compliance based matrix method.

EunJoo Hwang et.al. [7]has presented that Lever mechanisms are usually used to enlarge output displacements in precision stages. The theoretical analysis is done by considering a precision stage employing a lever mechanism and flexure hinges, with bending in the lever. He presented the relations between design parameters and magnification ratio, as well as parametric effects on stage displacement. These relations and effects can provide information at initial designing offlexure-hinge stages. In this research work proper lengths and optimal thicknesses for flexure hinges were obtained to achieve a longer stage displacement, and a new lever with the optimal thicknesses was suggested. He showed that adjustment of lengths and stiffnesses can increase the stage travel range significantly. The approach developed in this study can be very useful when designing stages.

U. Bhagat et.al. [8]focused a research work on the computational analysis of a miniature flexure-based mechanism. This novel flexure-based mechanism is capable of delivering planar motion with three degrees of freedom (3-DOF). He studied the stress distribution at all flexure joints, modal analysis and the workspace envelop of the mechanism. And this mechanism is used for three piezoelectric actuators to achieve desired displacement in X, Y and Θ. He designed a miniature 3 DOF micro/nano mechanism and analysis is done by using ANSYS. The FEA study and the collected data confirm the performance of the mechanism and the displacement of theTCP in the X-, Y- and Θ- direction. Stress levels in the hinges are found to be well below the yield point of the material.

Brian P. Trease et.al. [9]has shown the drawbacks of typical flexure connectors and presented new designs for highly effective, kinematically well-behaved compliant joints. He proposed a revolute and a translational compliant joint both of which have advantages over existing flexures in the qualities of a large range of motion, minimal "axis drift," increased off-axis stiffness, and a reduced stress-concentrations. He developed analytical stiffness equations for each joint and parametric computer models are used to verify their superior stiffness properties. Calculation of a joint range of motion is done by using finite element analysis. The new compliant joint designs surpass the range of motion of many conventional flexure joints,while the combined achievements in off-axis stiffness ratio and zero axis drift make them very competitive with the latest advances in flexures.

Mei-Yung Chen et.al. [10]presented a novel model of XY -dimensional submicropositioner,including mechanism, control, and analysis. The design of the submicropositioner utilizes amonolithic parallel flexure mechanism with built-in electromagnetic actuators and optical sensors to achieve the object of 3-DOF precise motion. From experimental analysis he achieved following goals:1) to integrate the electromagnetic actuator and the parallel flexure mechanism for planar positioning system; 2) to establish the mathematical modeling; 3) to develop an advanced adaptive slidingmode controller; and 4) to perform extensive experiments to test the realistic performance.

III. CONCLUSION

In this study, the designs to be presented 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. Future work is aimed at producing the algorithm to produce an efficient synthesis algorithm that would enable the determination of design parameters of a mechanism that satisfy a set of given constraints. The method presented is accurate and efficient finite elements method (FEM) simulations of planar compliant mechanisms with flexure hinges. In all literatures the validation is by using finite element analysis.

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