IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Stiffness Analysis of Actuator Flexure by FEM

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Abstract

Actuator is a fluid control component, which will be used in any of the fluid control requirements. The proposed actuator is normally closed and electro-mechanically actuated with armature configuration. The armature movement is the path opening to facilitate the actuator flow and is controlled by the flexure positioned over the armature. Flexure not only provides the armature movement but also guides in the designed path. Configuration and thickness of flexure plays vital role in the actuator design. Three configurations have been studied for this application. By considering the fabrication feasibility, flexure third configuration has been conceptualised for the actuator. Analysis has been carried out for the third configuration by considering the flexure material as SS302. Based on design requirement, flexure has to travel by 0.3mm maximum on both sides from neutral position to get the desired armature movement of 0.6mm. Three variants of thickness viz., 100, 150 and 250 microns are selected for the flexure third configuration. By flexure stiffness analysis, it is clear that the force required for achieving the desired deflection of 0.30mm for 150 microns thickness is nominal and is extent of 0.8N. Hence 150 microns thickness flexure was selected for the actuator design. This paper describes stiffness variation of flexure with varying thickness for the configuration and related analysis test results.

Keywords: Stiffness, Thickness, Flexure

Introduction

Actuators are basically shut off valves which feed gas or liquid at constant flow rates. These are remotely operated type, capable of actuating either continuously or in pulse mode on electrical command. The design and selection criteria for actuator are type of actuation, actuation time, power, operating pressure, leakage requirements, flow, pressure drop, flow medium and operating life. These requirements can be achieved by flexure based armature type configuration of actuator. Flexure design plays vital role and is the heart of the actuator for the response. Actuator has to be designed for continuous on and off cycles, which again depends on flexure.

Role of Flexure in Actuator Mechanism

Over the past decade, there has been wide variety of actuation mechanisms and methods employed for construction of actuators including electro-static, electro-magnetic and piezo - electric actuation [1]. Out of these, electro-magnetic type of actuator has been selected. The actuator has an actuating mechanism and sealing mechanism in one unit within a small envelope. When the actuator coil is energized, the coil builds up electro-magnetic field and as a result armature is attracted towards the stationary stop, thus opening the actuator outlet port. On de-energizing the coil, the magnetic field disappears, the armature moves back and closes the actuator port. Flexure is the dictating element for the movement of the armature. Flexure deflection makes the actuator to open/close. The desired motion is provided with the deflection of these flexible joints also called in the literature as "flexures" which provide high resolution, frictionless, smooth and continuous motion. Flexure based mechanisms are also called "compliant mechanisms"[2]. A lot of compliant mechanisms have been studied in to understand the phenomenon and analysis of flexure [3-5].

Flexure is the pivotal element in an actuator. The movement of flexure from extreme left to right will be used for armature movement, there by opening the actuator to get the desired fluid flow. Three flexure configurations have been conceptualised for this application. Based on the design requirements and

ISSN: 2277-9655
Impact Factor: 1.852

considering the fabrication feasibility, flexure third configuration has been selected for the actuator and is as shown in Fig.1.

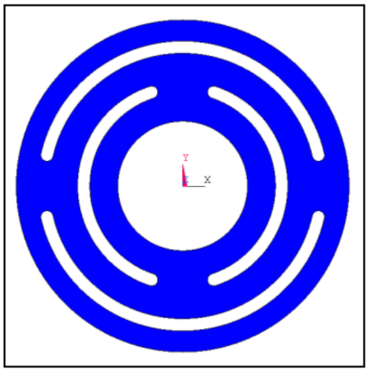

Fig. 1. Flexure configuration

FE Idealization

FE idealization has been carried out for the flexure third configuration. Configuration with depiction of boundary conditions and force applied and flexure is as shown in Fig.2. Armature is positioned between two flexures of the selected configuration. Outer diameter of the flexure is the fixed end and inner diameter of the flexure is the free end attached to armature to achieve the desired movement. FE analysis has been carried out for the flexure third configuration with different thickness of 0.100, 0.150 and 0.250 mm.

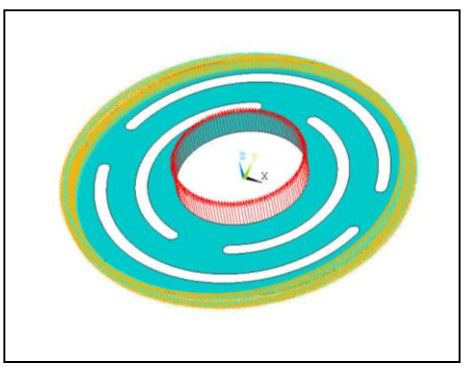

Fig. 2. Depiction of boundary conditions and force applied on flexure

Test Results

FE idealization has been carried out for the flexure configuration with varying thickness of 100, 150 and 250 microns. The material selected for flexure is SS 302 with young’s modulus of 2X10E5 MPa and Poisson’s ration of 0.3. Based on the designed armature movement of 0.6mm, flexure has to move 0.3mm both sides with the end conditions depicted in Fig.2. Three different thicknesses for flexure third configuration has been analysed for flexure stiffness. Analysis test results of force vs. deflection for three different thicknesses are as shown in Fig.3, Fig.4 and Fig.5 respectively.

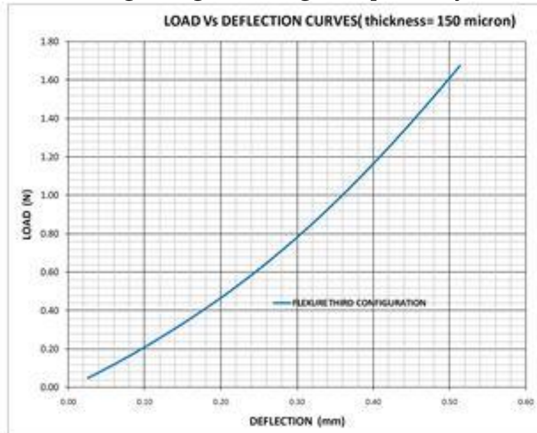

Fig. 3. Flexure with 100 micron thickness

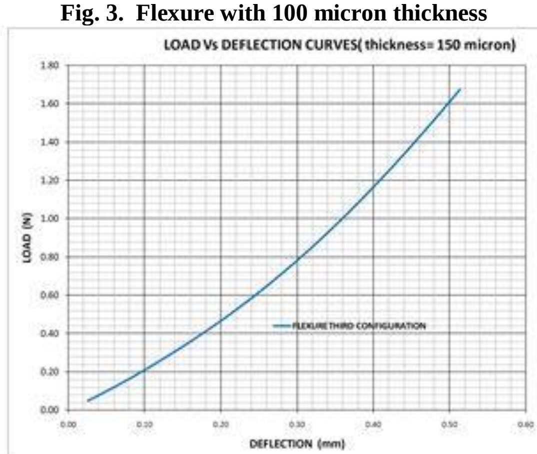

Fig. 4. Flexure with 150 micron thicknes

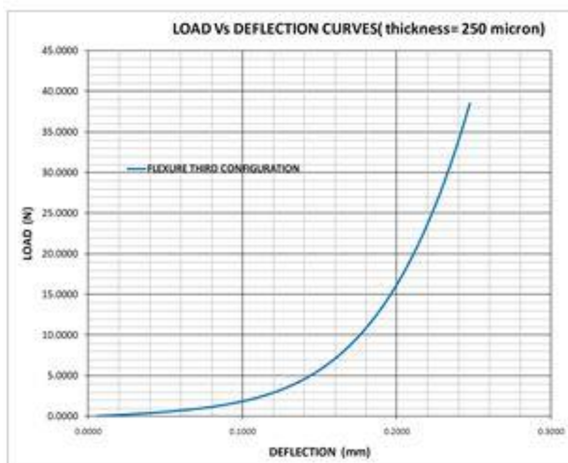

Fig. 5. Flexure with 250 micron thickness

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Discussion

Flexure with 100 microns thickness requires 0.19N for 0.30mm deflection. Flexure with 150microns thickness requires nominal force of around 0.80N for a deflection of 0.30mm. However, attaining the deflection of 0.3mm with 250micron thickness may not be feasible for this configuration.

Fabrication feasibility exists for all different thickness of configurations. From above analysis results, 150 micron thickness flexure can provide the required flexure deflection. Flexure with 0.100 mm thickness requires very less force of 0.19N to get 0.3mm deflection. Flexure with 0.150 mm thickness requires nominal force of 0.80N to get 0.3mm deflection. Based on this, third configuration with 150microns thickness is selected for the flexure to use in the present armature type electro- magnetic actuator.

Conclusion

Actuator is fluid control component. The selected configuration is normally closed, flexure based armature type electro magnet. Flexure plays an important role in the design of actuator. Flexure not only provides armature movement to provide fluid flow but also guides in the linear path. Three different types of configurations have conceptualized. Based on fabrication feasibility third configuration has been selected for the actuator. FE analysis was carried out for this configuration with 100micron, 150micron and 250micron thickness. Based on the designed armature movement of 0.6mm, which is to be provided by flexure with a nominal deflection of 0.3mm on both sides. Based on analysis, 150 micron thickness flexure can provide the required flexure deflection. For the required flexure deflection of 0.30mm, 100 microns thickness flexure requires 0.19N, 150 microns thickness flexure requires 0.80N. However 250 microns thickness flexure may not able to provide the required deflection. Based on this, it is prudent that third configuration with 150microns thickness is most suitable as flexure for the desired application.

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