Design and Analysis of Flexure Mechanism Considering Precision Control Strategy

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Abstract- Flexure mechanisms are the mechanisms that rely on material elasticity for their functionality and give the expected output with negligible error. The motion stage is moved with 1 mm of precise displacement with the help of an appropriate control strategy. The spiral flexure mechanisms are used with the angle of 120 degrees, 540 degrees, and 720 degrees and the results are compared in terms of stiffness and displacement. For minimum and precise motion of the motion stage; we attach the voice coil motor to the motion stage. The current has been provided to the voice coil motor with the help of the LCAM circuit. With the help of control desk software, we can give the required frequency and amplitude. The software is interfaced with the Dspace microcontroller which then supplies the signal to the LCAM and Voice coil motor to get the current from it. The results come from control desk software that is then interpolated with MATLAB software with position estimator algorithm. The results came from MATLAB compared with ANSYS results.

Indexed Terms- Flexure Mechanism, voice coil motor, MATLAB, ANSYS, optical Encoder, Spiral flexure mechanism, Dspace microcontroller, LCAM Circuit.

I. INTRODUCTION

As we know that compliant flexure mechanisms are the mechanisms by which we can get the exact force and the displacement as input same as output with a very minimal amount of error. there are two priorities for which compliant flexure mechanisms generally used:

i. For smooth motion
ii. For a very small range of motion

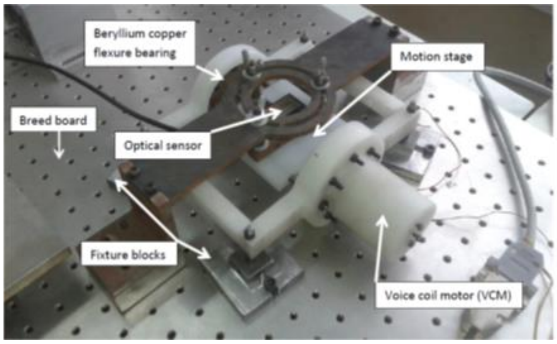
Spring design is a popular example of a compliant flexure mechanism. Most of the compliant flexure mechanisms are designed in such a way in consideration of design constraints. Applications like Nano-positioning, high-quality motion attributes require a very precise and small range of motion. So, the flexure mechanisms are made as monolithic. By considering this, flexure mechanisms make it indispensable for microfabrication, where the assembly is generally difficult or even impossible.

- Objectives of Spiral Flexure Mechanism with Specific Control Strategy:

a) To achieve the precise and very small range of motion by assembling a spiral flexure mechanism.
b) To identify the range of motion of motion stage with the help of appropriate mechatronic integration.
c) To correlate the displacement and stiffness with varying spiral angles.

II. EXPERIMENTAL METHOD

The prime aim is to smooth and small range of motion of the motion stage with appropriate mechatronic integration. The dimensions of 90*90*10 mm of the motion stage and external body of the mechanism are made up of polycarbonate (white nylon). The bar which is connected with two spiral flexure mechanisms is made up with mild steel. Flexure mechanism is made up with beryllium copper considering the high thermal conductivity.



Setup of flexure mechanism

III. MATERIAL SELECTION

The spiral flexure springs are made up of beryllium copper which has higher thermal conductivity which avoids the failure of the flexure ring due to thermal stresses. The external body is made up of light weight polycarbonate (white nylon) material.

Before performing the experimentation, we have to ensure that each and every sub-components of the assembly are properly aligned with no parasitic error. It is expected that the alignments are within acceptable range. The optical encoder should be mounted in such a way that it should be parallel to the motion stage and the distance between two is around 0.8 mm (less than 1 mm). Proper alignment of an optical encoder is ensured by green light indication.

To achieve movement of the motion stage by assembling the voice coil motor with spiral flexure mechanism this then moves very precisely. The input is provided through control desk software in the form of amplitude and frequency; which eventually converted into the current and voltage across the circuit and then transferred to the voice coil motor using LCAM circuit. By providing the different amplitude and frequency ranges the response of the motion stage has been recorded as the displacement with a set of files. The same procedure is followed for every change in spiral angle; E.g., 120-degree, 540 degree and 720 degrees. The recorded displacement files from control desk software are interfaced with the MATLAB program to achieve the end results like force Vs stiffness and force Vs displacement.

'Amp * LCAM factor * VCM gain = force N'

Sr. No.	Amplitude	L-CAM factor	VCM gain	Force	U
1	0.25	2	22.6	11.3	N
2	0.50	2	22.6	22.6	N
3	0.75	2	22.6	33.9	N
4	1.00	2	22.6	45.2	N
5	1.25	2	22.6	56.5	N
6	1.50	2	22.6	67.8	N
7	1.75	2	22.6	79.1	N
8	2.00	2	22.6	90.4	N
9	2.25	2	22.6	101.7	N
10	2.50	2	22.6	113	N
11	3.00	2	22.6	135.6	N
12	4.00	2	22.6	180.8	N
13	5.00	2	22.6	226	N

Force Calculations corresponding to Amplitudes and gain values

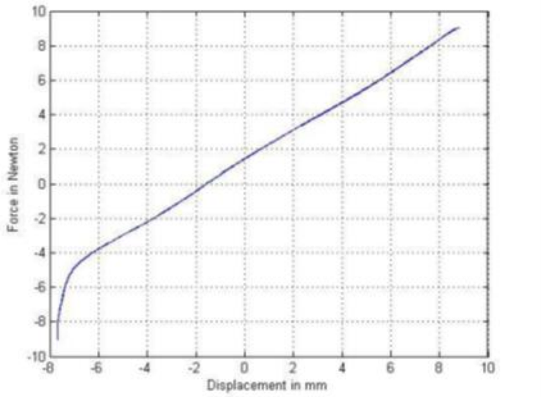
The analysis of spiral flexure is carried out using ANSYS software assuming linear static condition. The force is applied at the center of the spiral flexure from 1N to 15N and we get the displacements; which is then compared with experimental end results.

- Numerical Work:

While considering the experimentation, the input we provided in the form of amplitude and frequency. In numerical analysis we have input as a force. So, with the help of the formula mentioned above, convert the applied frequency into the force which is then used as an input force in FEA software. The force values are 4.52 N, 11.3 N, 22.6 N, 33.9 N, 45.2 N, 56.5 N, 67.8 N, 79.1 N, 90.4 N and 101.7 N.

IV. RESULTS AND DISCUSSION

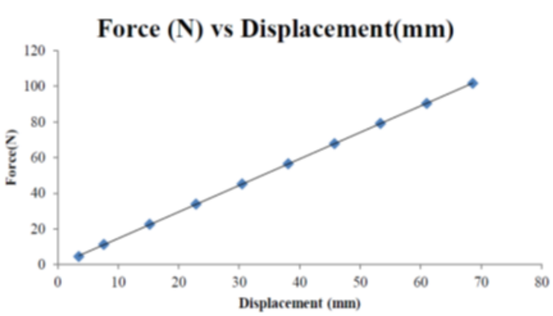
For the results we can say that deflection of the spiral flexure mechanism is directly proportional to the force we apply at the center of the spiral flexure ring.



Investigation of force Vs deflection from Experimentation

FORCE (N)	DISPLACEMENT (mm)
4.52	3.512
11.3	7.638
22.6	15.25
33.9	22.88
45.2	30.512
56.5	38.14
67.8	45.78
79.1	53.39
90.4	61.02
101.7	68.652

Force Vs deflection



Investigation of force Vs deflection from Numerical analysis

By calculating the stiffness from the formula F=K*δ at each force we get the average of the stiffnesses value 1.4617. The stiffness value comes from numerical analysis is 1.0211. The deviations between these two stiffnesses are very low. The reason behind the minimal deviations is due to design tolerance and assembly errors.

CONCLUSION

Thus, the beryllium copper spiral flexure ring mechanism is manufactured with three types of spiral angles. The other parts of the assembly are made up of high strength and low weight nylon 66 material.

We successfully displaced the motion stage in X direction with precise movement. The displacement we provide to the motion stage with the help of appropriate mechatronic integration systems.

Actuating force given to the mechanism after converting it to corresponding current voltage value. Since the current being low; LCAM is used to amplify the current which works in compliance with microcontroller Dspace DS 1104 which provides interface between mechanical and digital systems.by providing mentioned amplitudes and frequencies; find out the forces. These forces are used to apply in numerical analysis and find out stiffness value. The stiffness values obtained through experimentation and numerical analysis are found to be 1.4617 and 1.0211 respectively which depicts close agreement.

The similar work can be carried out by double spiral flexure mechanisms and find out the stiffness values from experimentation and numerical analysis. The design can be made in such a way that simultaneous motion of the motion stage is achieved in XY and Z direction.

Such types of mechanisms are used in the applications like atomic force microscopy, Microstereolithography, scanning electron microscopy, etc.

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