01.110: Computational Fabrication Summer 2017

Lab 3: Fabrication and Measurement of Flexures

June 6th/8th 11:30am-1:30pm Fab Lab. Learn how to design the Flexures

June 13th/15th 11:30am-1:30pm Characterization Lab. Measure the Flexures

Report Due June 25th at 11:55pm.

1 Overview

The purpose of this lab is to design, fabricate, and measure a mechanical flexure (Figure 1). Specifically, you will be provided with a parameterized flexure design (Figure 5) which you will 3D print using the 3Dision 3D printer which you have used during Lab 2. You will then measure the stiffness of the printed flexure using the Instron machine in the Characterization Lab.

2 Software Requirement

You will be provided with a parameterized flexure in the form of an OpenSCAD design. The OpenSCAD code provides a method called flexure which works in the following manner:

```
flexure(side cut ratio, wall thickness ratio, extruded depth ratio);
side cut ratio - fraction of width of flexure to be used for side cut
wall thickness ratio - wall thickness in fraction of flexure width
extruded depth ratio - extrusion depth in fraction
```

See Figure 5 for more information.

For this assignment the width and height of the flexures are (and should remain) hardcoded to 2x2 cms.

You will use this method to generate three (3) flexures for this lab.

In order to plot measurement results you will also need graphing software. MATLAB or Microsoft Excel will suffice.

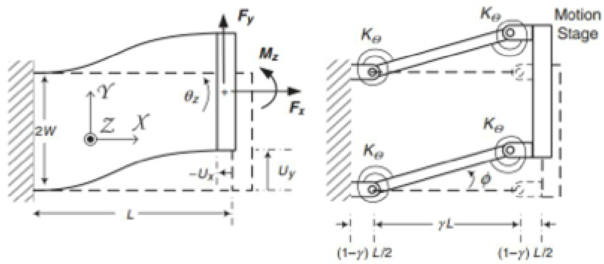

Figure 1: The left image shows the deformation of a flexure. The right flexure shows the deformation of a linkage mechanism with compliant joints.

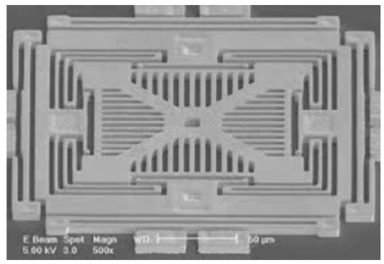

Figure 2: SEM image of a 3-Axis MEMS accelerometer similar to those found in most smartphones.

3 Background

A flexure is a mechanical structure designed for compliance (compliance refers to springiness). In a practical sense, flexures are linkage mechanisms with compliant joints. The geometry of the linkages and the joints determines how compliant (or springy) the flexure is in a given direction. Figure 1 gives an example of the flexure-linkage analogy.

Flexures are used in a variety of applications for the following reasons: simplicity, no moving parts, no hysteresis, smooth resistance to movement, manufacturability, and scalability, flexures come in all shapes and sizes because they are easy to model and design. Your smartphone accelerometer has a MEMS (Micro Electro Mechanical System) flexure in it Figure 2!

4 Designing the Flexure

The flexure model shown in Figure 3 is parameterized with three parameters: extruded depth, wall thickness, and width of the internal cut. Figure 5 depicts these three parameters.

Generate three (3) different flexure designs using OpenSCAD. Table 1 shows the parameter values you can choose from for your different designs. Please choose one flexure from each category, denoted by the double horizontal lines

The assignment archive contains the OpenSCAD file for the flexure. Change the parameters according to Table 1 and generate the three (3) different .stl files for 3D printing.

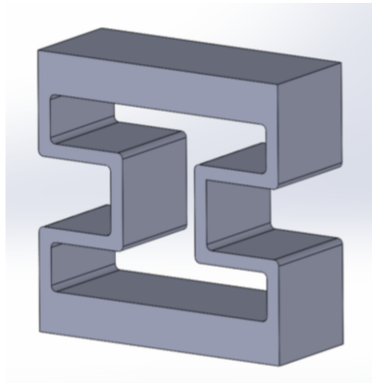

Figure 3: Flexure Model

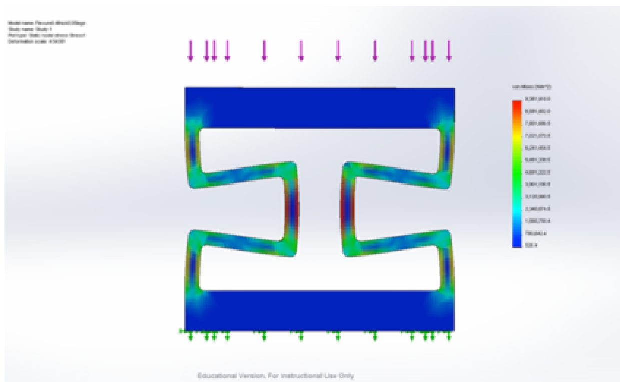

Figure 4: Displacement of the flexure as calculated by an FEM simulation when a 5 N force is applied to the top of the flexure.

5 3D Printing Flexures

Once the .stl files for all three (3) designs have been generated, import them into 3Dison software. Make sure your flexures are organized neatly and compactly. Follow the steps in Lab 2 to print out the flexures.

6 Measuring Flexure Stiffness

After 3D printing the flexures, you will measure their stiffness properties. Make sure you keep track of the flexures. We will use the Instron machine in the Charaterization lab for the measurement. Please read Instron.pdf in the Lab archive before going to the Characterization lab. There will be Lab technician to help with the process.

You should be able to get a series of measurements from the Instron software. You can uniformly pick three measurements and record them in Table 2 (bring a thumb drive to store the file from the Instron software).

Use the values in Table 2 to graph the results (using Excel, Matlab, or your favorite plotter). Plot the results. Convert your force measurements to stress by dividing by the area of the top surface of the flexure.

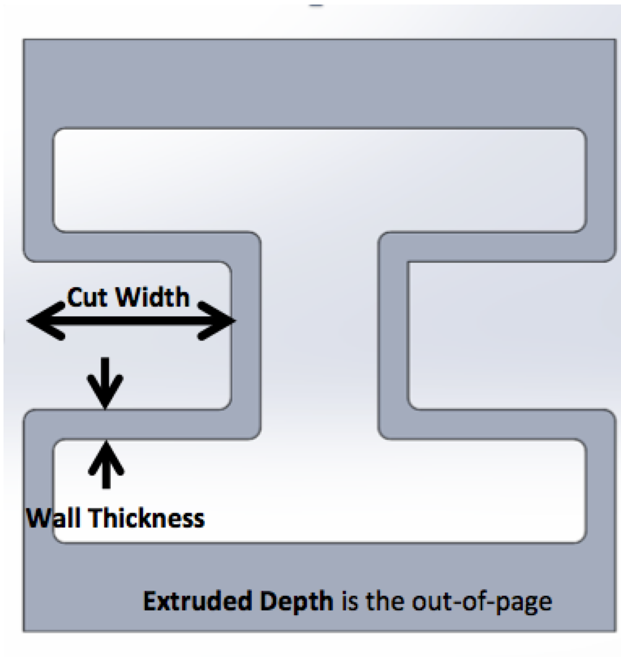

Figure 5: The three main parameters: Cut Width, Wall Thickness, and Extruded Depth.

Table 1: Table of design parameters

Flexure	Cut Width	Wall Thickness	Extruded Depth
1	0.375	0.025	0.4
2	0.375	0.05	0.4
3	0.325	0.075	0.4
4	0.35	0.05	0.3
5	0.35	0.05	0.5
6	0.35	0.05	0.4
7	0.3	0.05	0.4
8	0.25	0.05	0.4
9	0.35	0.05	0.5

Table 2: A Table for recording force-displacement measurements

Flexure	(Force, Strain)$_1$	(Force, Strain)$_2$	(Force, Strain)$_3$	Stiffness
1				
2				
3				

Convert your displacement measurements to strain by dividing by the original height of the flexure. Plot the stress strain curve. Compute the stiffness of the flexure by calculating the slope of this curve.

7 Printing with other orientations

Pick any design from Section 5, print it with a different orientation (set in the 3D printer software). Do the measurement again as in Section 6. Report if there is any difference. Explain why.

8 Submission

A write-up for your group in either a text file or a pdf file which includes the following

- Pictures of all printed flexures
- A table showing the parameters used for each flexure
- Force displacement tables for each flexure
- A plot showing the stress-strain curve for all flexures.
- The stiffness (Young's modulus) of each flexure.