01.110 Computational Fabrication

Lab 3 Report

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Fabricating Flexures

Pictures of 3D Printed Flexures

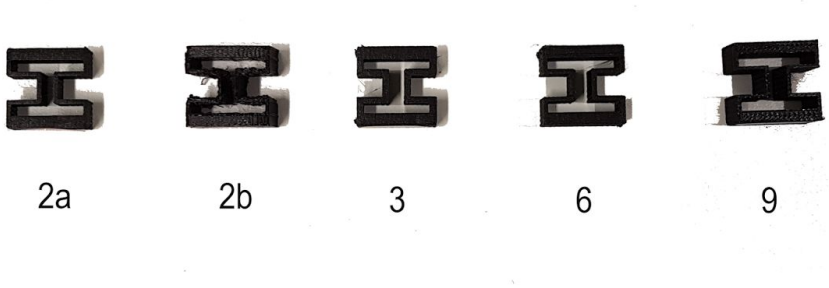


Table of Parameters for Flexures

Flexure	**Cut Width**	**Wall Thickness**	**Extruded Depth**	**Print Orientation**
2a	0.375	0.050	0.4	Lay Flat
2b	0.375	0.050	0.4	Upright
3	0.325	0.075	0.4	Lay Flat
6	0.350	0.050	0.4	Lay Flat
9	0.350	0.050	0.5	Lay Flat

Measuring Flexure Stiffness

Force-Displacement Tables for Flexures to Calculate Strain

Height of Flexure = 2cm = 20mm

Flexure	**Force $(N)_1$, Displacement $(mm)_1$**	**Force $(N)_2$, Displacement $(mm)_2$**	**Force $(N)_3$, Displacement $(mm)_3$**	**Height (mm)**
2a	4.15632, 0.41573	8.53148, 0.83262	12.78628, 1.24902	20
2b	3.14681, 0.41603	6.81804, 0.83254	10.58503, 1.24902	20
3	15.95217, 0.41596	32.68245, 0.83238	47.37463, 1.24922	20
6	6.90294, 0.41563	14.06963, 0.83257	21.00917, 1.24904	20
9	7.1389, 0.41561	14.49527, 0.83259	21.70978, 1.24917	20

Force-Strain Tables for Flexures

Strain (%) = Displacement (mm) / Height (mm)

Top Surface Area (mm^2) = Length (mm) * Width of Flexure (mm) = 20mm * Extruded Depth of Flexure (mm)

Flexure	**Force $(N)_1$, Strain $(\%)_1$**	**Force $(N)_2$, Strain $(\%)_2$**	**Force $(N)_3$, Strain $(\%)_3$**	**Top Surface Area (mm^2)**
2a	4.15632, 0.0207865	8.53148, 0.041631	12.78628, 0.062451	160
2b	3.14681,	6.81804,	10.58503,	160

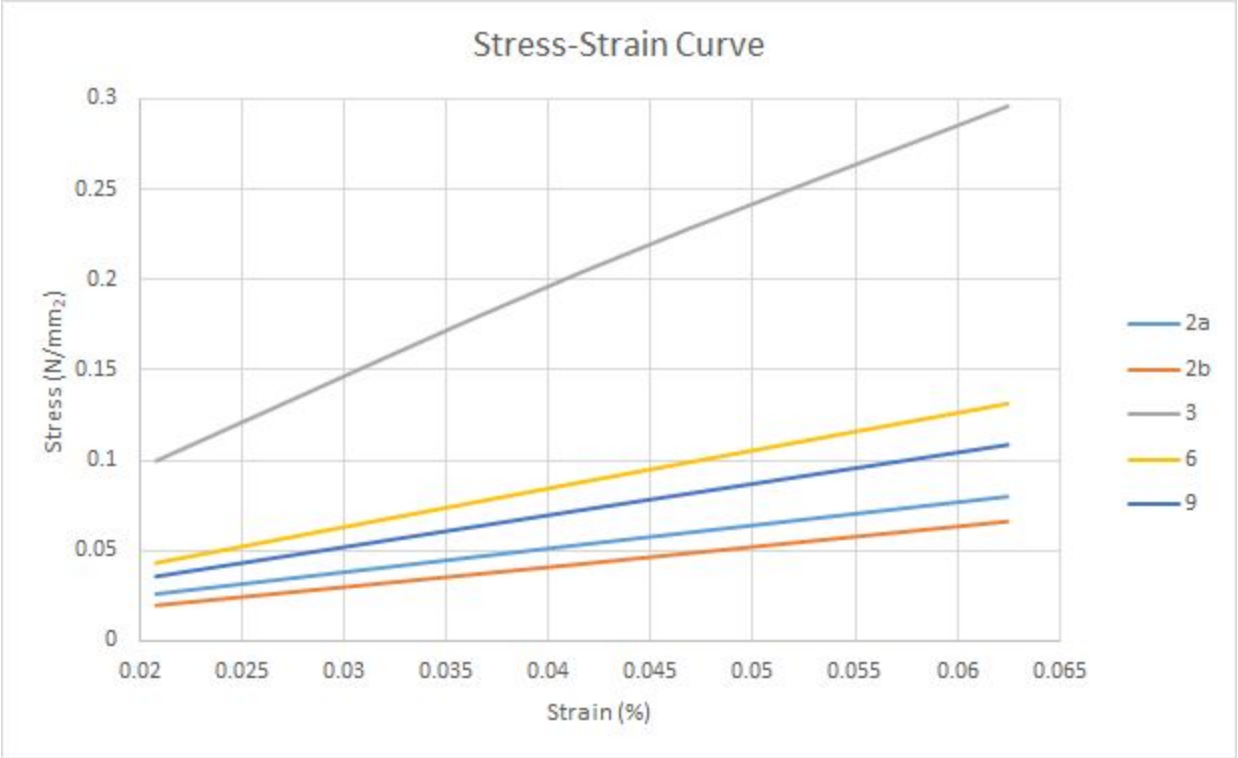
	0.0208015	0.041619	0.062451	
3	15.95217, 0.020798	32.68245, 0.041619	47.37463, 0.062461	160
6	6.90294, 0.0207815	14.06963, 0.0416285	21.00917, 0.062452	160
9	7.1389, 0.0207805	14.49527, 0.0416295	21.70978, 0.0624585	200

Stress-Strain Tables for Flexures

Stress = Force / Area of the top surface of the flexure

Flexure	**Stress (N/mm^2)$_1$, Strain (%)$_1$**	**Stress (N/mm^2)$_2$, Strain (%)$_2$**	**Stress (N/mm^2)$_3$, Strain (%)$_3$**
2a	0.025977, 0.0207865	0.05332175, 0.041631	0.07991425, 0.062451
2b	0.0196675625, 0.0208015	0.04261275, 0.041619	0.0661564375, 0.062451
3	0.0997010625, 0.020798	0.2042653125, 0.041619	0.2960914375, 0.062461
6	0.043143375, 0.0207815	0.0879351875, 0.0416285	0.1313073125, 0.062452
9	0.0356945, 0.0207805	0.07247635, 0.0416295	0.1085489, 0.0624585

Stress-Strain Curve for Flexures



Data used in Excel for the stress-strain plot

Flexure	Strain (%)	Stress (N/mm^2)	Gradient
2a	0.0207865	0.025977	
	0.041631	0.05332175	
	0.062451	0.07991425	1.294561317
2b	0.0208015	0.019667563	
	0.041619	0.04261275	
	0.062451	0.066156438	1.116192871
3	0.020798	0.099701063	
	0.041619	0.204265313	
	0.062461	0.296091438	4.713783813
6	0.0207815	0.043143375	
	0.0416285	0.087935188	
	0.062452	0.131307313	2.115739852
9	0.0207805	0.0356945	
	0.0416295	0.07247635	
	0.0624585	0.1085489	1.748030136

Stiffness (Young's Modulus) for Flexures

Stiffness = Slope of stress-strain plot = Average (Stress / Strain)

Flexure	**Stiffness**
2a	1.294561317
2b	1.116192871
3	4.713783813
6	2.115739852
9	1.748030136

Discussion on Flexure Parameters and Stiffness

Flexure 2a, 3, 6, and 9 vary between each other in the following parameters (while keeping the other parameters constant):

- **Cut width**: 2a is 3.75; 6 is 3.50
- **Extruded depth**: 6 is 0.4; 9 is 0.5

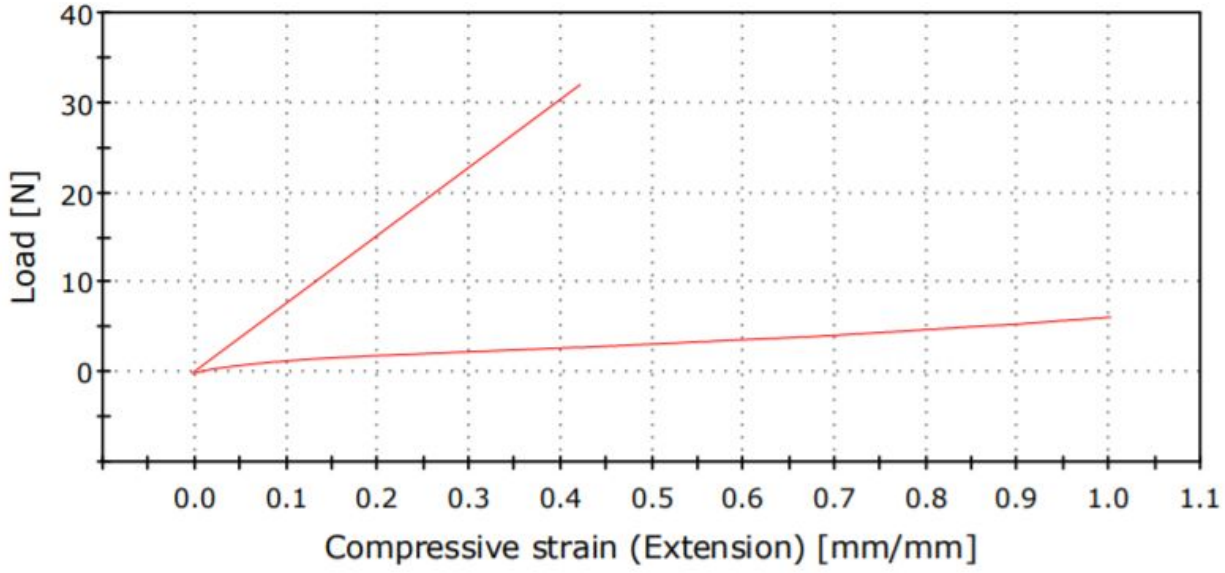
From the stiffness measurement result, we observe that 2a has a lower stiffness than 6, suggesting that a smaller cut width makes the structure stronger. Also, comparing 6 and 9, 6 has a higher stiffness, showing that a lower extruded depth results in a stronger flexure, unlike what we would normally assume.

Discussion on Printing Orientations and Stiffness

One of our flexures, 2b, is printed with a different orientation from the rest. By comparing flexures 2a and 2b using the Stiffness Table above, we observed that the orientation of the print will affect the stiffness of the object even though the other parameters are kept constant. In our case, flexure 2b had a lower stiffness compared to flexure 2a as it was printed in an upright position. This results in a suboptimal fibre grain direction with respect to the force applied. To increase the stiffness while preserving the same parameters, we should orientate the object to ensure that the plastic fibres are aligned to the direction of the force.

Bonus: Force-Strain Curve for Candy

To find out the force-strain behaviour of object other than the 3D printed flexure, we also conducted the measurement for a candy. It's force-strain plot generated by the Instron machine in the Characterization Lab is shown below:


40
30
20
10
0
Load [N]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Compressive strain (Extension) [mm/mm]