Flexure based Machine Design

"How to make almost anything"

Nov. 6 2006

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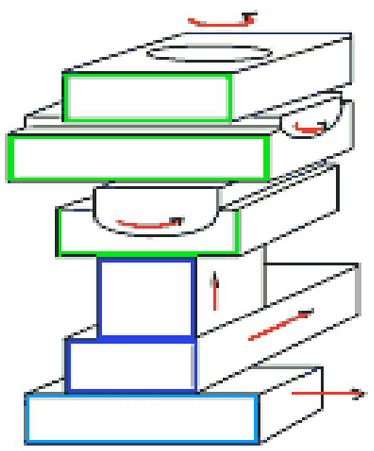
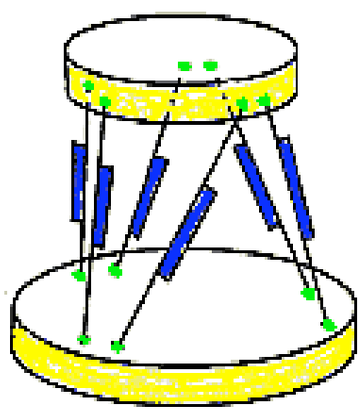
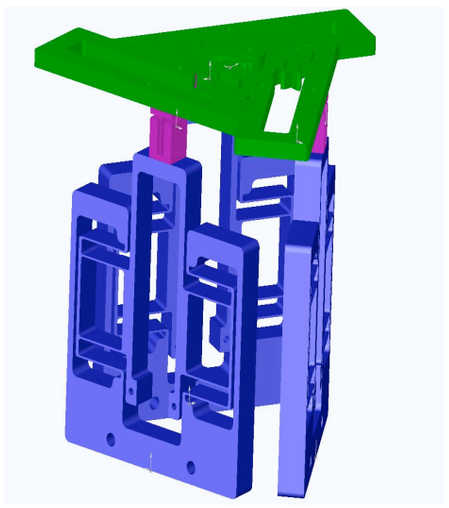
Serial and Parallel

- Serial : actuators mounted on top of each other
  - Bulky for high DOF, slow response
- Parallel : each actuator mounted on ground base
- Close chain parallel design, increased cross-sensitivity



Vs.



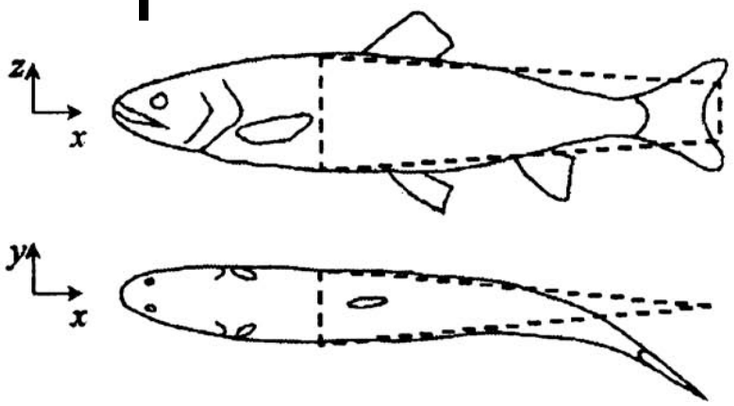


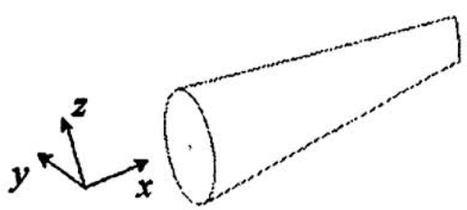
Flexures

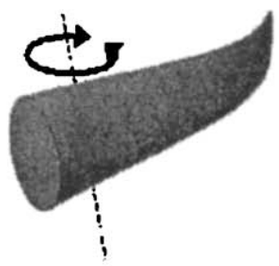
- Overcome backlash with repeatable joints
- Ease of fabrication
- Very few joints
- Sub-micron accuracy achieved easily
- Limited range of motion
- Careful material selection

Flexures in biology

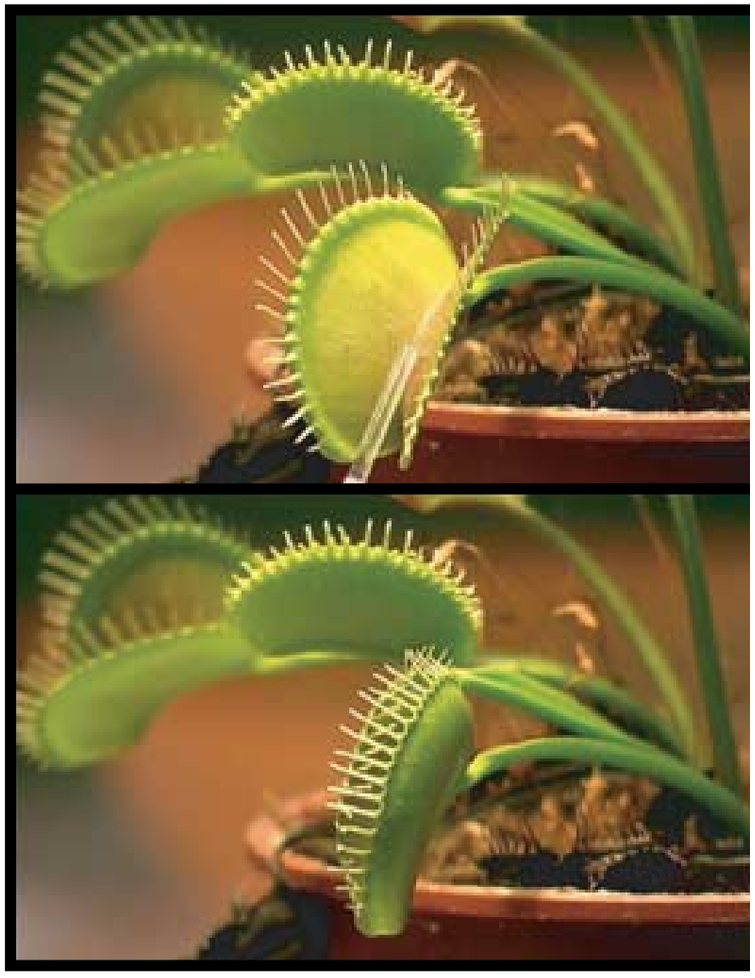
Fish fin and body dynamics - ziplock demo



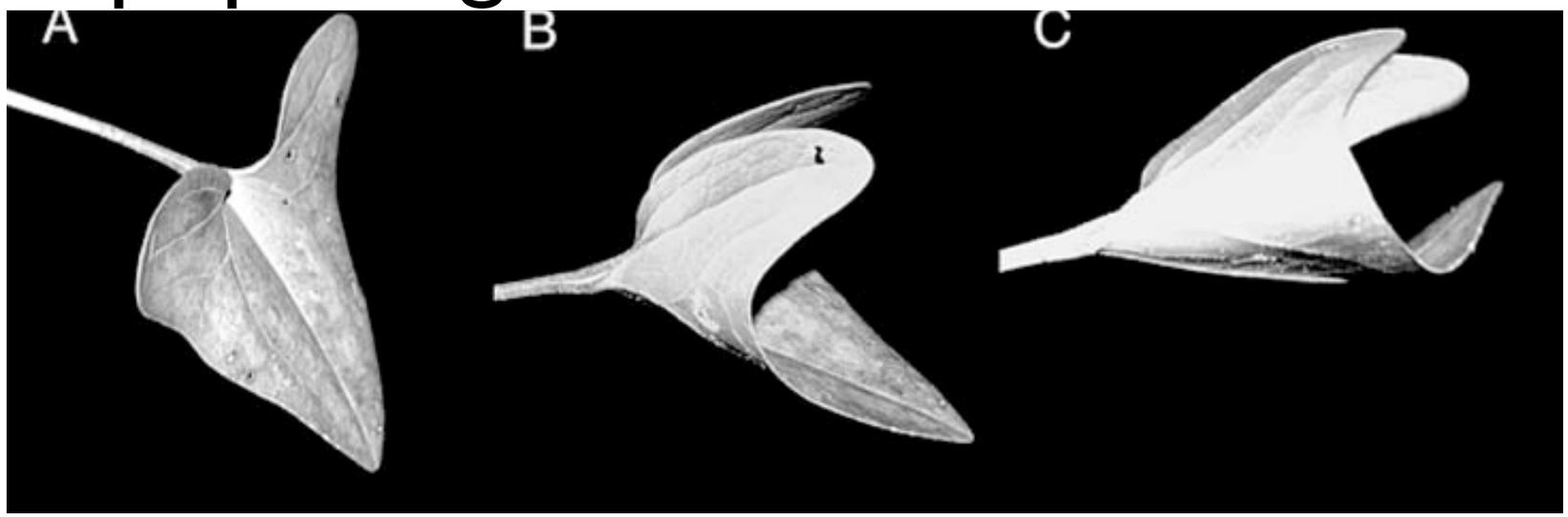




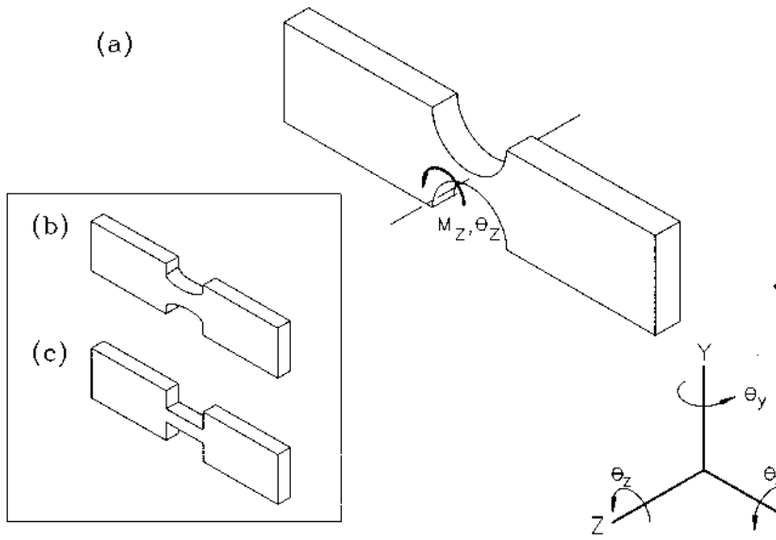
Energy storage in Venus fly trap



Drag reduction in leaves - aquaplaning



Flexure hinges



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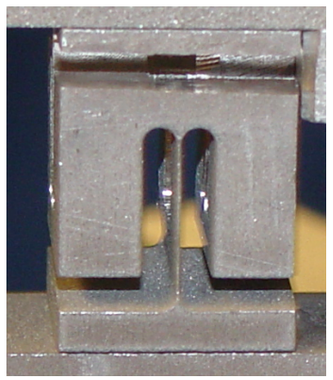
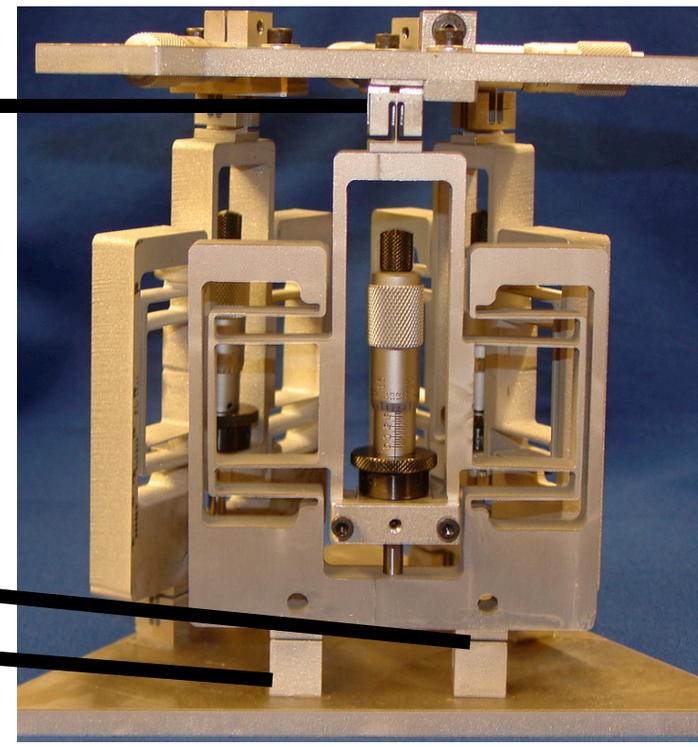
2 axis



1 axis



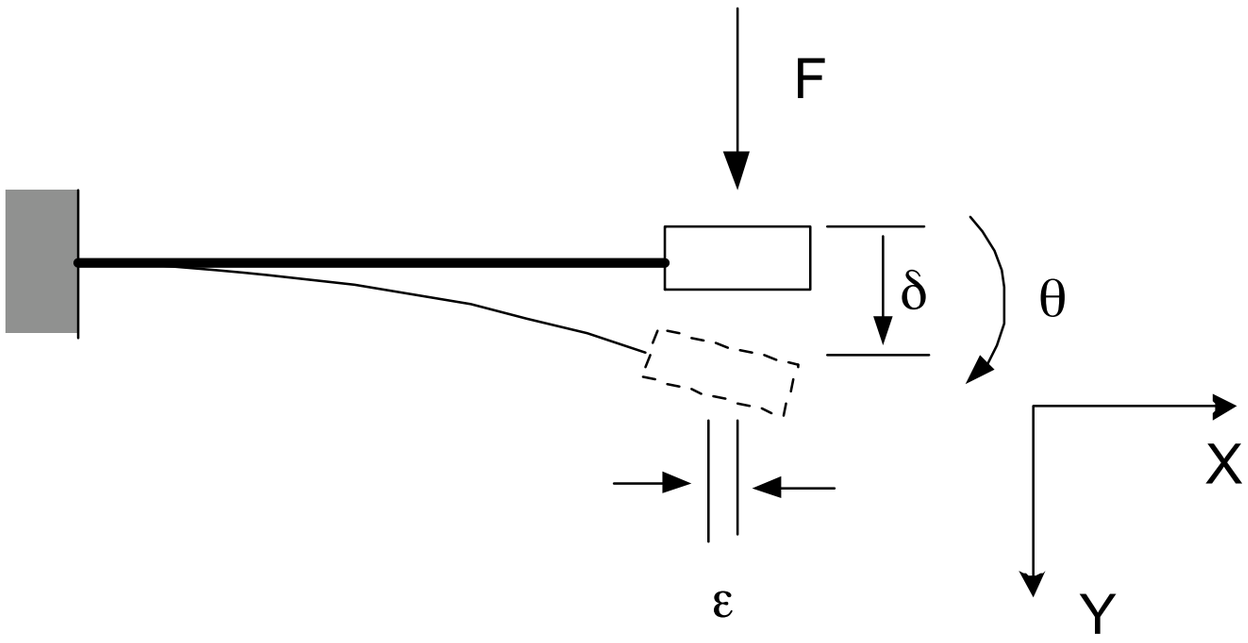
Circular, elliptical and rectangular hinge

2D

3D

Flexure analysis

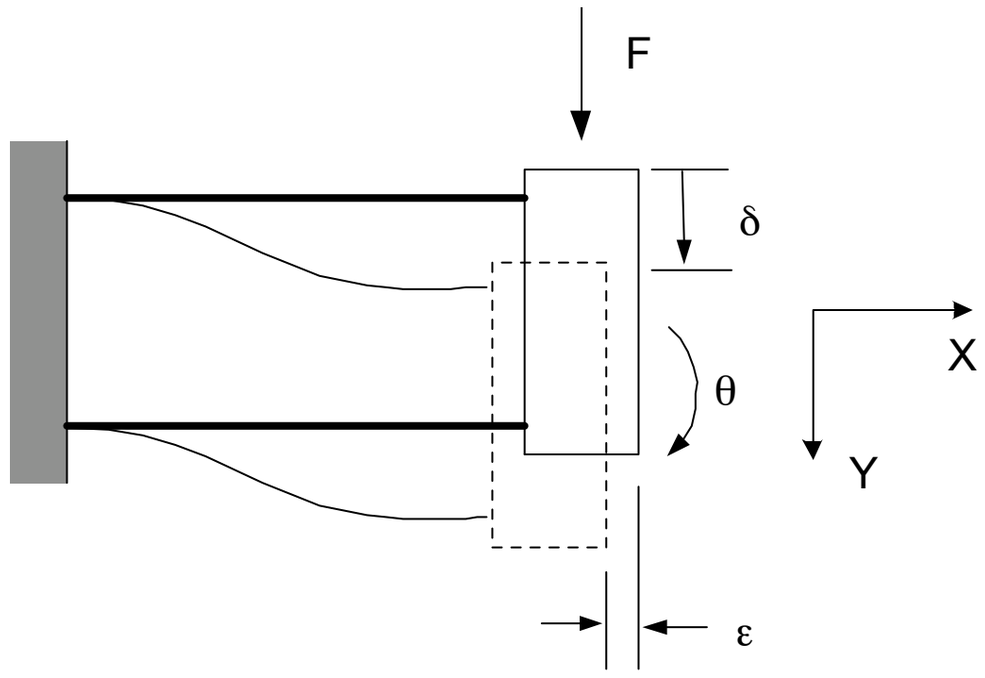
Simple beam flexure



$$\delta = \frac{FL^3}{3EI} \quad ; \quad \theta = \frac{FL^2}{2EI} \quad \text{and} \quad \varepsilon \sim \frac{\delta}{L}^2$$

where,
L is the length of the beams
E is the Young's modulus of the material
I is second moment of the area of the beam cross-section

Parallelogram flexure

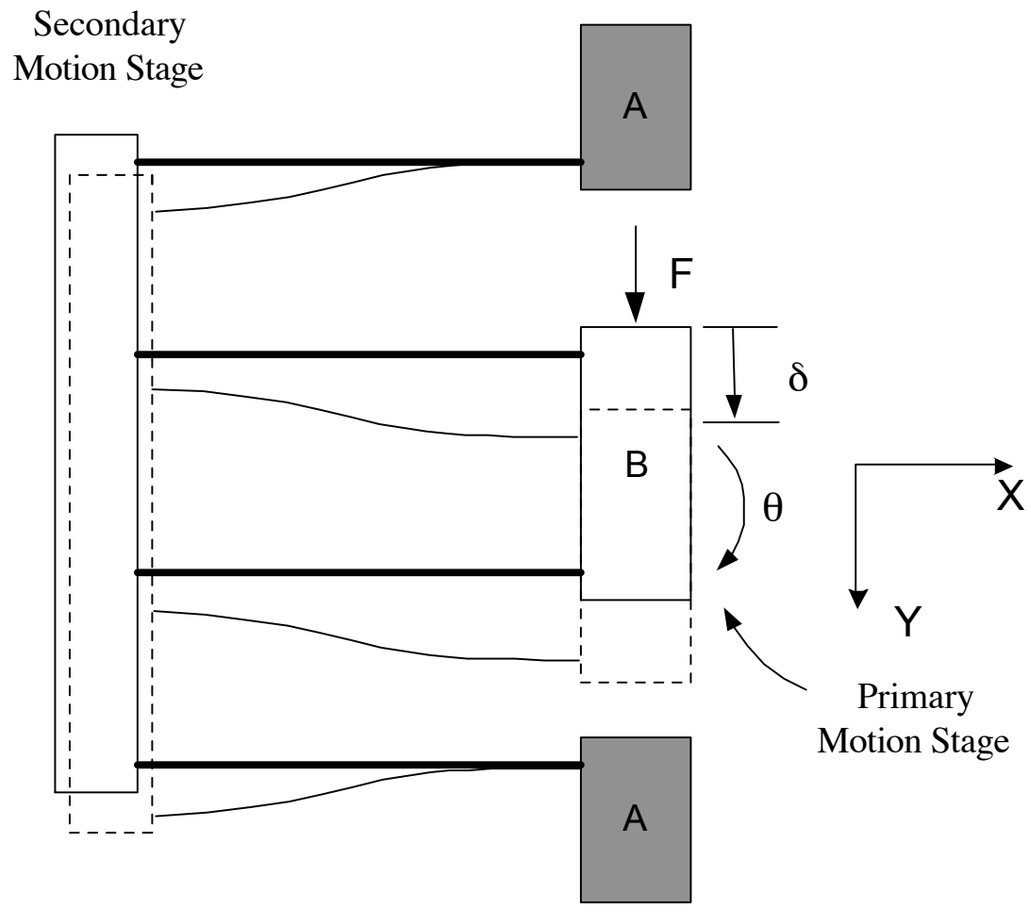


$$\delta = \frac{FL^3}{24EI} \quad ; \quad \theta \approx 2\left(\frac{t}{b}\right)^2 \frac{\delta}{L} \quad \text{and} \quad \varepsilon \approx \frac{3}{5}\frac{\delta}{L}^2$$

where
t is the thickness of the beams
b is the separation between the two beams of the parallelogram
all other quantities are same as defined earlier

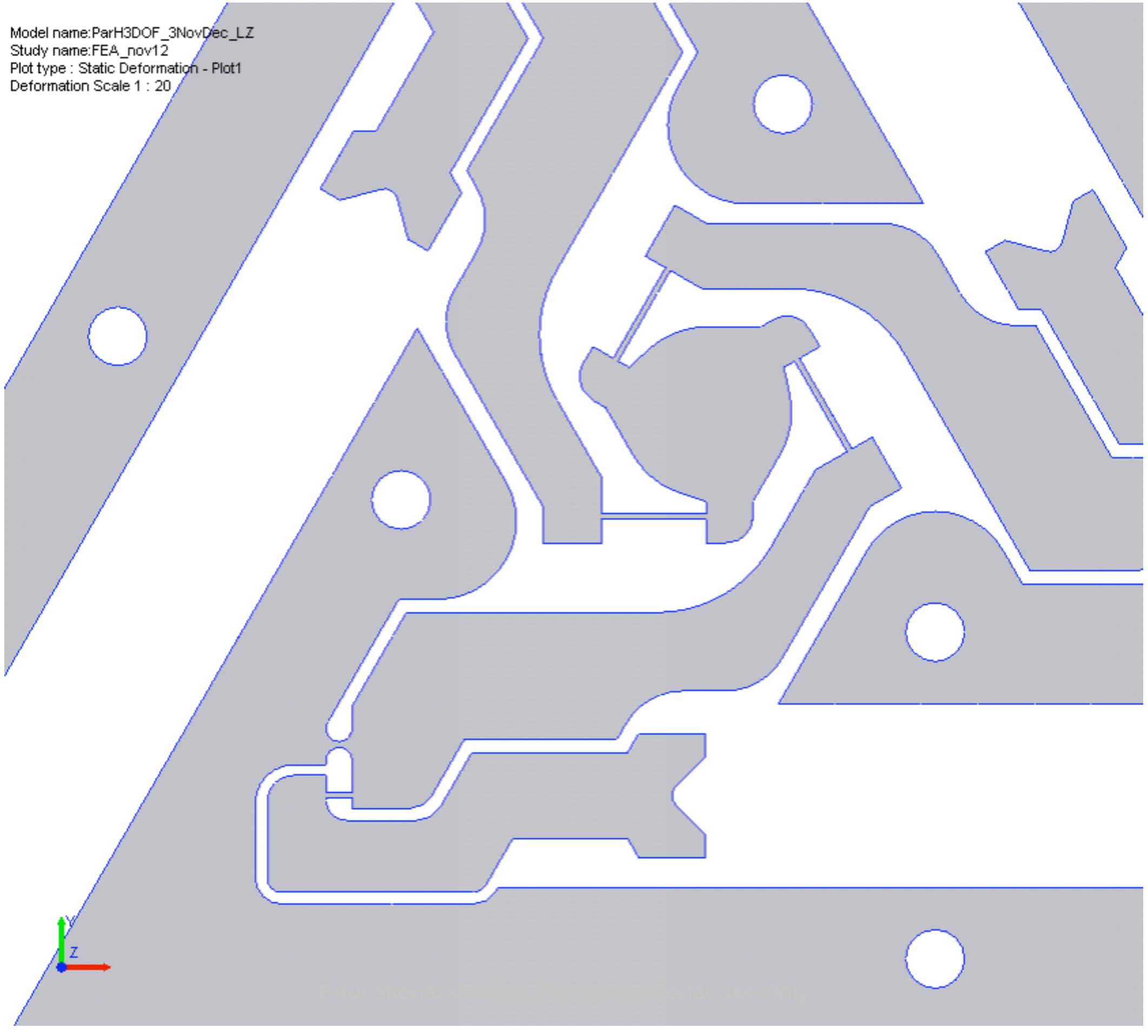
Analysis contd.

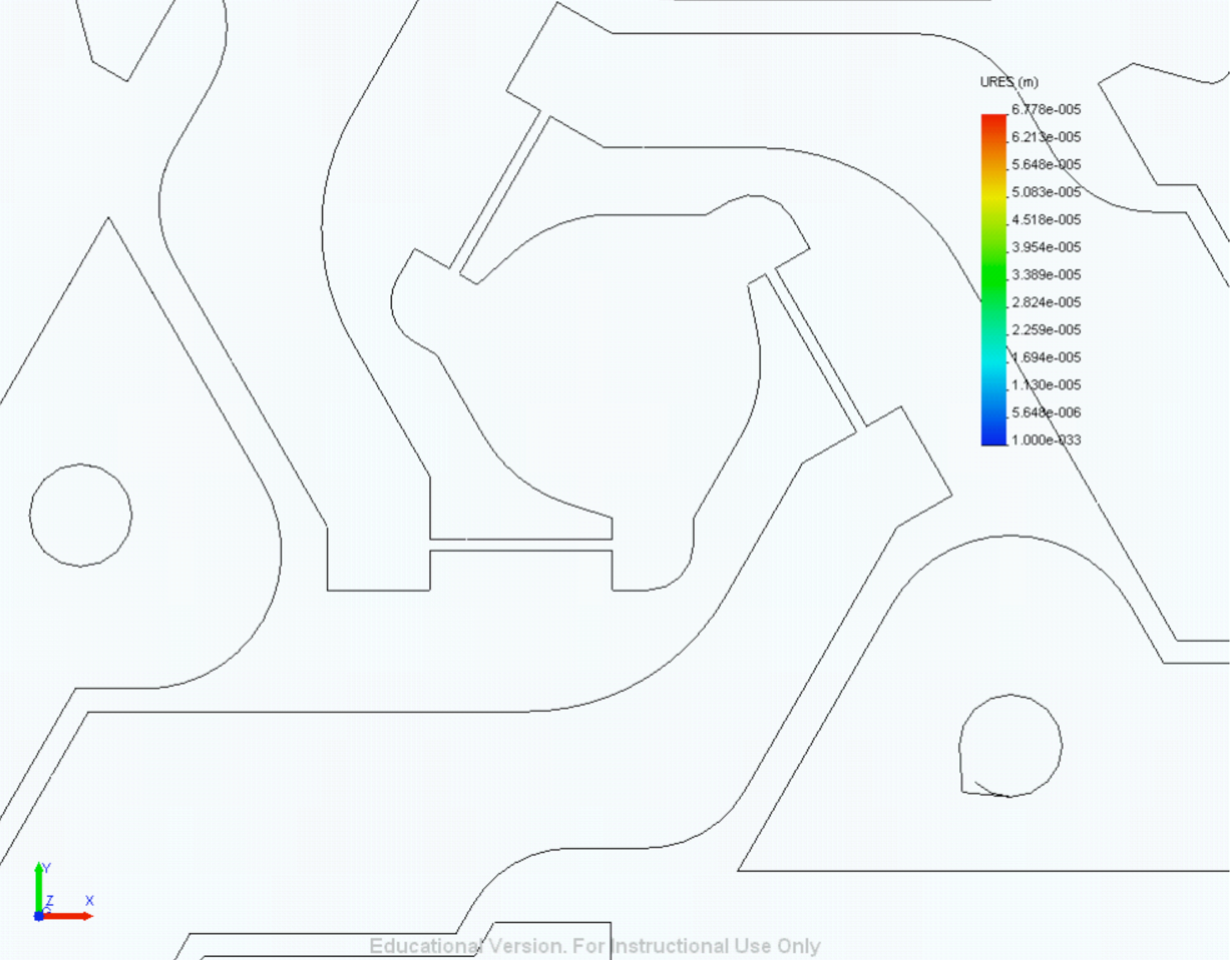
Double Parallelogram flexure



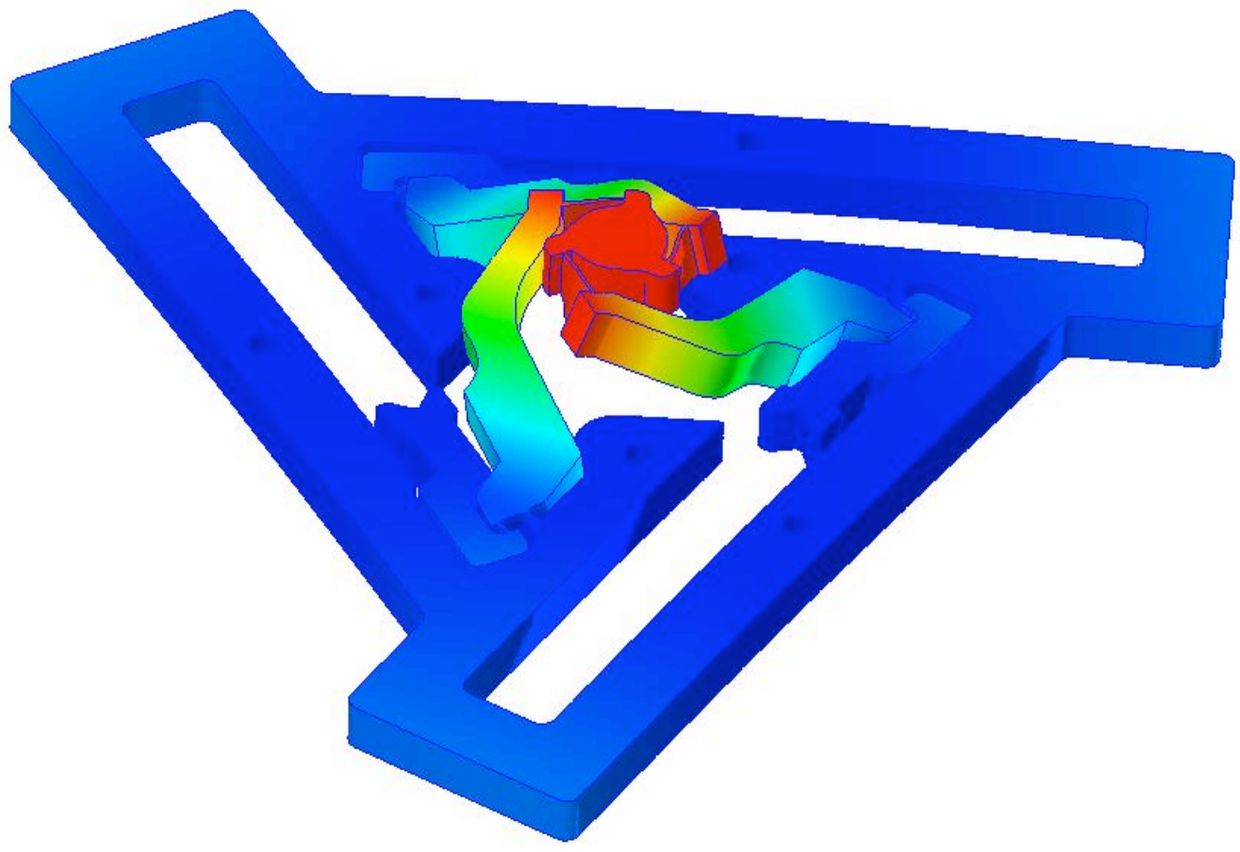
$$\delta = \frac{FL^3}{12EI} \quad ; \quad \theta \approx t^2 \left(\frac{1}{b_1^{\,2}} + \frac{1}{b_2^{\,2}} \right) \frac{\delta}{L} \quad \text{and} \quad \varepsilon = 0$$

Model name:ParH3DOF_3NovDec_LZ
Study name:FEA_nov12
Plot type : Static Deformation - Plot1
Deformation Scale 1 : 20



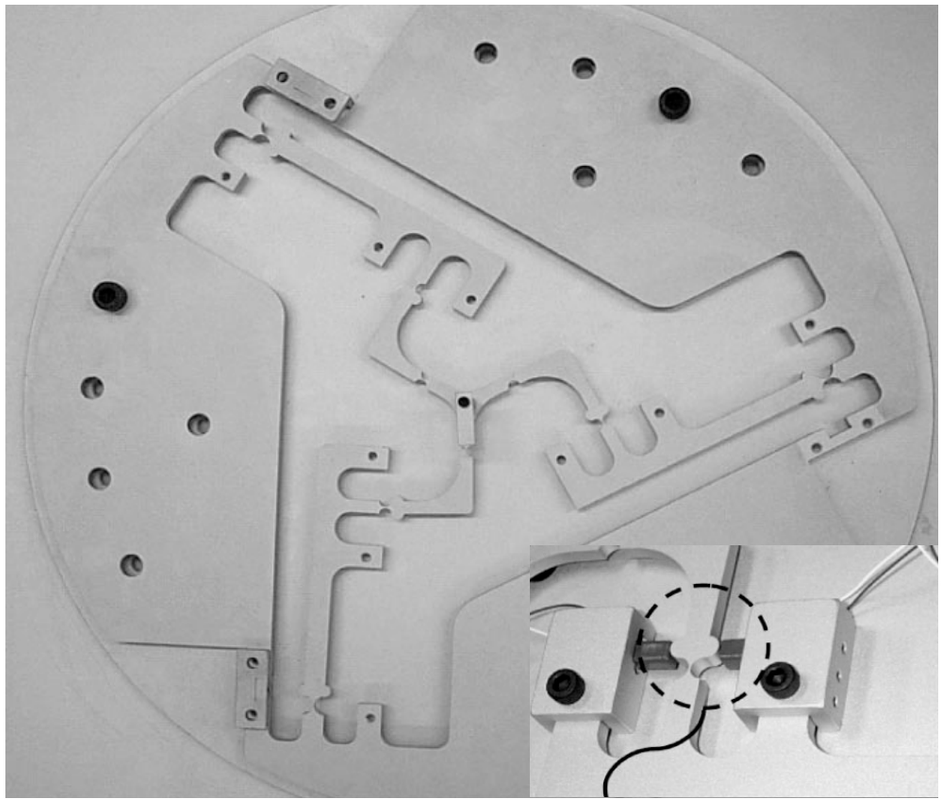

URES (m)
6.778e-005
6.213e-005
5.648e-005
5.083e-005
4.518e-005
3.954e-005
3.389e-005
2.824e-005
2.259e-005
1.694e-005
1.130e-005
5.648e-006
1.000e-033
Y
Z
X
Educational Version. For Instructional Use Only

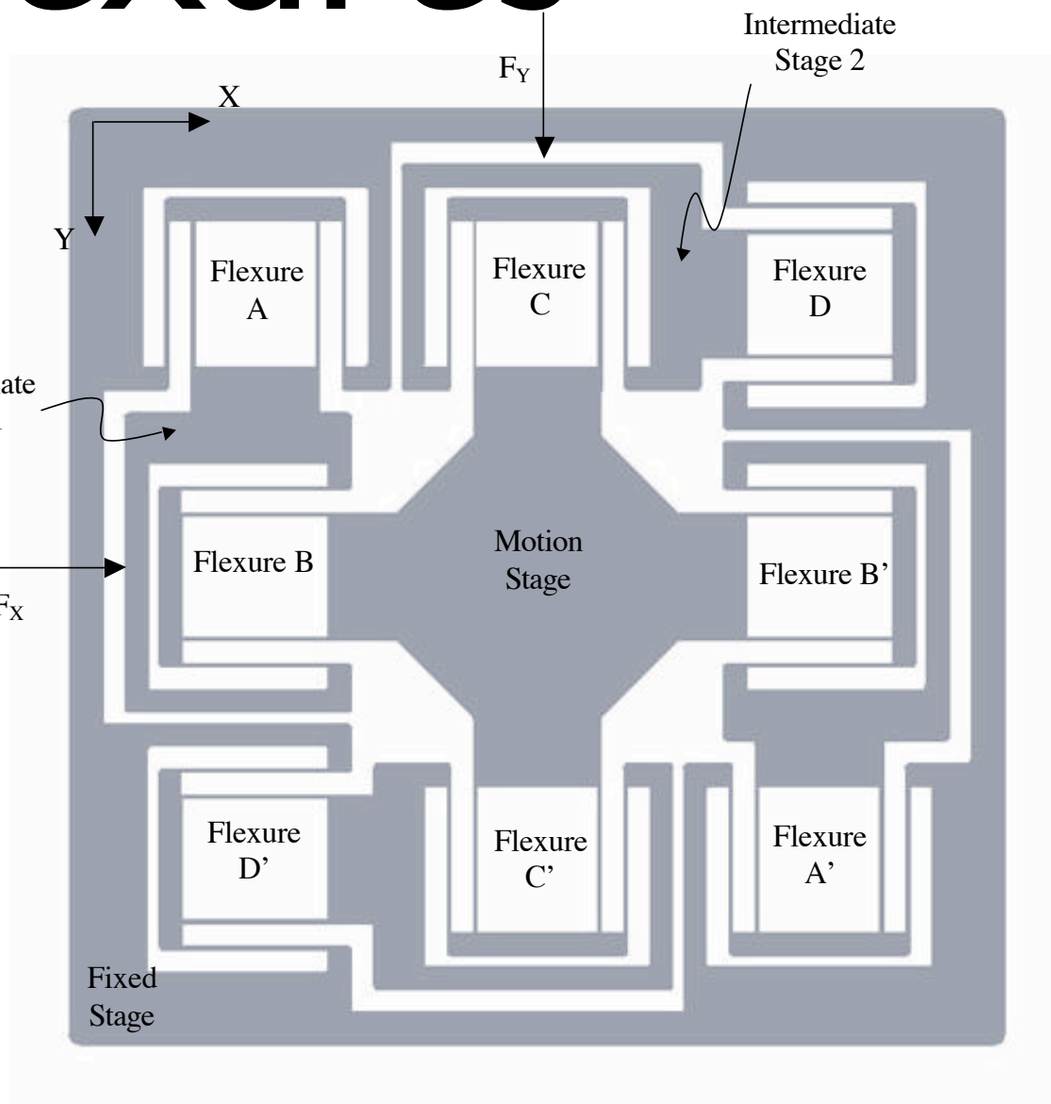
Analysis contd.

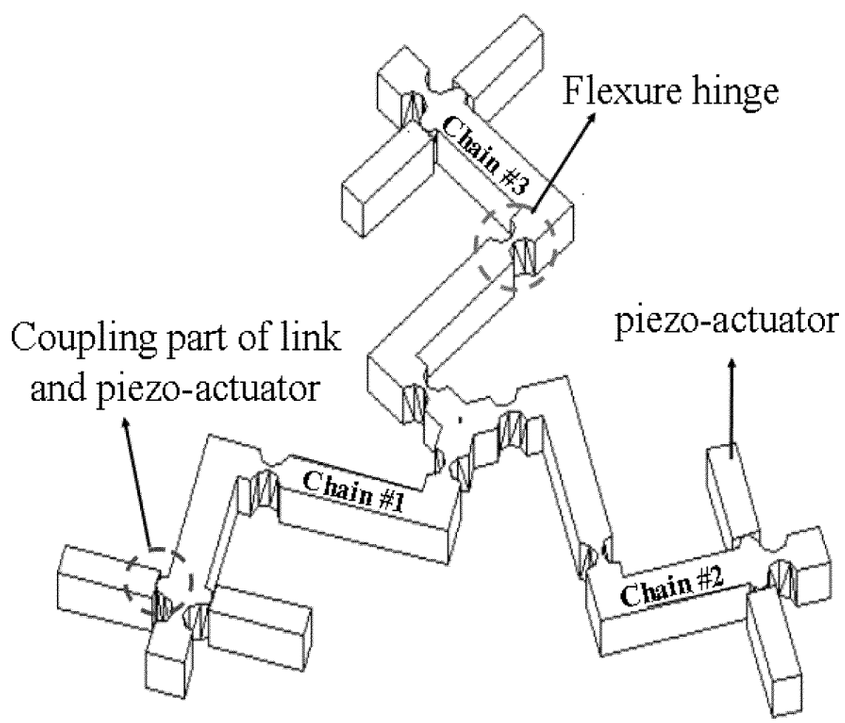


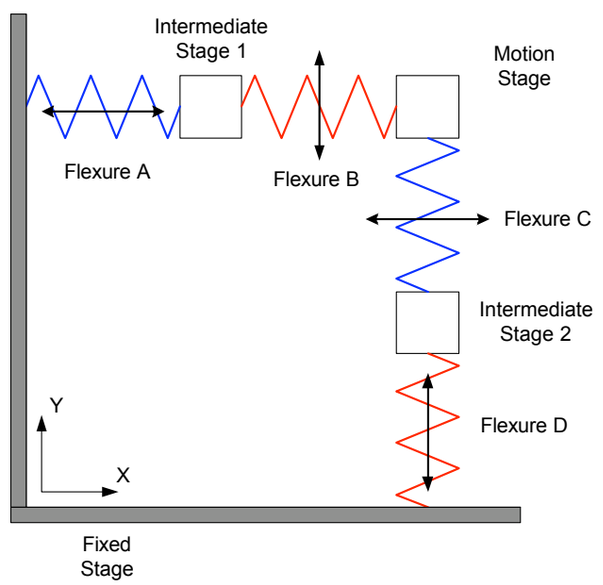
Finite element analysis

Planar flexures



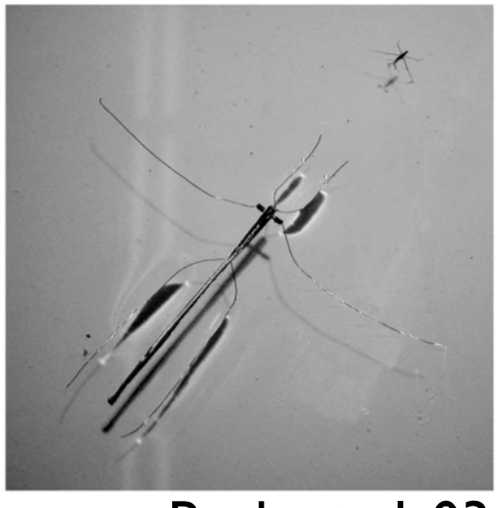






Micro-flexures/thermal actuators

Very Light weight = 0.07gm
Integrated actuator/flexure
High force



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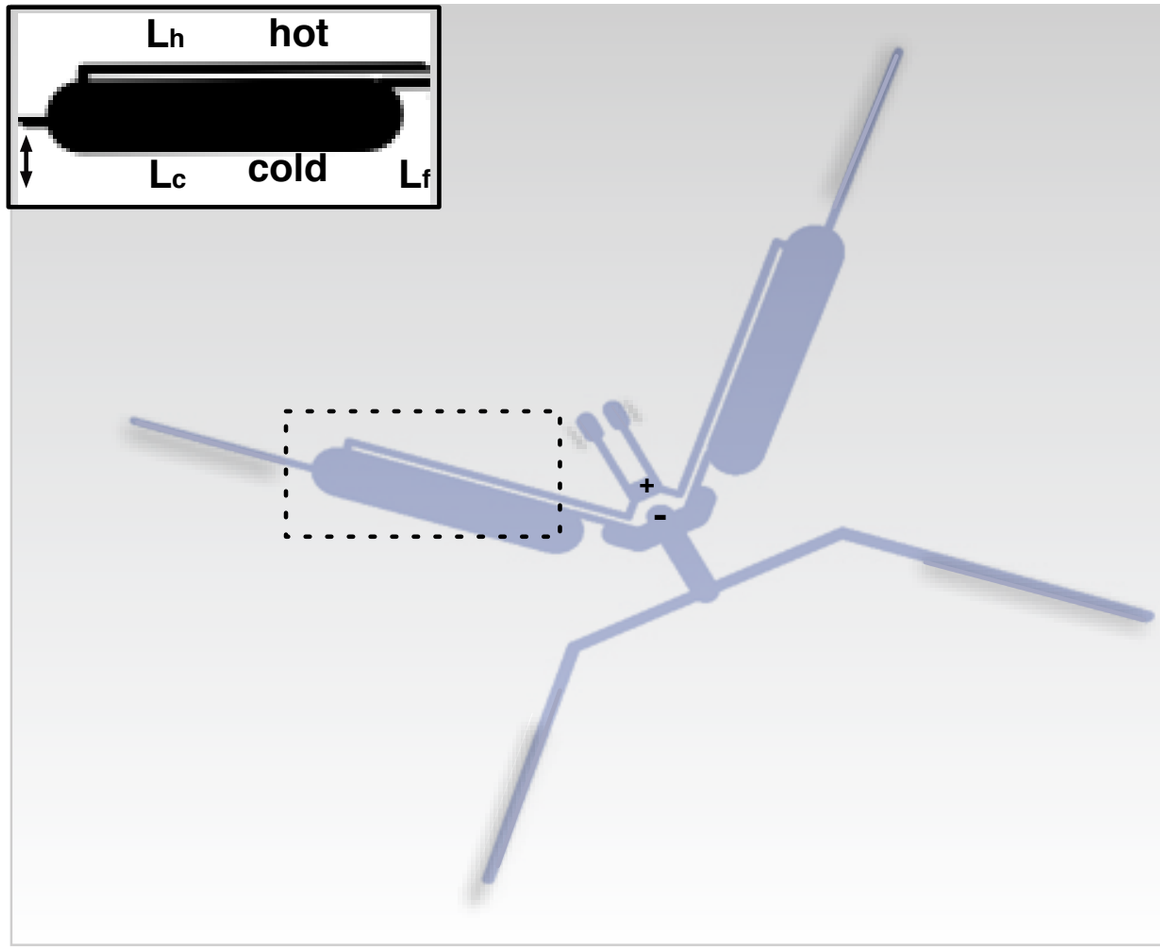
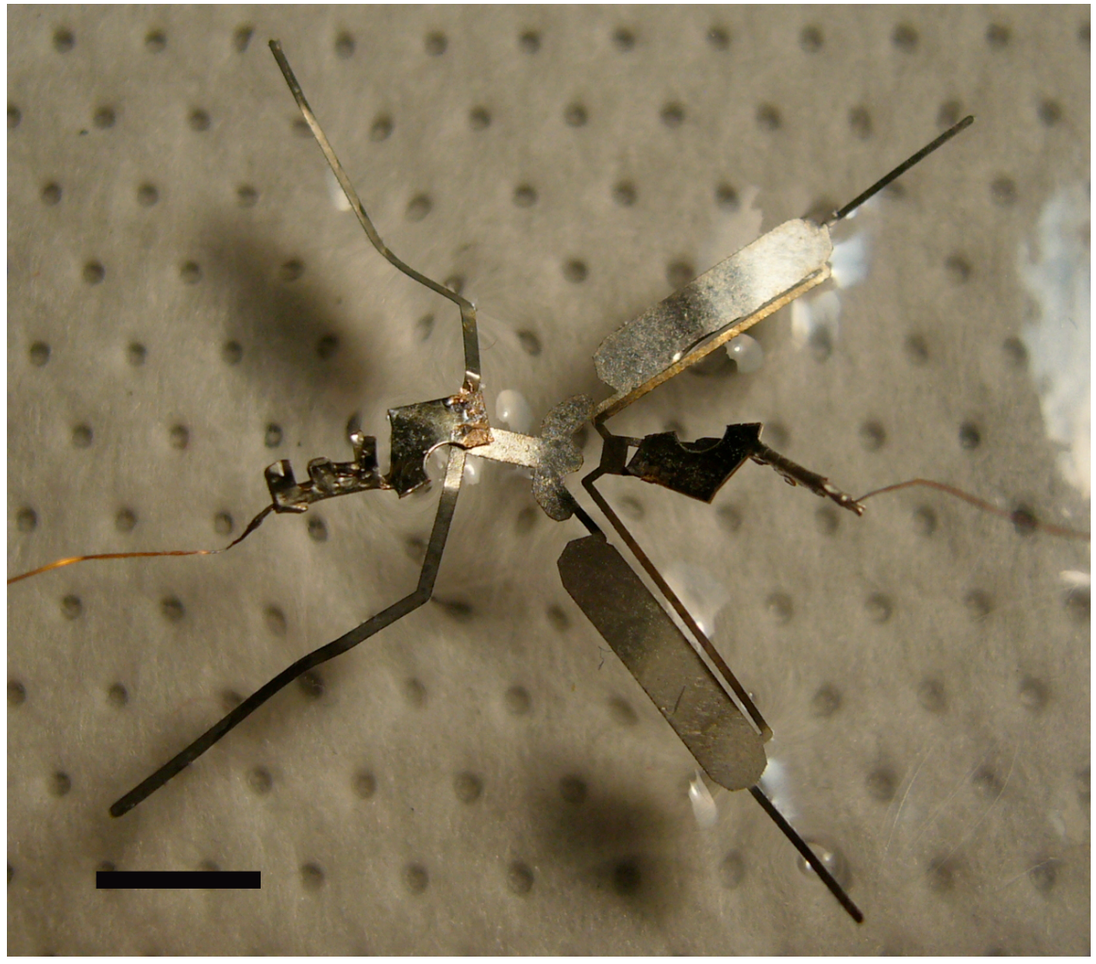
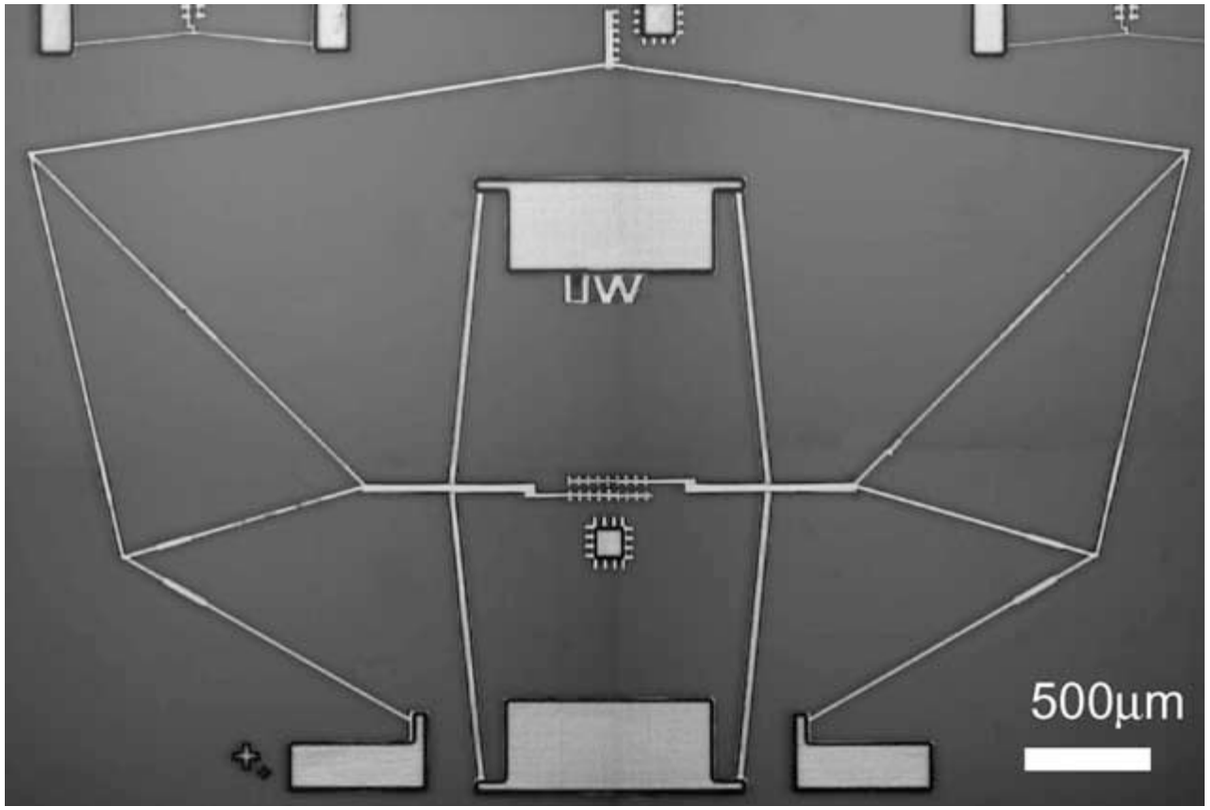
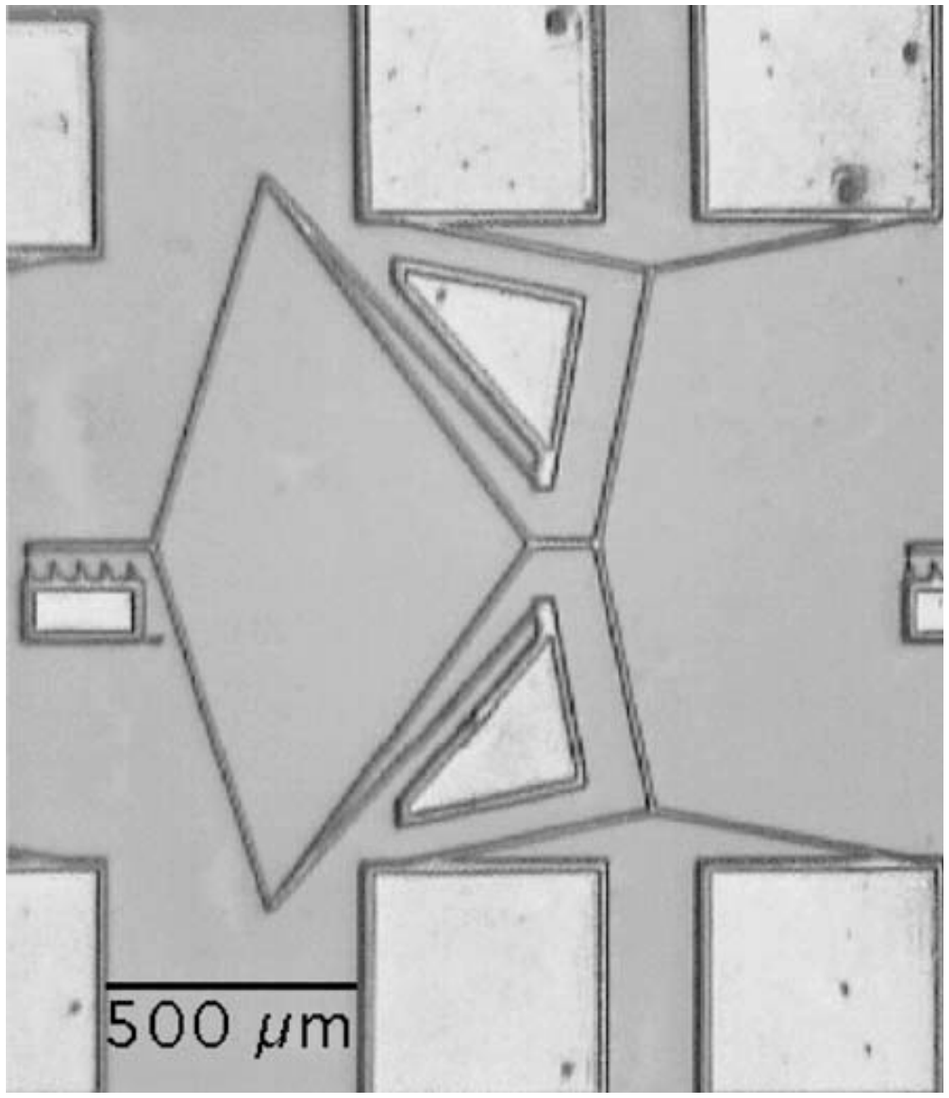
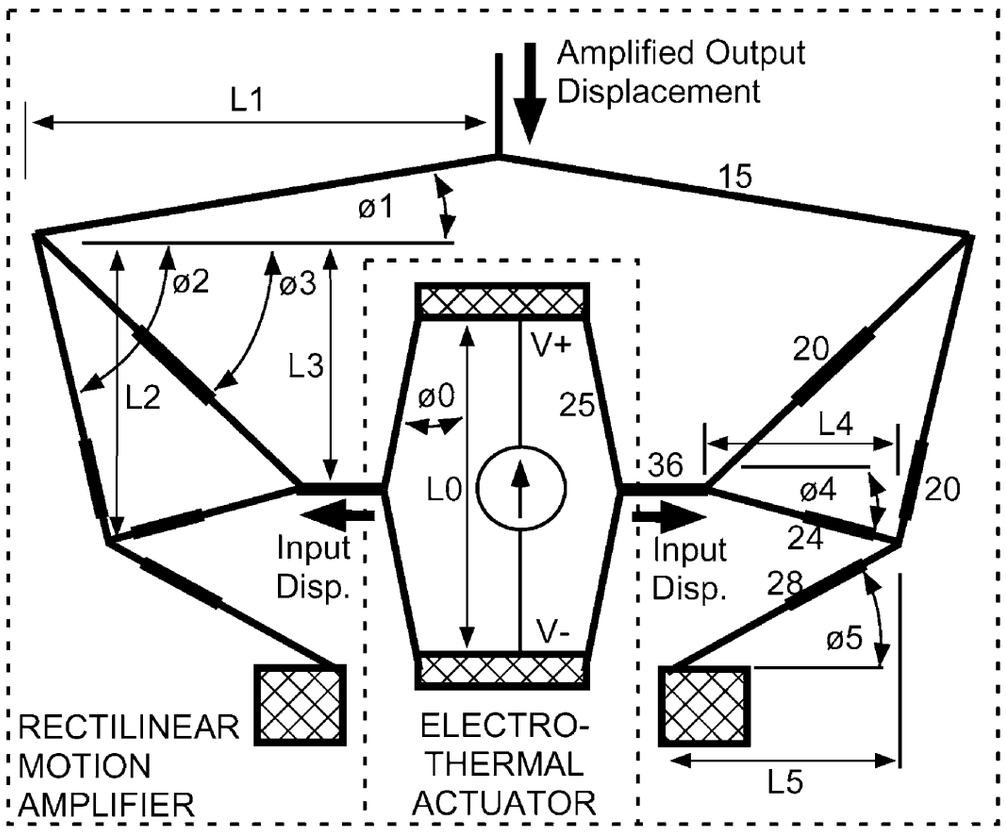




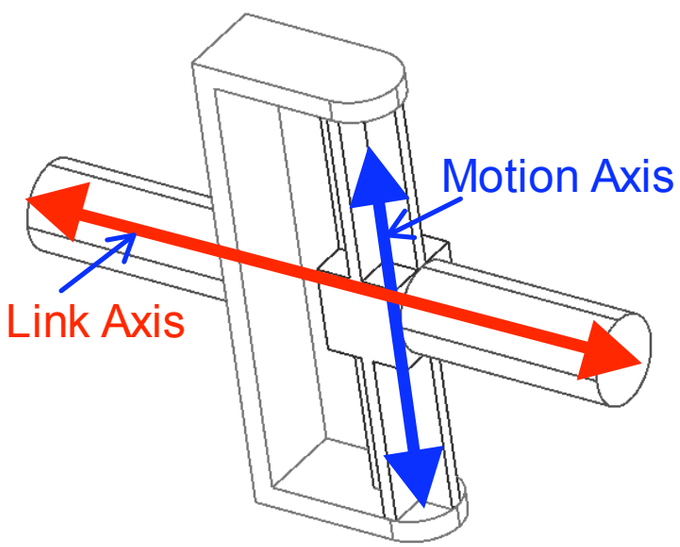
Micro-flexures



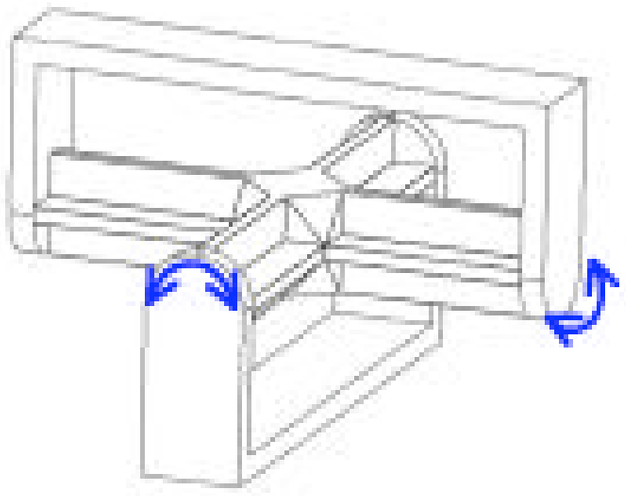




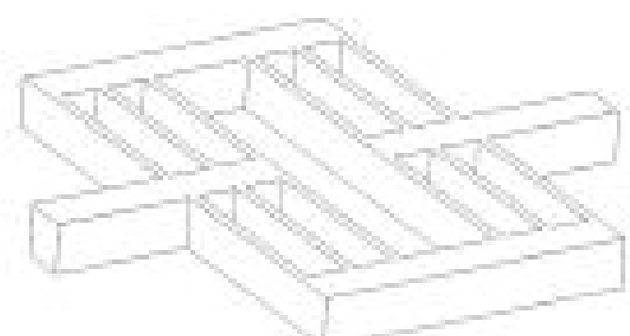
Large displacement Printed flexures



Compliant Revolute joint



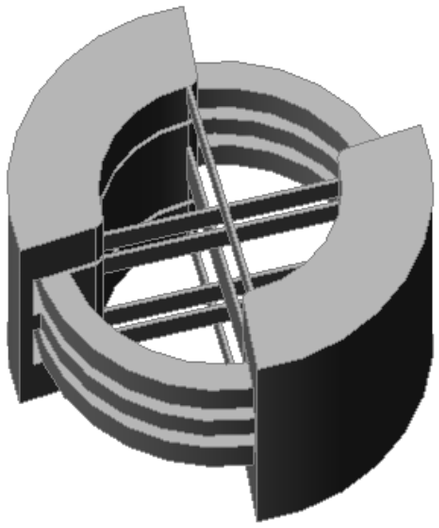
Compliant Universal joint

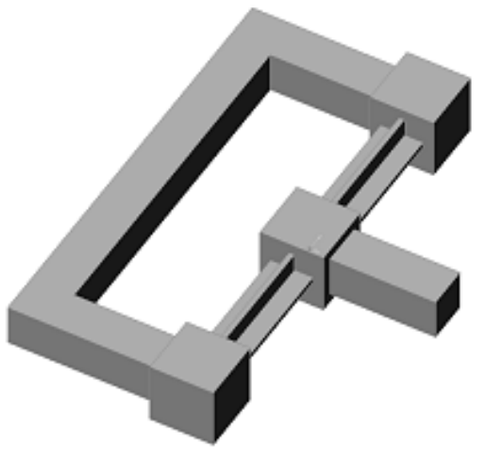


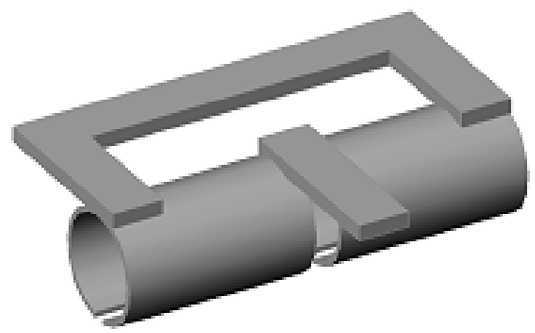
Compliant Prismatic joint

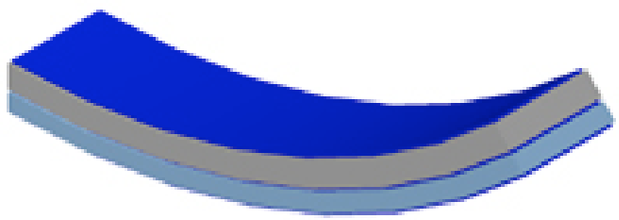
6-DOF printed Compliant parallel kinematic mechanism

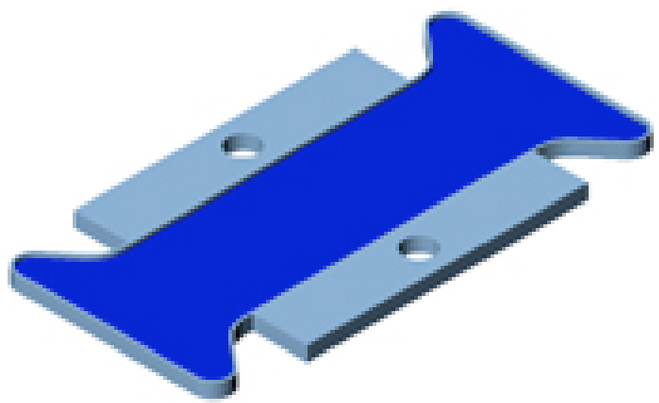
Printed flexures contd.

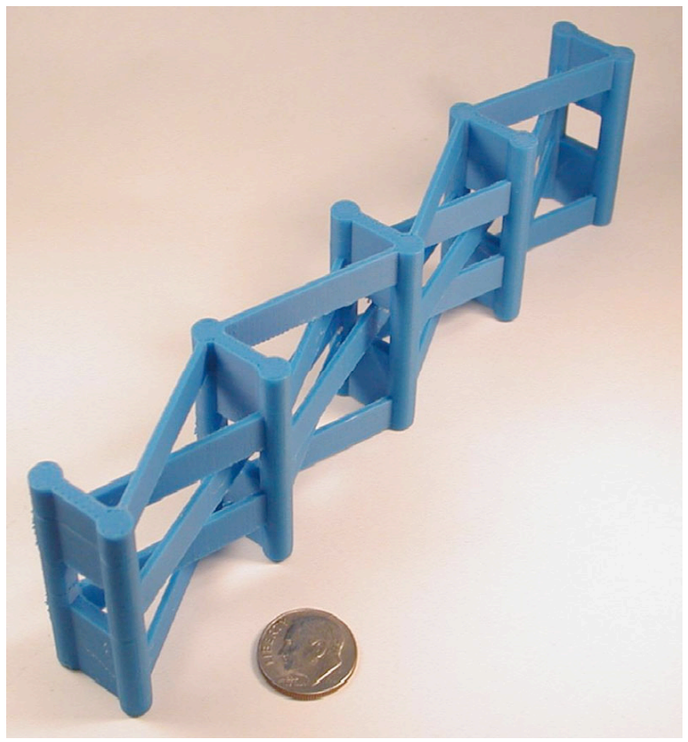












Questions