3D Printed Flexures

Tips by Akaki Kuumeri

Outline

What are flexures

Can I 3D print these?

Why not?

Ok, but how would I go about it?

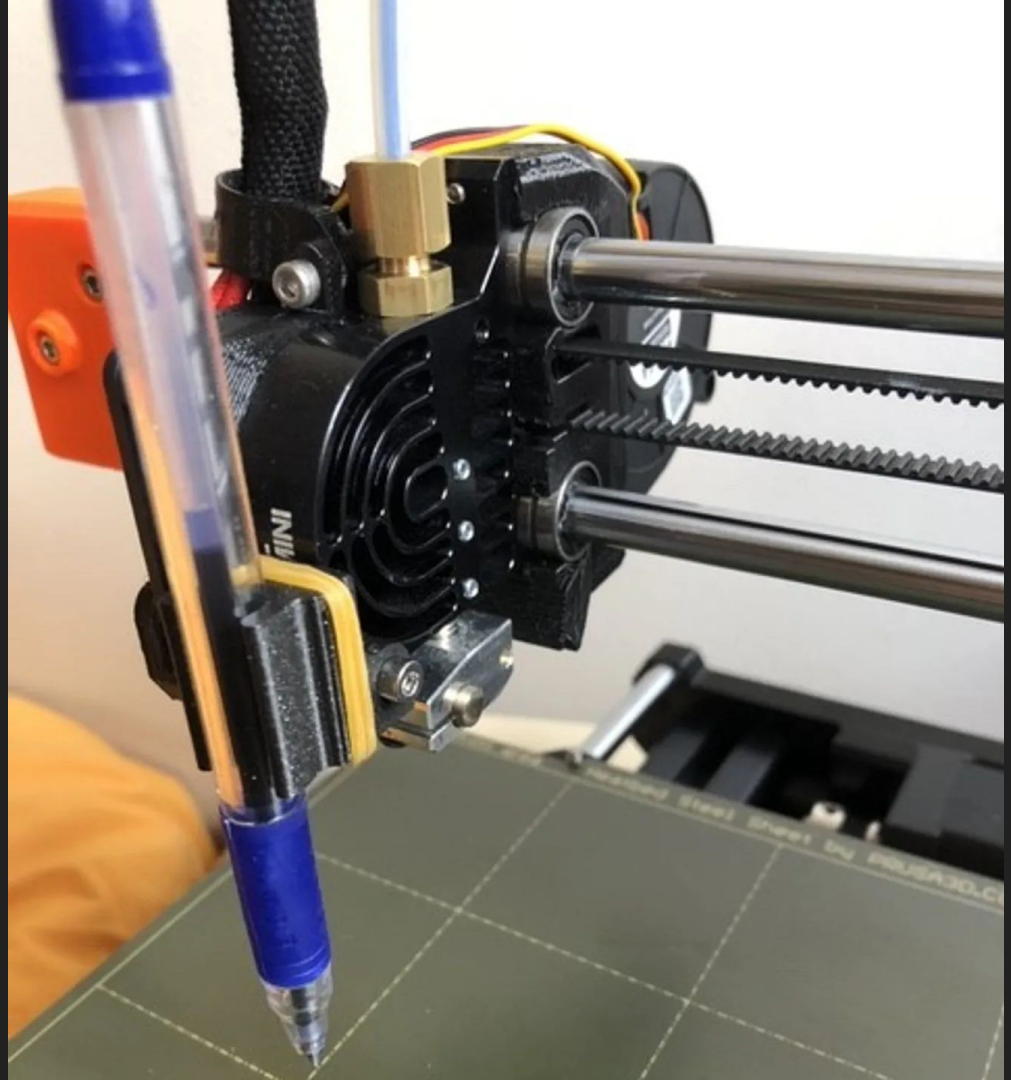
Akaki’s flexure primitive

Tips to print better flexures

About Akaki

3D printing enthusiast
Studied computer science

I love flight simulators, and interesting control interfaces
You might have seen my 3D printed controller designs using flexures



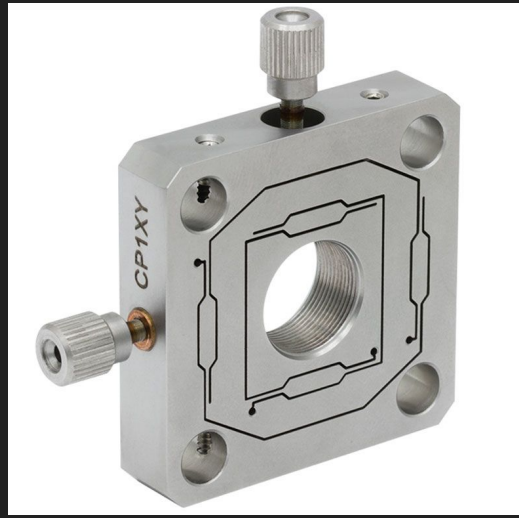
What is a flexure?

Compliant Design

Flexible Structure

A part that is designed to flex, but also to work as a structure

Flexes in one axis, but rigid in another



Advantages of Flexures

No moving parts

No slop

No wear

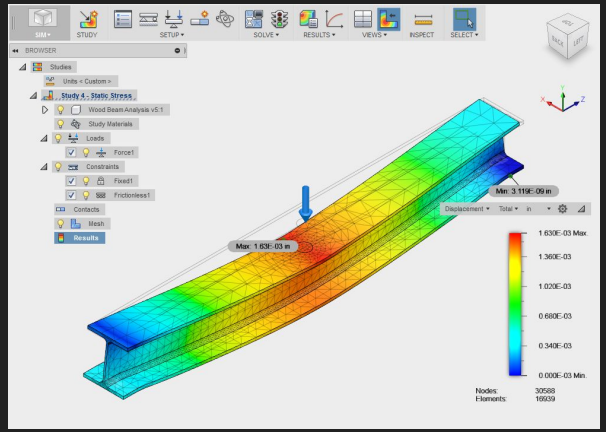
Less parts, less assembly

Disadvantages of flexures

Not easy to design (or simulate)

Limited movement (compared to hinges etc.)

Creep



Can I use these in 3D printing?

Kind of

3D printers can’t make very good flexures

Examples of 3D Printed Flexure Mechanisms

Why hobbyist FDM printers can’t make great flexures

PLA and other common plastics yield easily

- Plastic deformation - when you bend it permanently

And they creep easily

- Leave a flexure bent for a day, and it won’t return to center

And they are not isomorphic

- Print orientation makes a difference
- Difficult to predict or simulate -> difficult to design

But, I still think hobbyist FDM printing and flexures make a good match

3D printed mechanisms are often ephemeral

Rapid prototyping -> trial and error design

Very complex shapes possible -> possibility to reduce a lot of assembly steps by printing

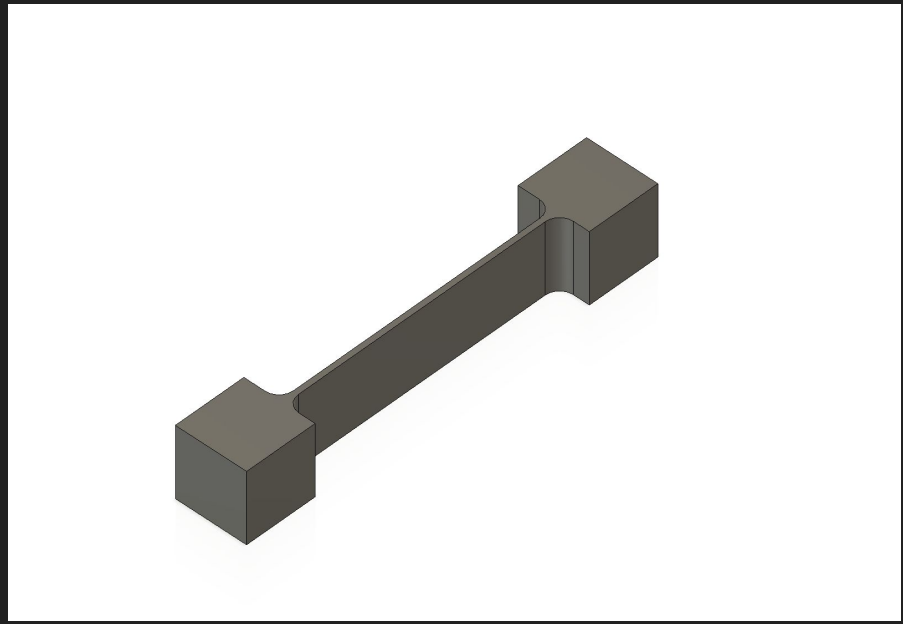
FDM printing is not very precise -> flexures can replace imprecise hinges and fittings

My solution to designing 3D printed flexures: The Flexure Primitive

A 0.75 mm thick, 40 mm long wall, 5 mm displacement at the end

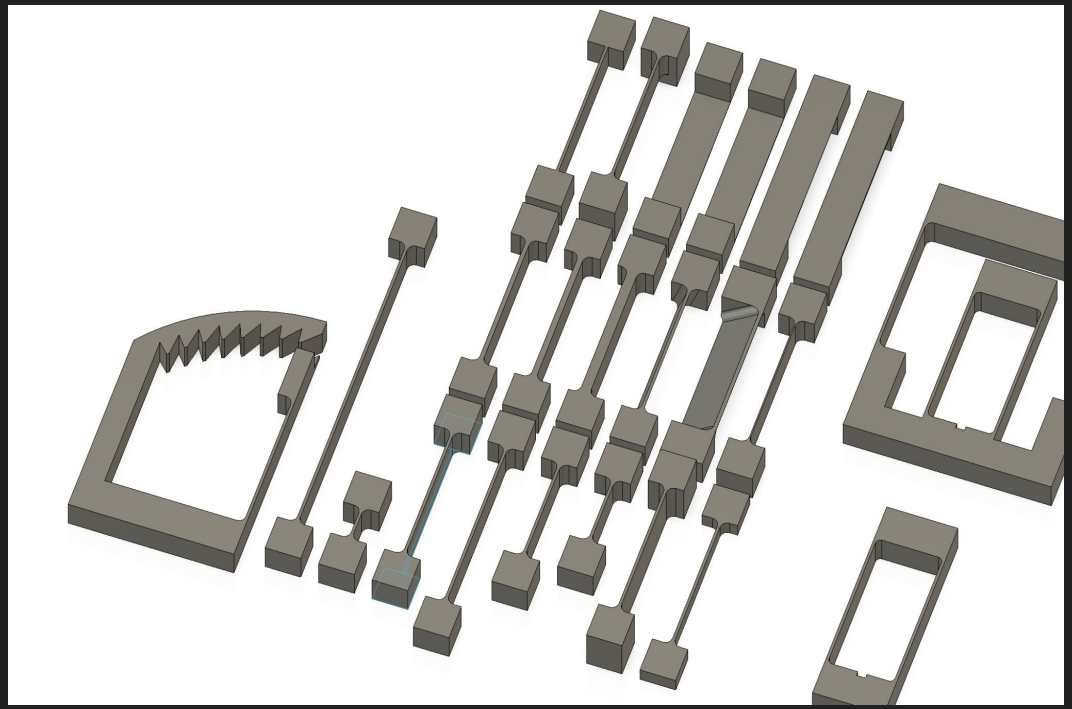
Selected through trial and error

More complex flexure mechanisms can be built from this primitive



How I arrived at my primitive

You might want to go through this same procedure if you want to use some other material



Thickness 0.75 mm

- Assuming a 0.4 mm nozzle, your slicer will print exactly two lines wide
- It is not easy to get your slicer to print a single line.
- Thicker than three lines suffers from non-isomorphism

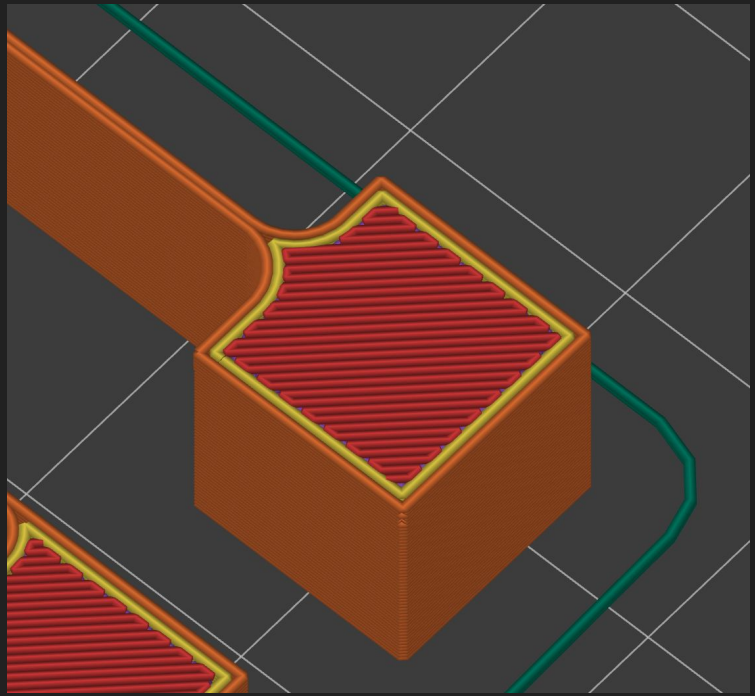
Width at least 10 mm

- Any narrower, and it becomes too easy to twist

Length 40 mm+

- Shorter, and it doesn’t bend well
- Longer and you might get multiple bends

Always printed vertically



Building up from the flexure primitive

Simple hinge

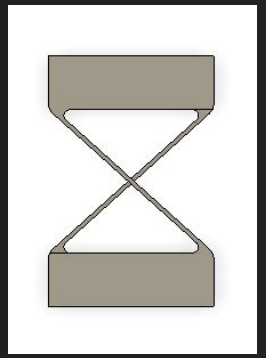
X-Hinge

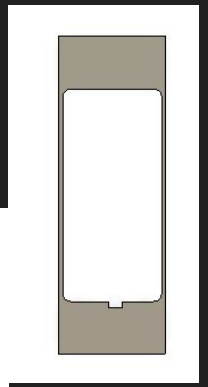
Linear movement

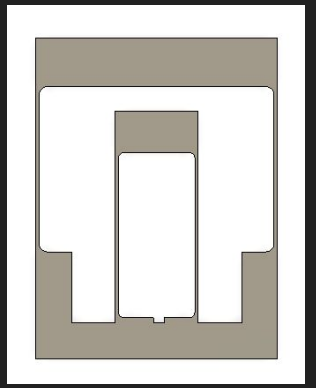
Linear-er movement with two stages

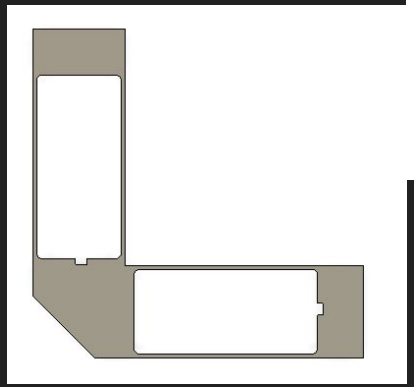
X-Y movement
External hinge

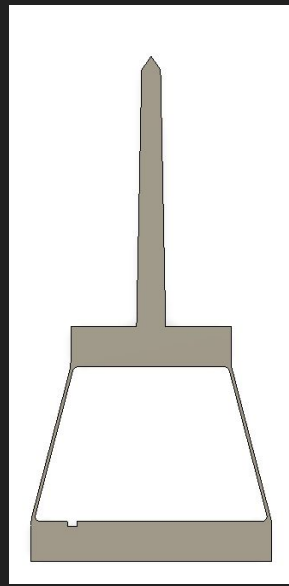
… To the next dimension?











Closer look at my flexure mechanisms

Tips for longevity

- 3D printed plastic yields early
  - Use end stops
- 3D printed plastic creeps easily
  - Never leave under tension

Tips for easier printing

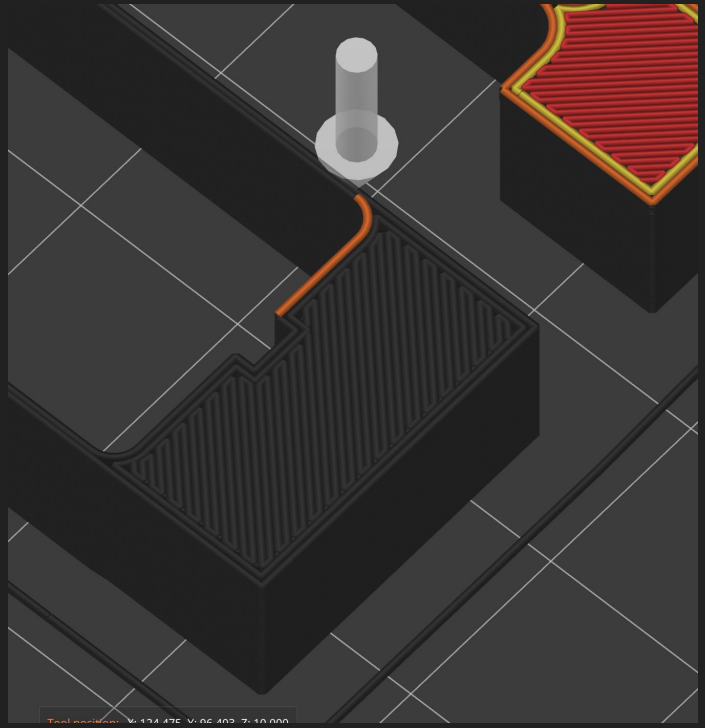
Filleted corners + seam attractors

Print line seam must not be near the flexure

Extend from a parallel wall if possible

You can bridge vertical flexures in thin air!

If you must print flexures laying flat, make sure the print lines are longitudinal



Materials considerations

In my very non-clinical tests, PLA+ has been the most useful

PETG is said to be more flexible (yields later, creeps less) but in my experiments not a big difference

Please let me know if you try with nylon and other exotic plastics

Where to learn more

Brigham Young University Compliant Mechanism Research

https://www.compliantmechanisms.byu.edu/about-compliant-mechanisms

Unironically, search “flexures” on Pinterest

For hobbyists, especially those with laser cutters: https://www.youtube.com/watch?v=K0wr_ZhhtbE Flexure Lecture by Amy Makes Stuff

Links to models shown during presentation

https://www.thingiverse.com/akaki/designs my joysticks etc.

https://www.printables.com/social/106360-akaki/about one handed controller, joyant-con

https://www.printables.com/model/30984-customizable-pen-mount-for-prusa-mini Pen holder

https://www.thingiverse.com/thing:2591740 gripper

https://www.thingiverse.com/byu_cmr/designs BYU flexure mechanisms

https://www.thingiverse.com/thing:4808398/files spherical joint

https://www.printables.com/model/77081-xy-flexure-translation-stage XY platform