Controlling Mechanical Properties in a Metamaterial Structure

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Making Structures More Efficient

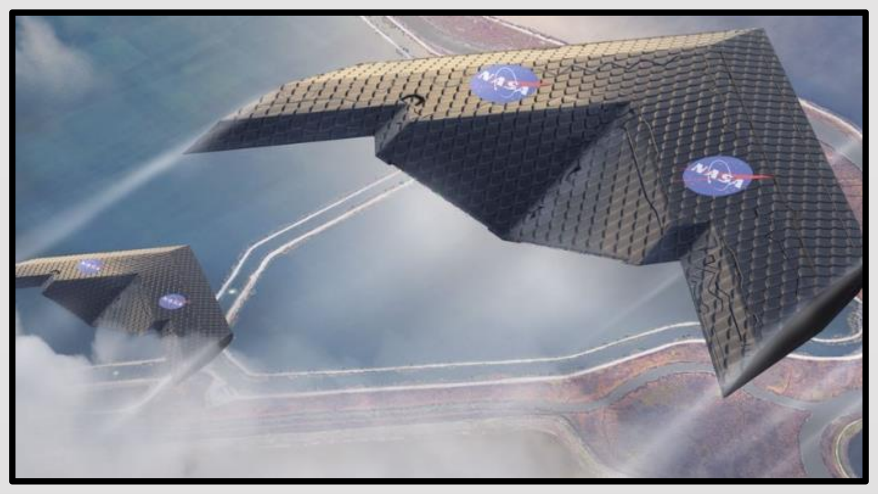
Typical Structures usually have a fixed stiffness during design and fabrication.

Allowing structures to change stiffness on demand and adapt to their environment can make the structure more efficient.

Metamaterials can be used for changing stiffness on demand.

Applications of controlling mechanical properties in a metamaterial

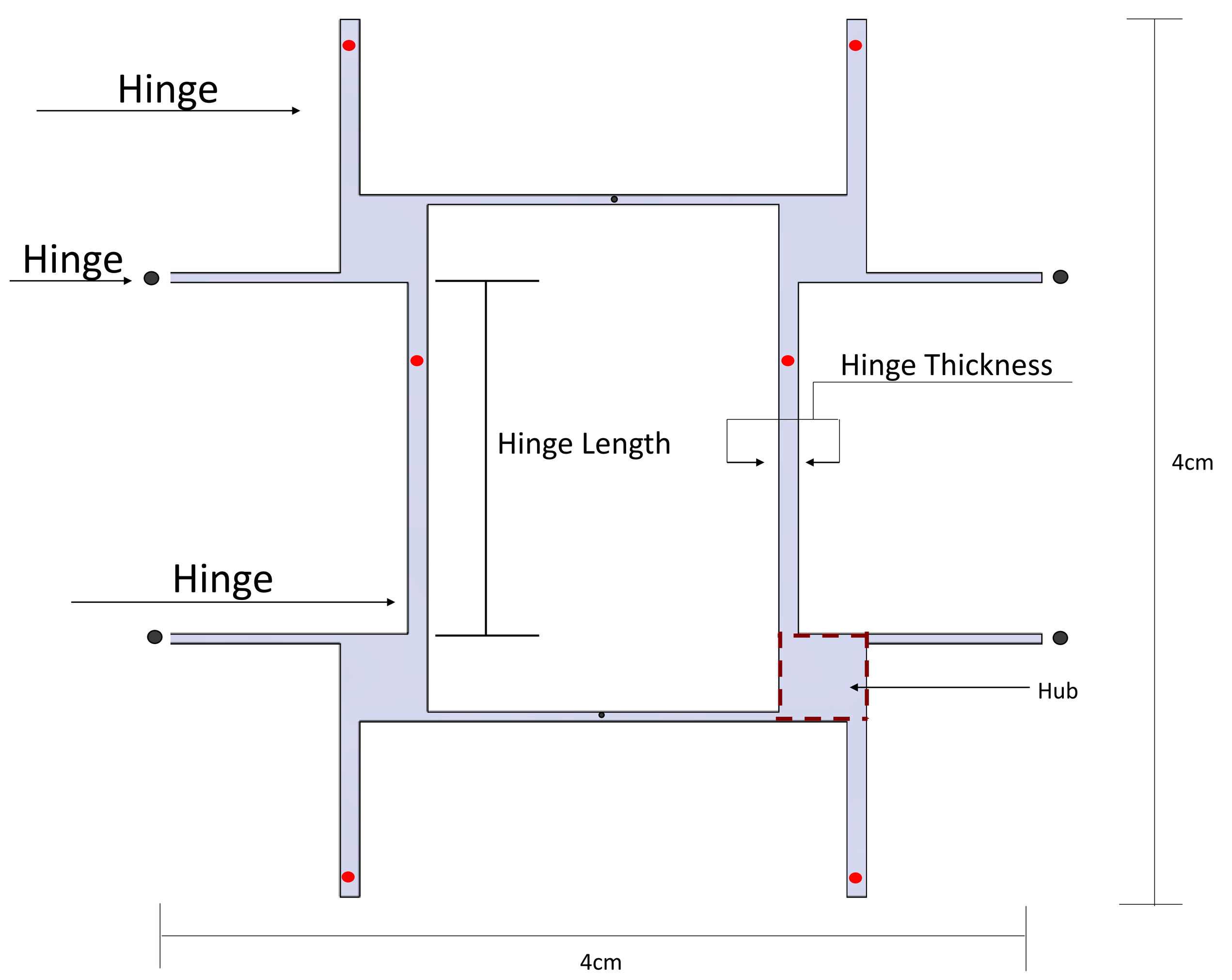
- Reconfigurable spacecraft antennas
- Deployable spacecraft structures
- Controllable lift and stability characteristics via wing morphing



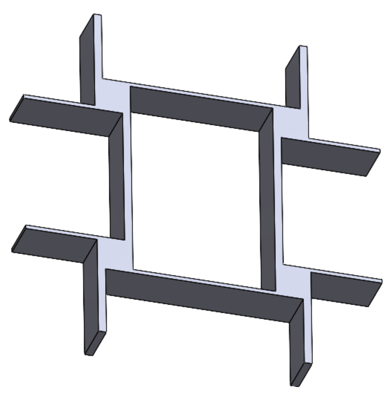
[1] A metamaterial concept to increase efficiency in aircraft designs

The Anti-Tetrachiral Metamaterial Structure

Unit Cell

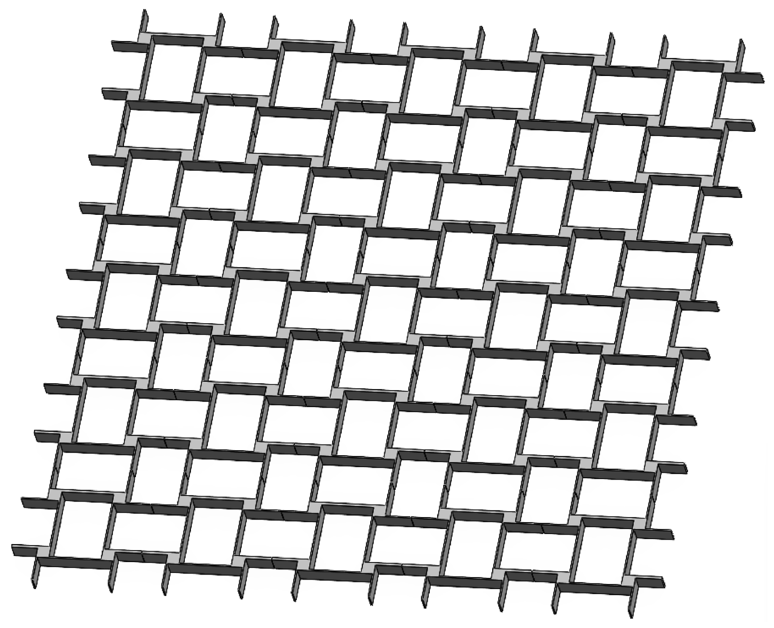


Stiff Hinge = Thick Hinge
Non Stiff Hinge = Thin Hinge



Changing hinge thickness results in a change of hinge stiffness.

Full Model

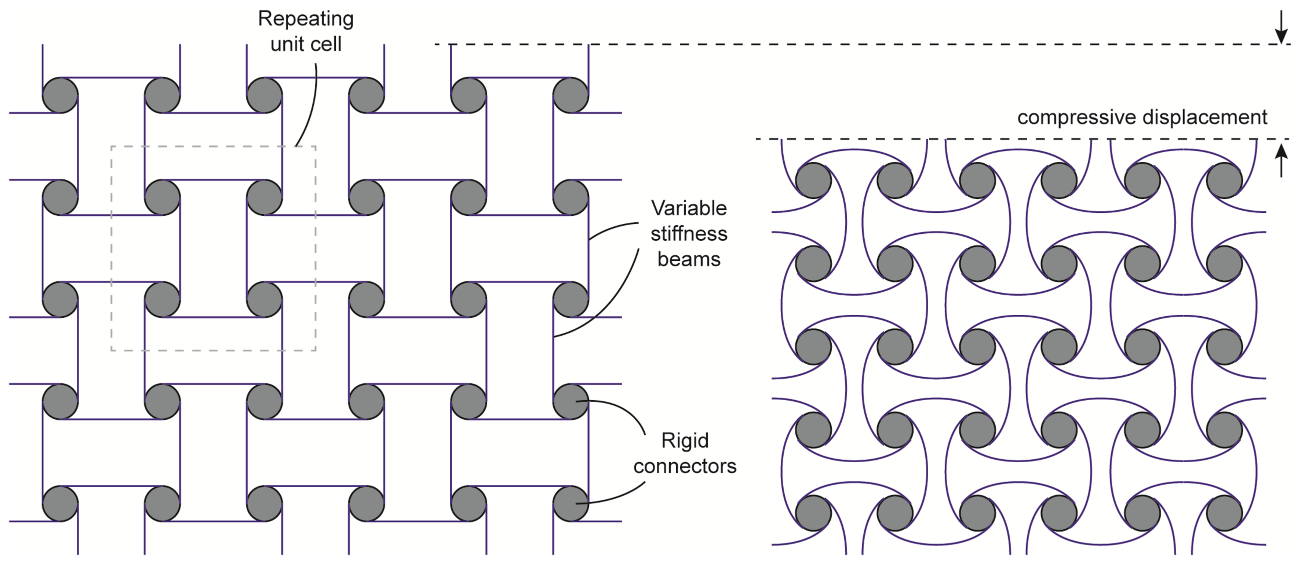


20cm x 20 cm x 5mm low fidelity model

Different hinge stiffness patterns result in a different global stiffness of the anti-tetrachiral material.

For application, each hinge would have an actuation method to select a stiff or soft configuration.

Demonstration of how metamaterial hinges react under compressive displacement



The anti-tetrachiral material structure has an in-plane negative Poisson's ratio.

As the material structure is compressed longitudinally, it also contracts in the lateral direction.

Objective

To demonstrate that global stiffness can be controlled **by changing hinge stiffness.**

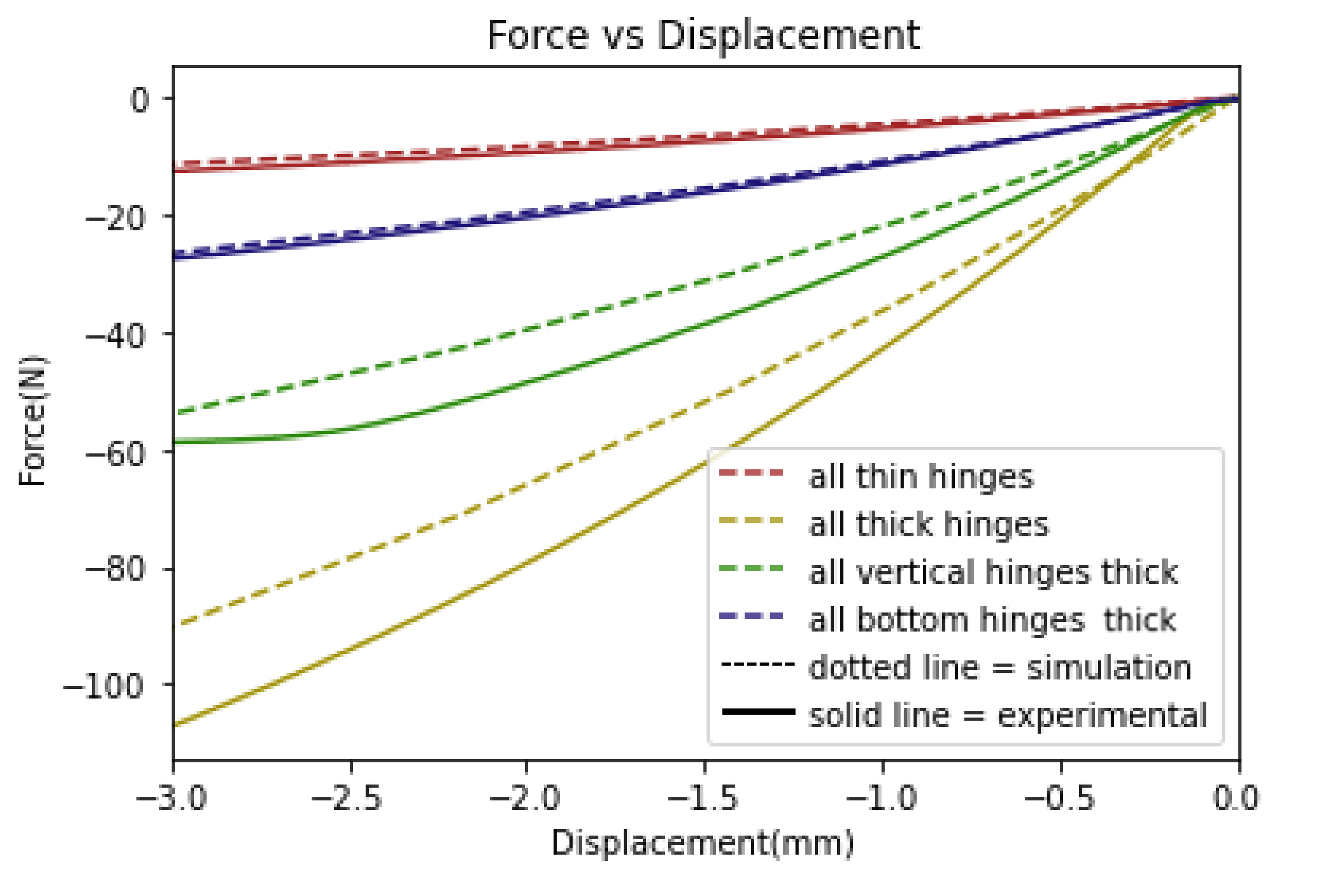
To compare Abaqus FEA compressive simulations to real world compressive experiments.

Testing Different Material Geometries

Four different anti-tetrachiral material structure patterns were created in a CAD software

- 3D printed with PLA → Compression tested with an instron machine → **Results**
- Compression tested in Abaqus FAE simulation → **Results**

Global Stiffness Can Be Controlled



Each material structure configuration has a different force vs displacement curve.

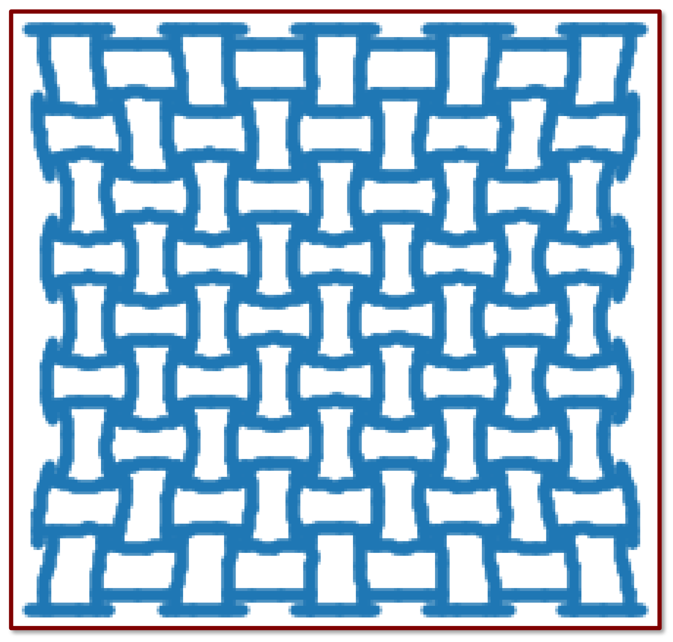
Slope = Stiffness

For a given amount of force, each material structure configuration has a different displacement under compression.

All 3D printed structures have a higher stiffness than simulation predictions.

Deformation Comparison

Experiment



Simulation

Shape change comparison between experiment and simulation for the "all hinges thin" configuration.

Differences in the experimental results and simulation results may be due to the uncertainty in the material properties of the 3D printer PLA material.

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Bibliography

[1] Eli Gershenfeld, MIT and NASA engineers demonstrate a new kind of airplane wing (Image). Available from: MIT News. <https://news.mit.edu/2019/engineers-demonstrate-lighter-flexible-airplane-wing-0401>. (August 4, 2022)