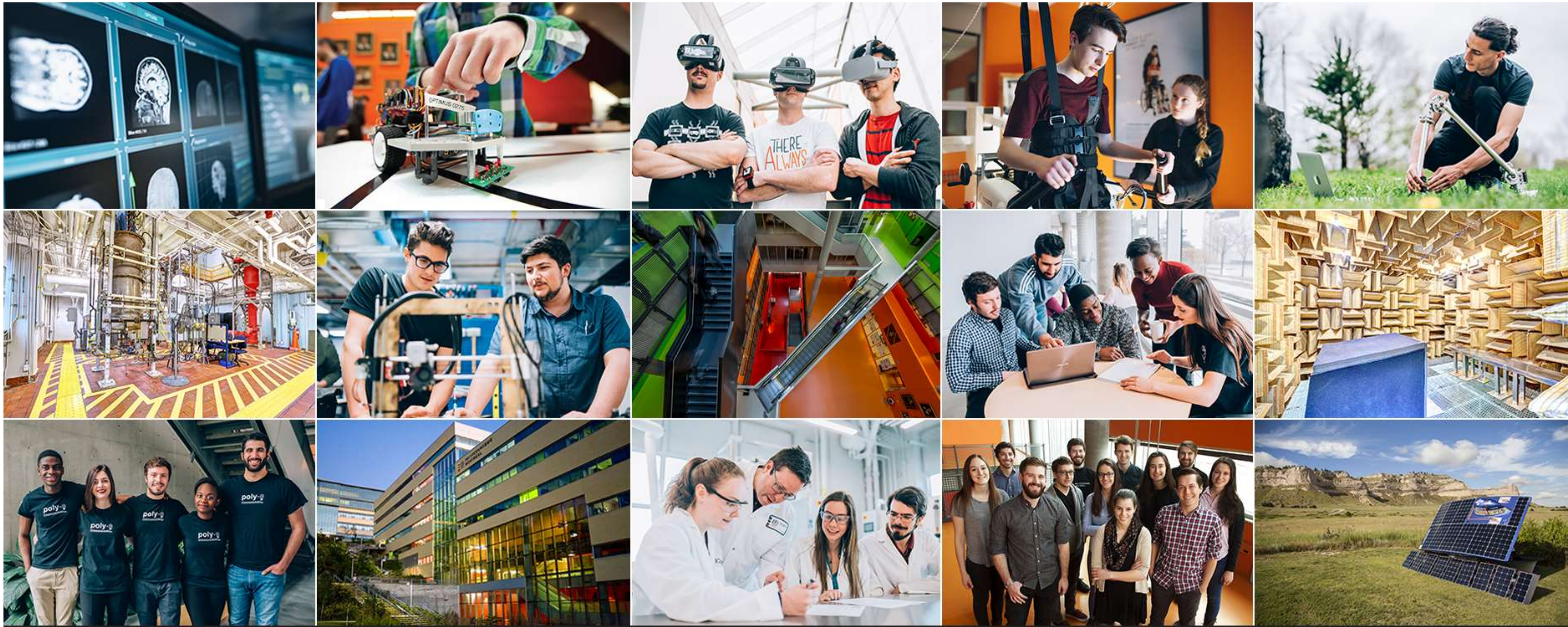

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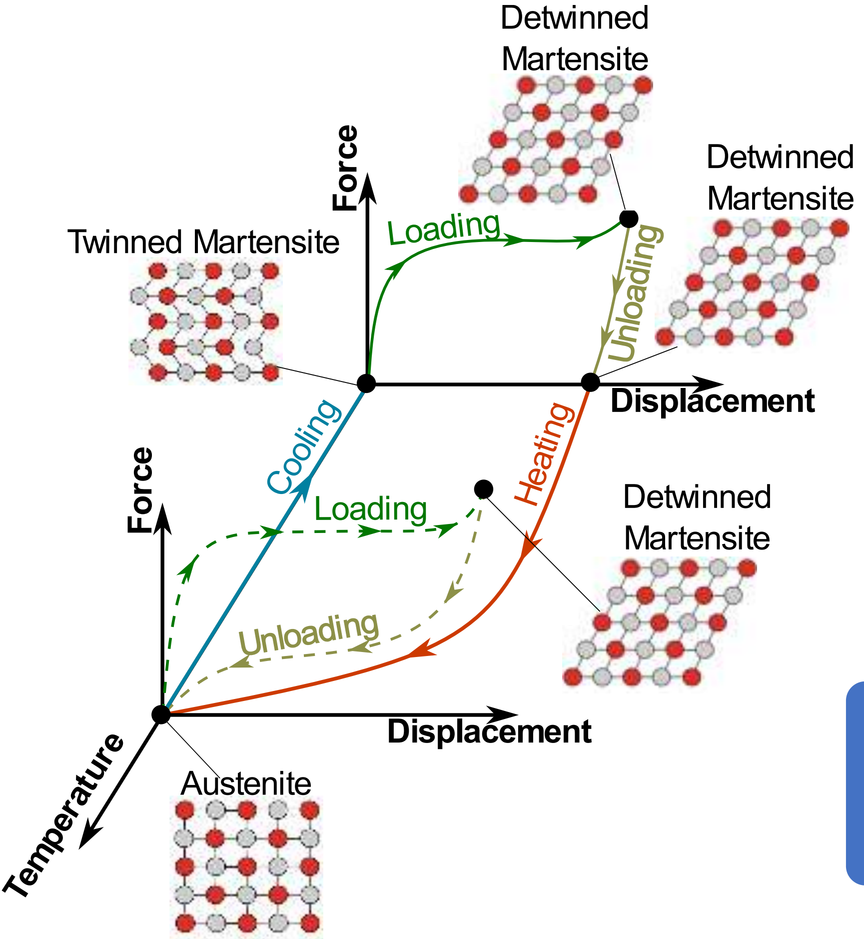
Additively Manufactured Thermally Bistable Structures

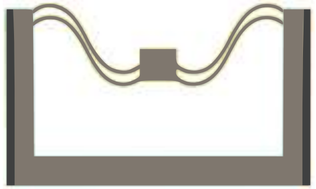
Sampada Bodkhe
Assistant Professor, Department of Mechanical Engineering

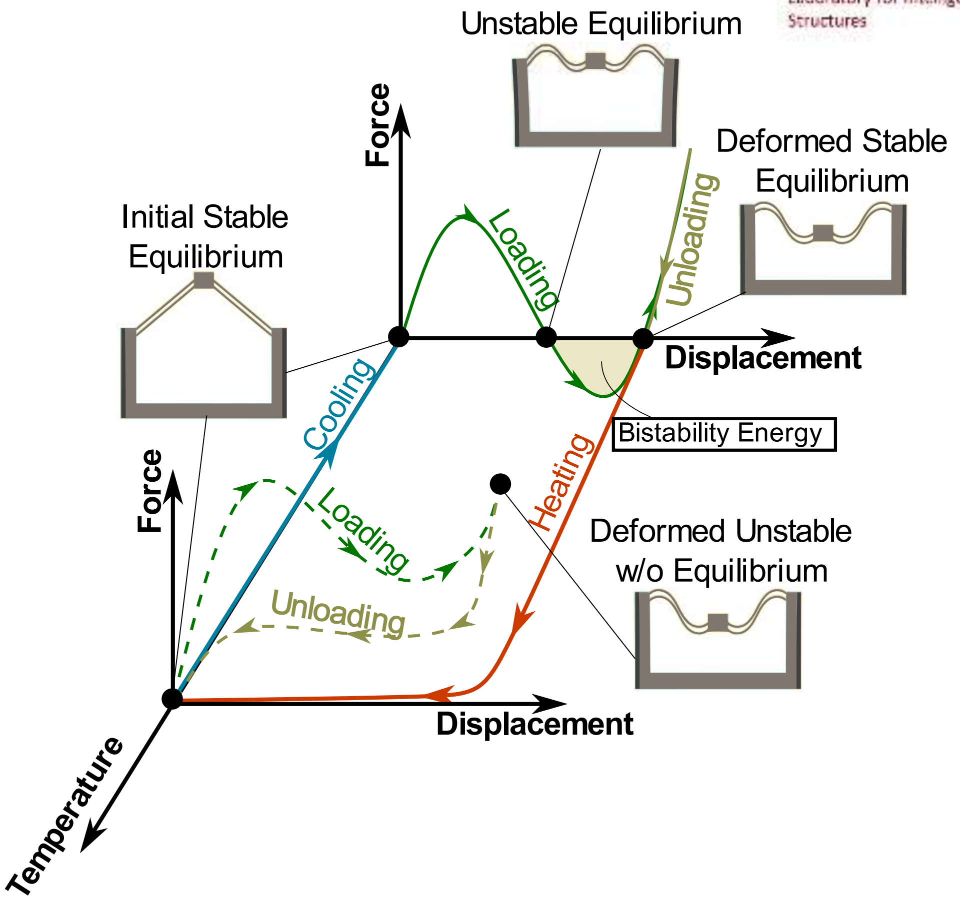
The International Conference on Composite Materials 2023, Belfast, Ireland

Introduction



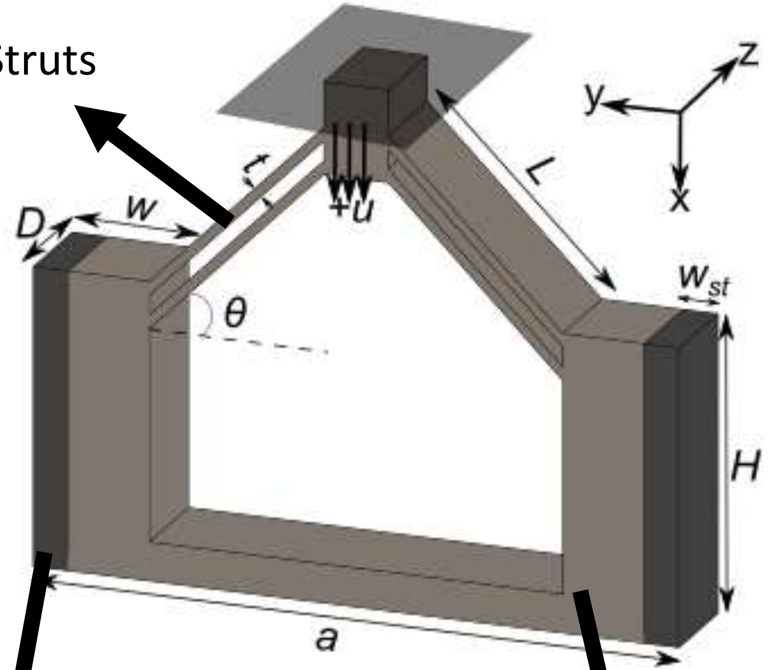
- Bistable structures
  - Binary response to loading conditions
    - Initial configuration
    - Deformed configuration





Proposed Design

Struts



Stiff Material in walls

Soft Material

Carbon-Reinforced Nylon

TPU 95A

Regular non-smart materials

Collaborators
Prof. Hamid Akbarzadeh, McGill
Prof. Daniel Therriault, Poly

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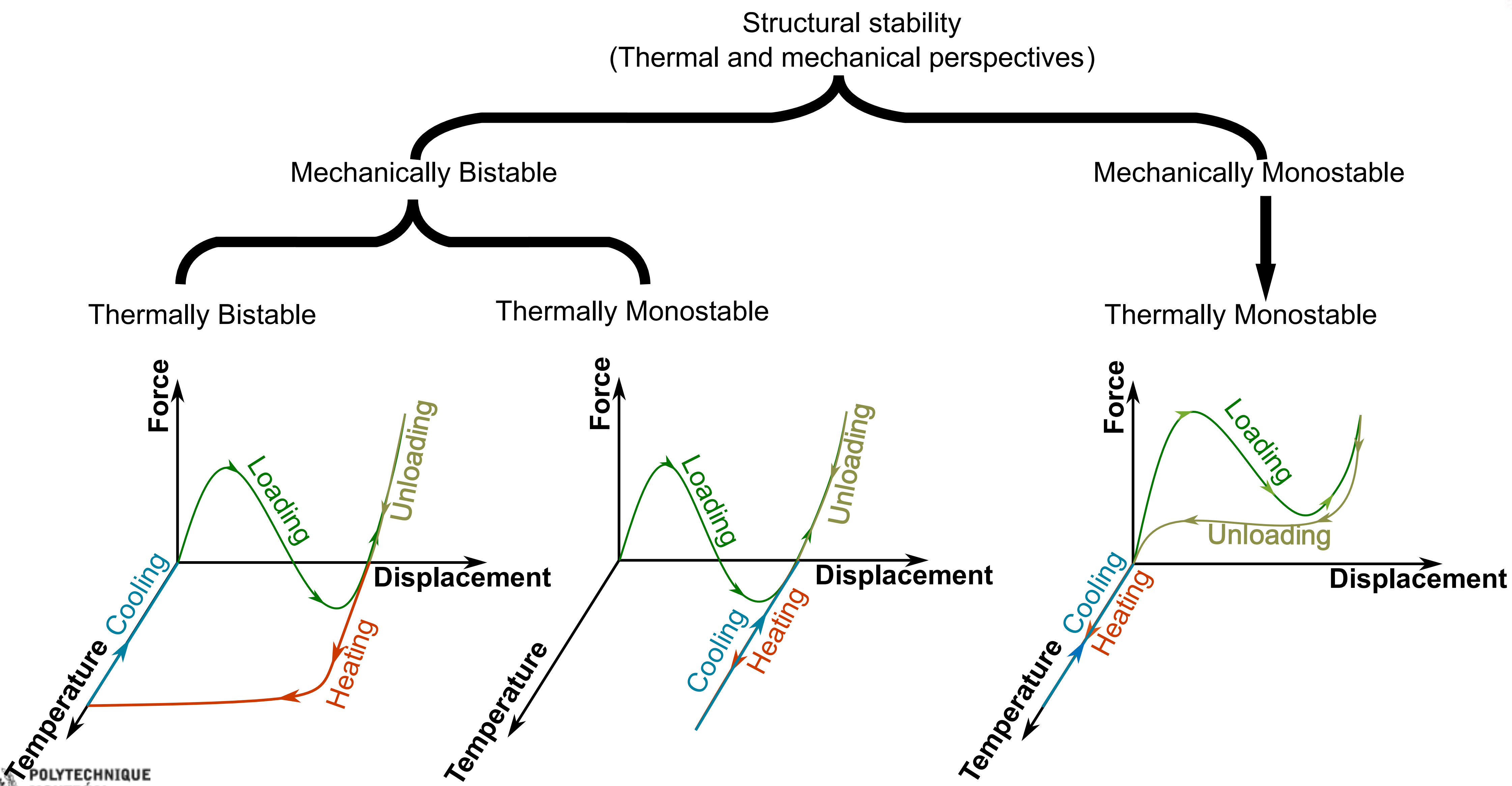
Niknam H et al., Applied Materials Today, 2022.

Mechanical Bistability Vs. Thermal Bistability



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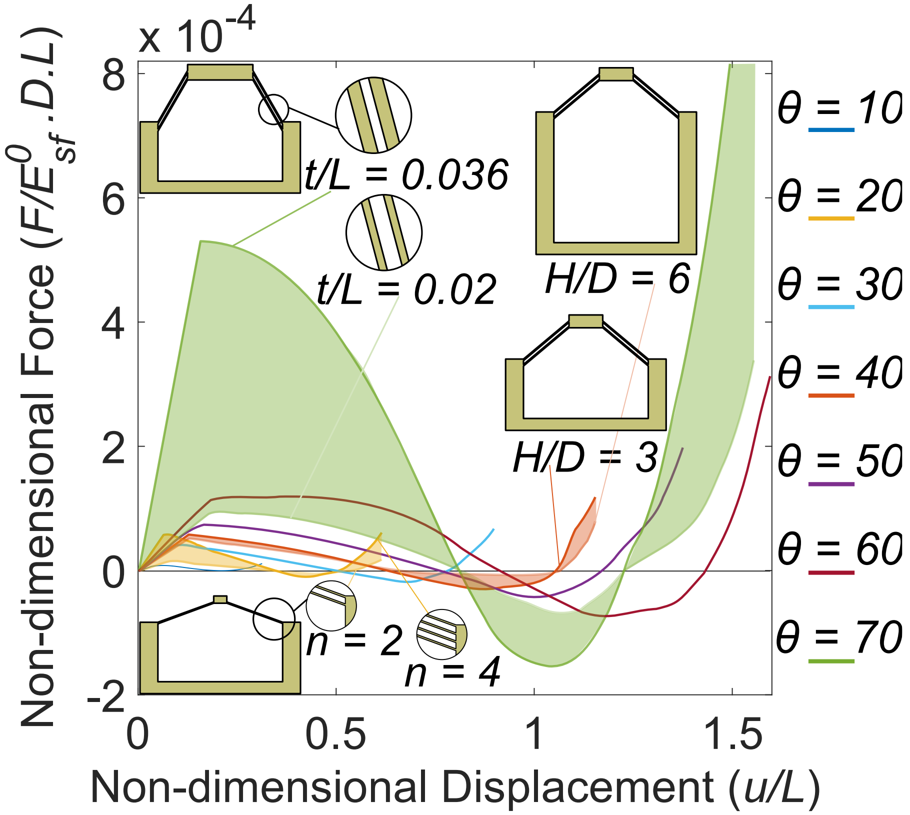
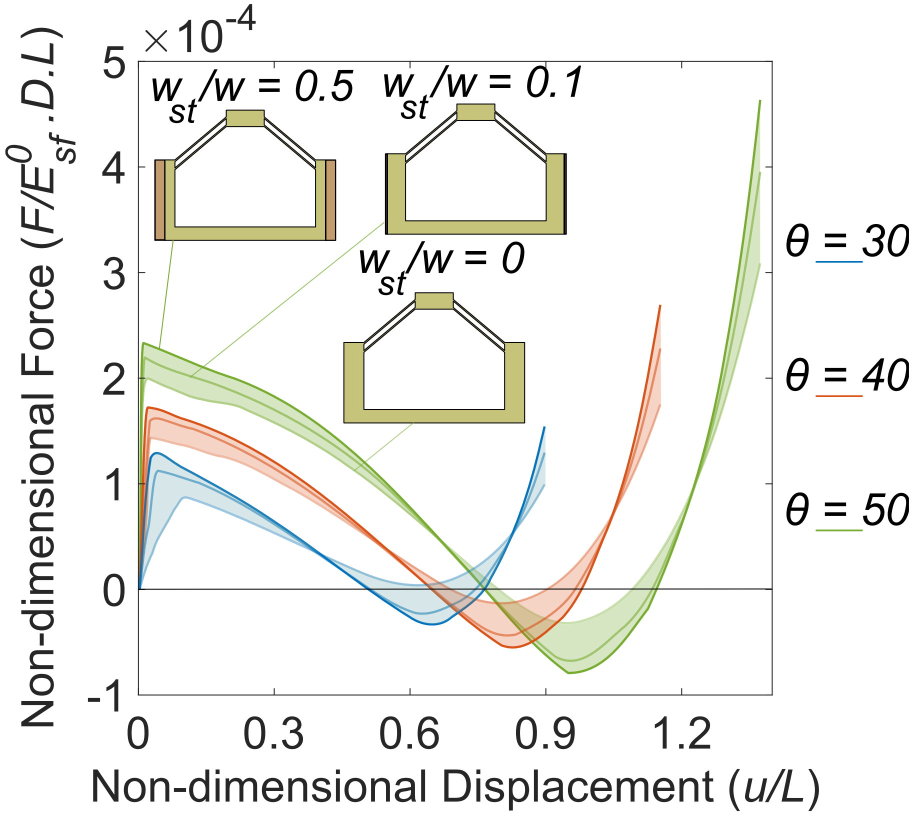
Effect of design Features on Mechanical Bistability



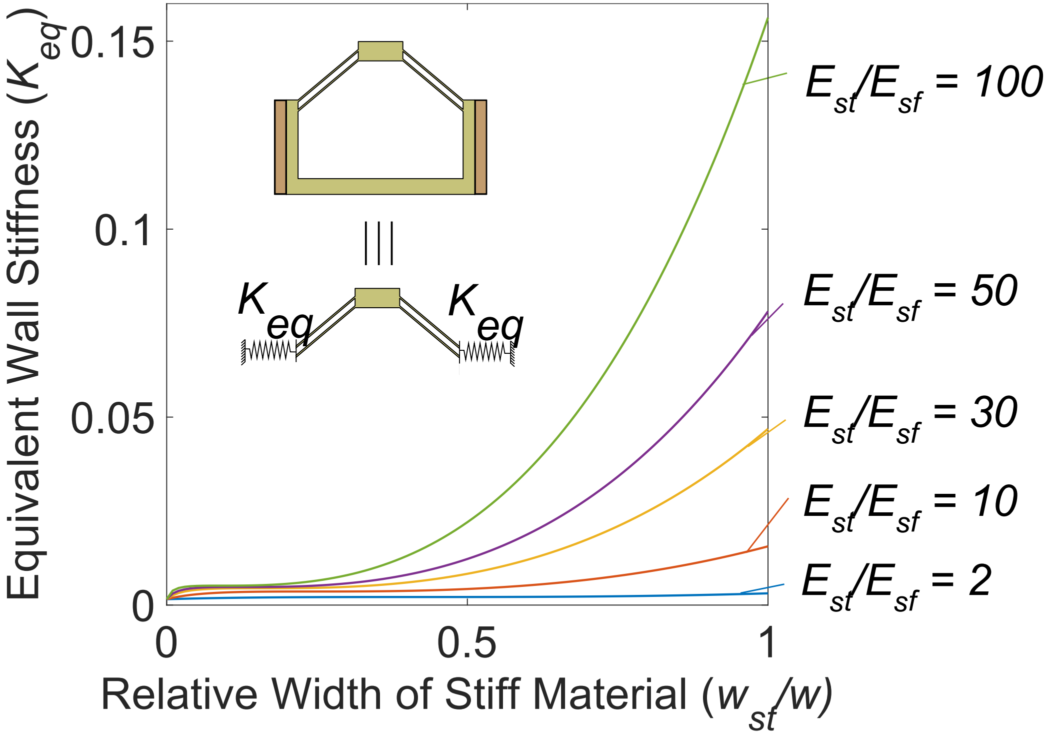


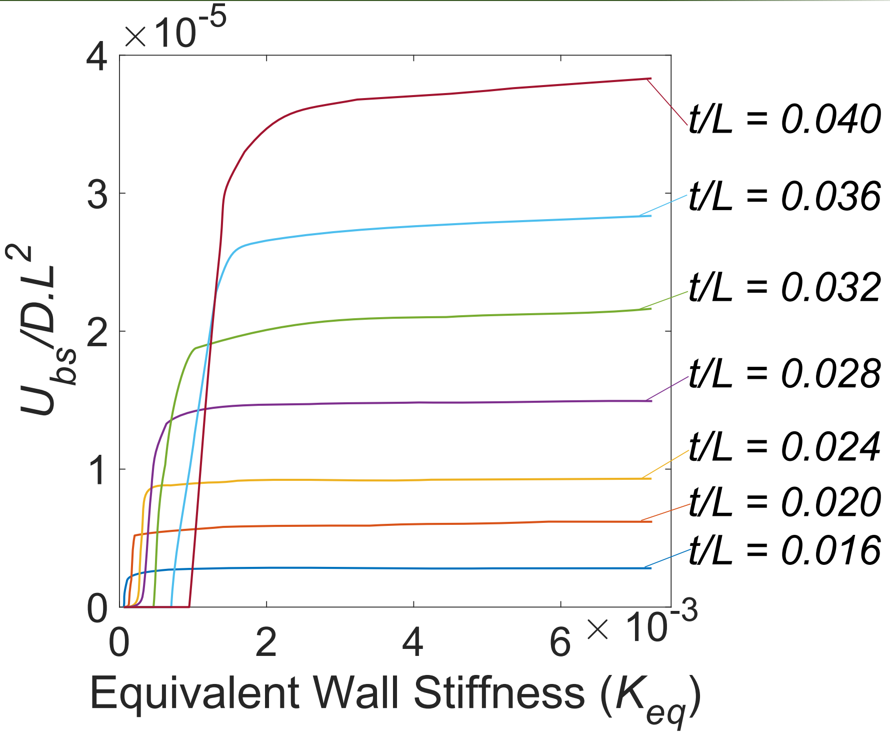
Takeaways:

- Maximum force has a direct relation with: struts' angle, struts' thickness, wall thickness, number of parallel struts
- Adding a ribbon of stiff materials to the walls can turn a monostable structure to a bistable structure

Niknam H et al., Applied Materials Today, 2022.

Wall stiffness and Bistability Energy

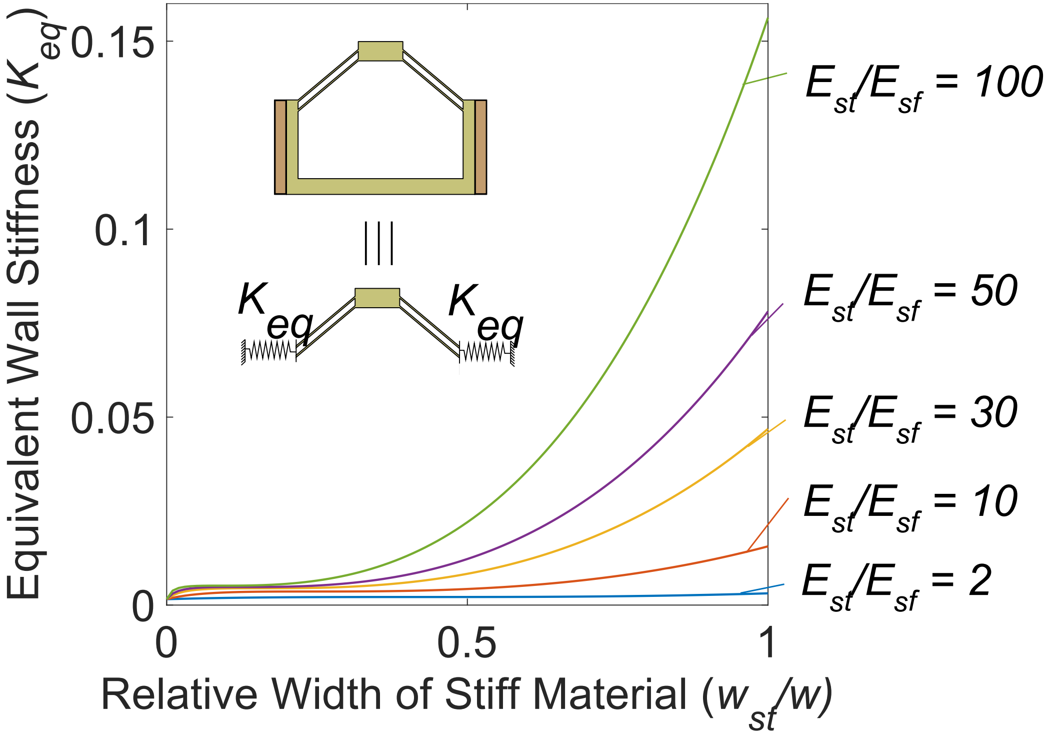


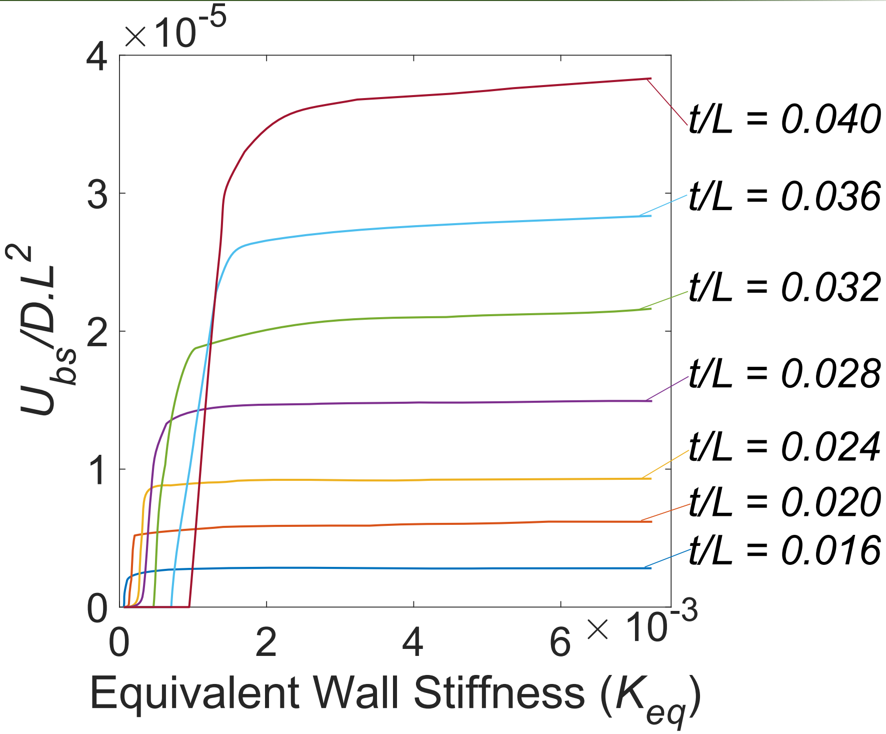


- The “Equivalent wall stiffness” is obtained using cantilever composite beam theory
- There is a “Critical equivalent wall stiffness” for a design with specified strut angle and thickness
- For walls stiffer than the critical value the structure is bistable

Niknam H et al., Applied Materials Today, 2022.

Wall stiffness and Bistability Energy





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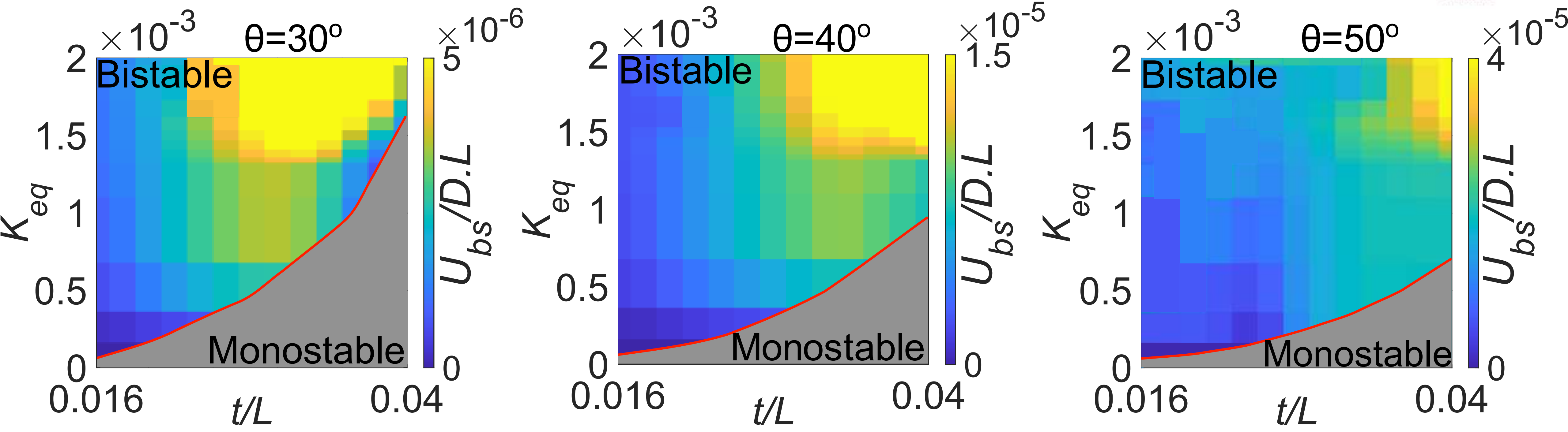
Wall stiffness and Bistability

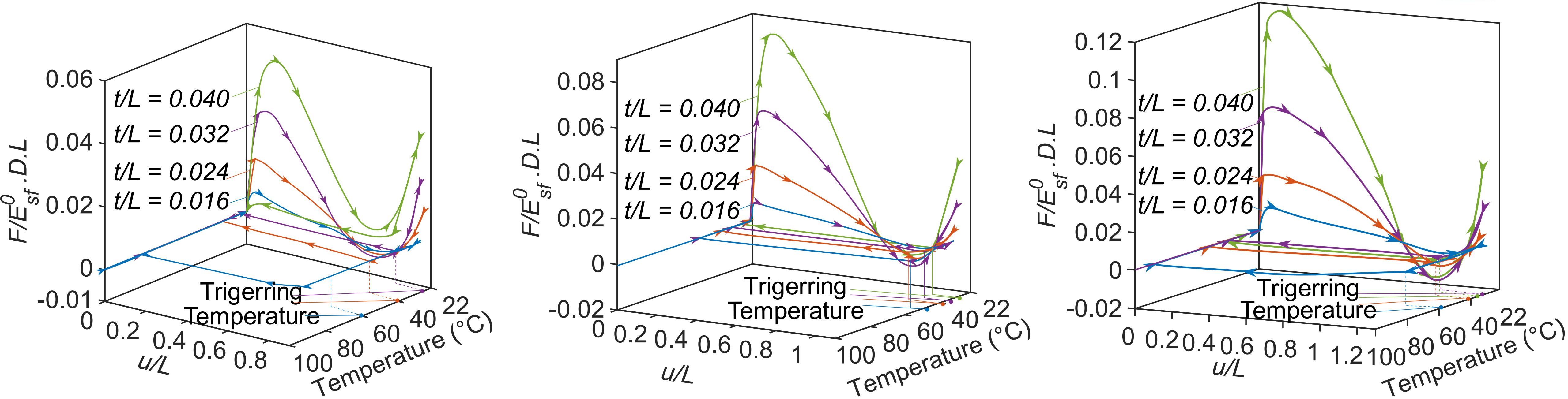


Takeaways:

- The critical value for "Equivalent wall stiffness parameter" has a direct relation with strut thickness and opposite relation with strut angles
- The non-dimensional bistability energy has a direct relation with "Equivalent wall stiffness parameter" for bistable structures

Niknam H et al., Applied Materials Today, 2022.

Force – Displacement – Temperature

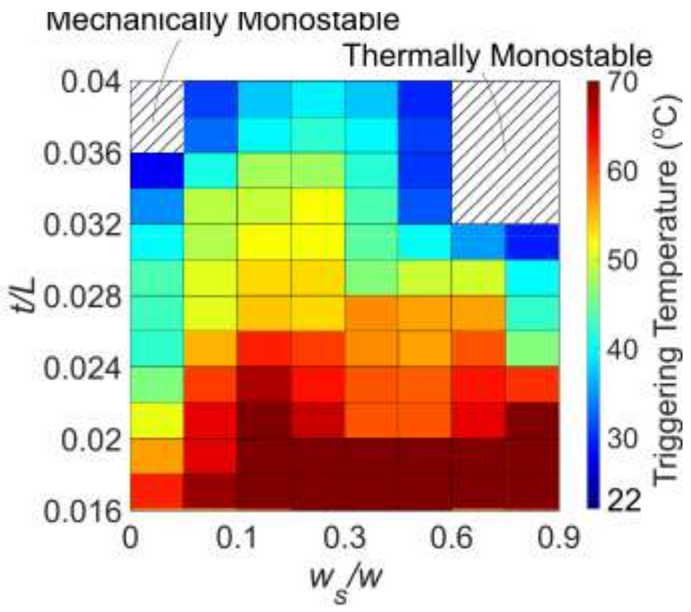


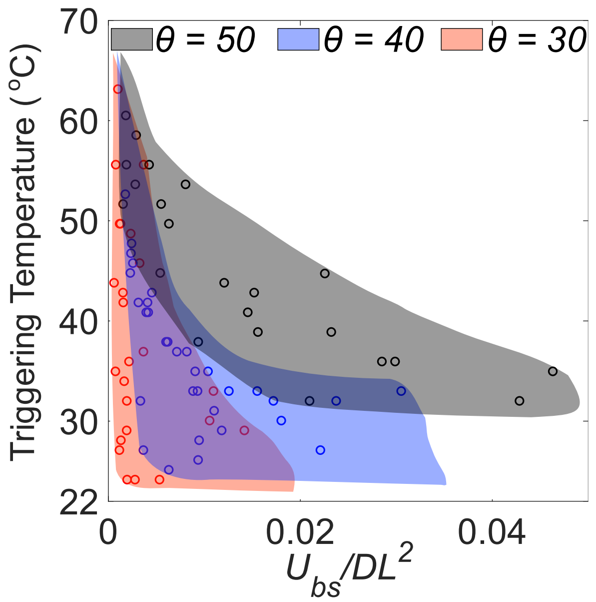
Takeaways

- According to FE results Triggering temperatures vary between 20ºC to 55ºC
- Force – Displacement – Temperature of the thermally bistable structure resembles shape memory alloys

Niknam H et al., Applied Materials Today, 2022.

Effect of design Parameters on Triggering Temperature



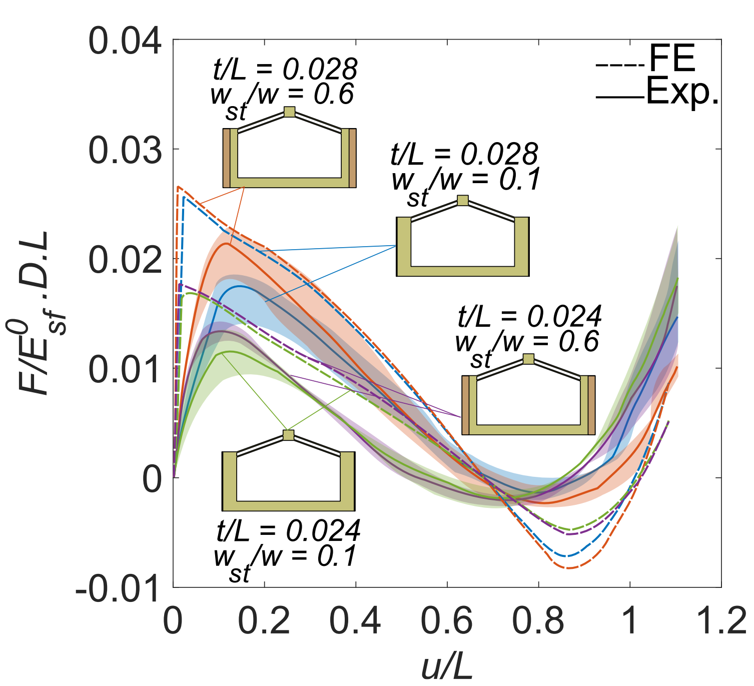


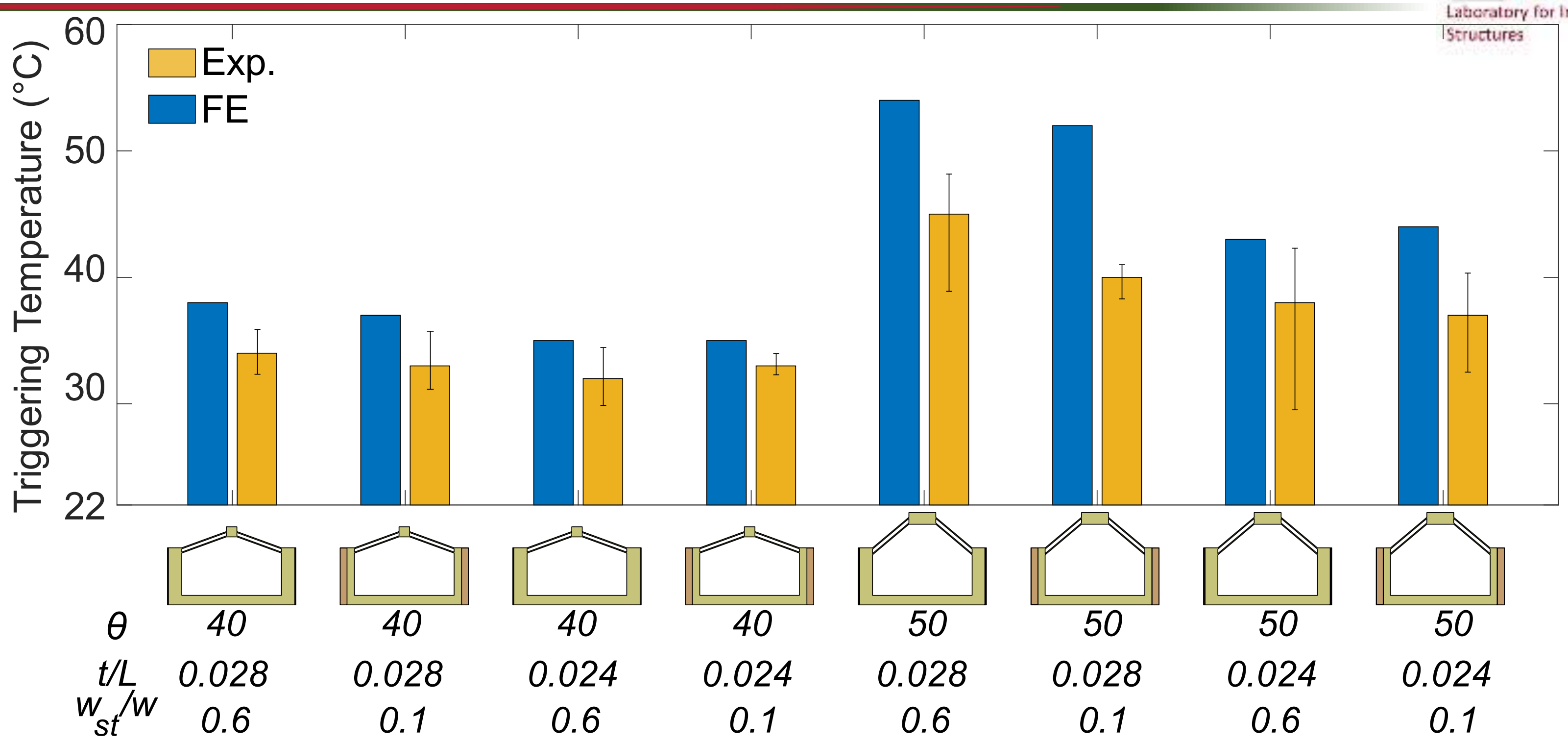
Takeaways

- Triggering temperature has an inverse relation with the strut thickness
- Triggering temperature has a direct relation relation with the wall stiffness
- Triggering temperature has an inverse relation with the bistability energy

Niknam H et al., Applied Materials Today, 2022.

Experimental Results





Takeaways:

- In general, FE and experiment predict same trends
- FE generally overestimates the maximum and minimum force of the bistable structures
- Experimental results for Triggering Temperature is less than FE prediction

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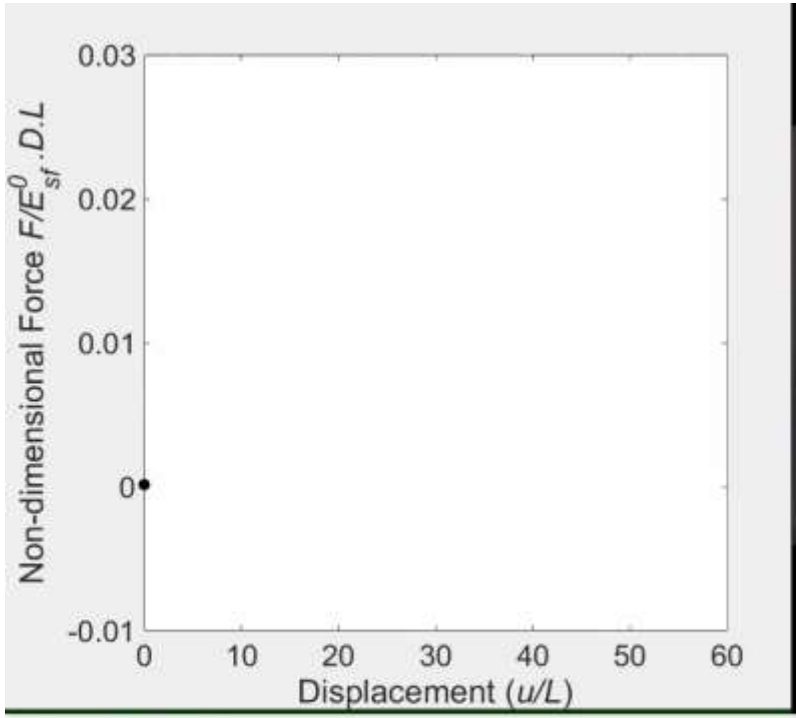
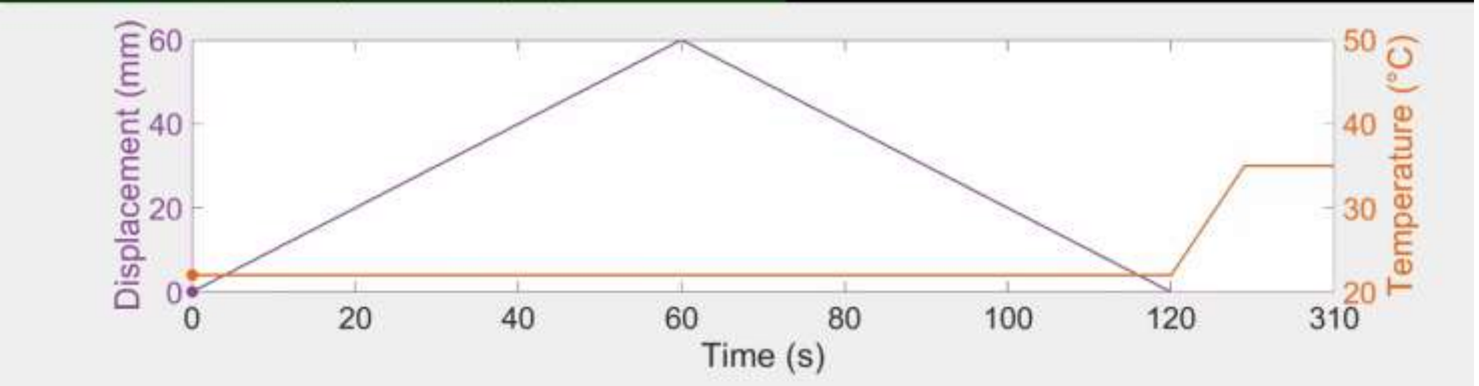
Experimental Results





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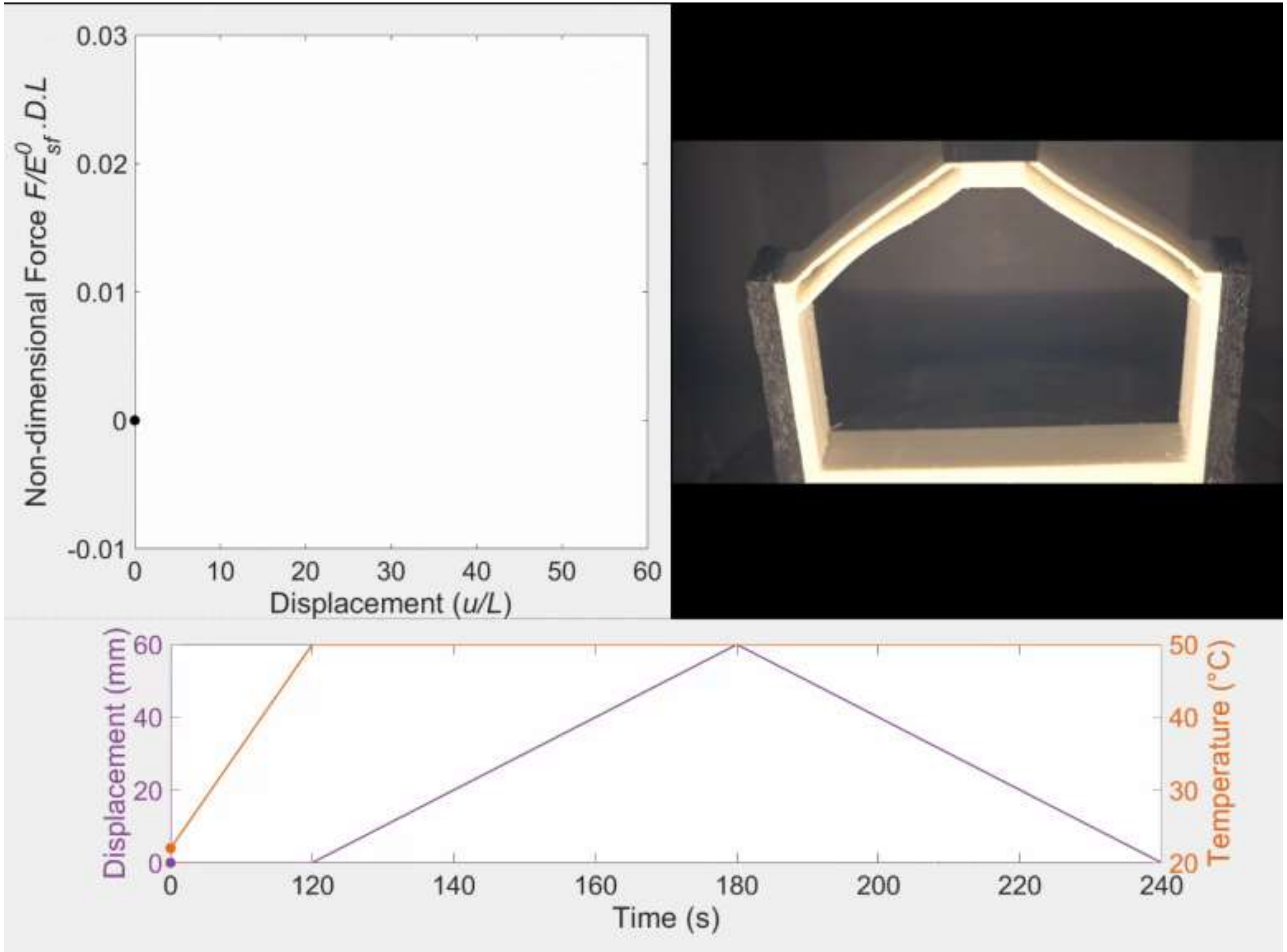
Experimental Results



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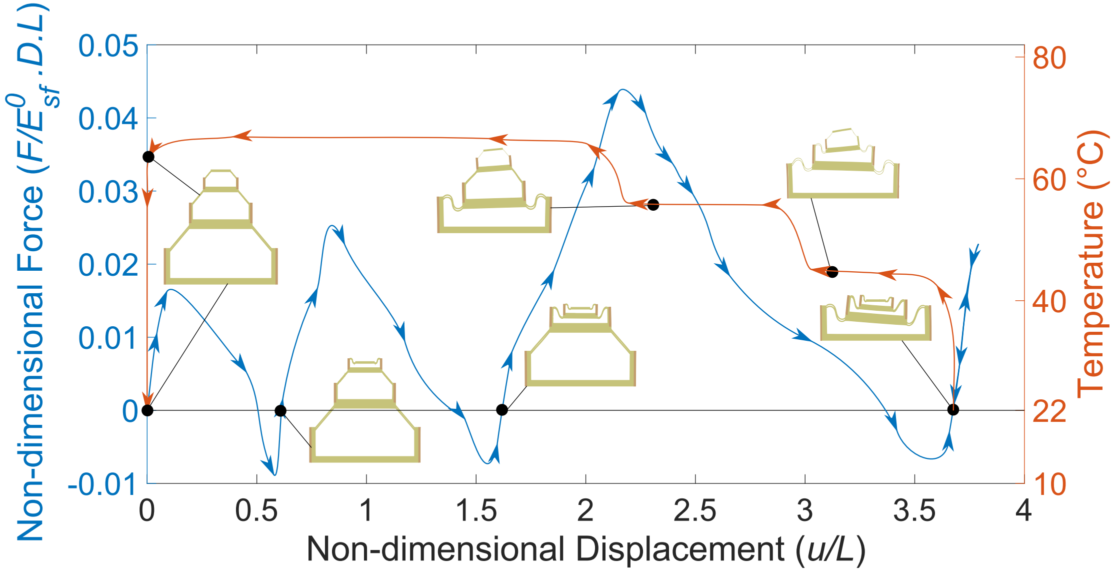
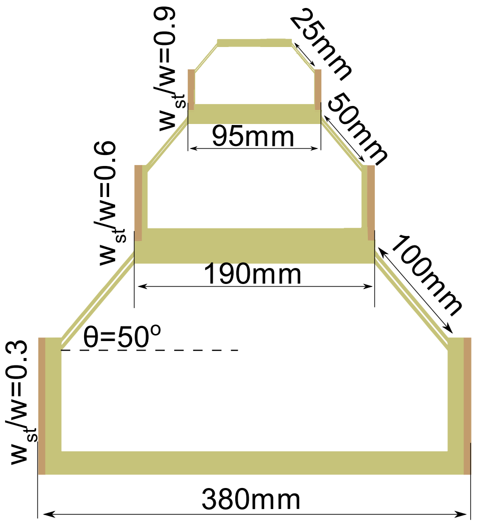
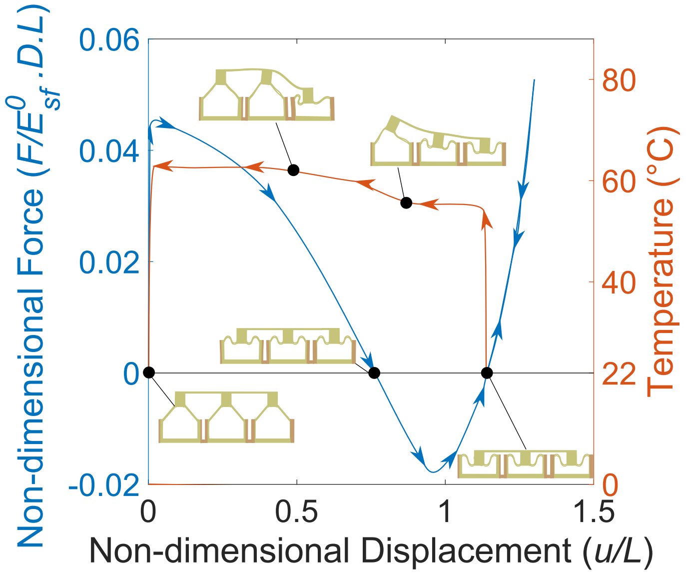
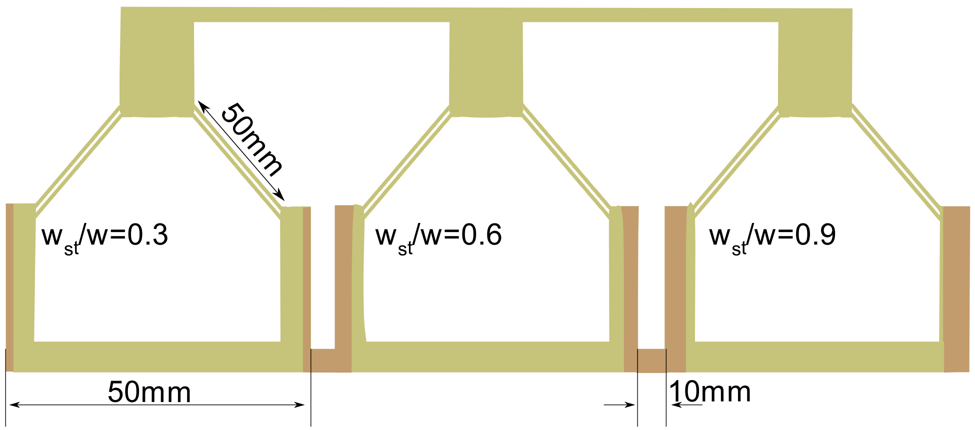
Tessellated Thermally Bistable Structure









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Concluding Remarks

- The proposed design paradigm enables attaining shape memory behavior without exploiting special polymers
- Unlike SMA and SMPs, the restoration of initial configuraiton happens in a snap-like behavior
- The triggering temperature can be tuned by changing the design parameters
- Through tessellation strategies, we can customize the response of thermally bistable structure by amplifying the deformation or tailoring the triggering temperatures
- Further research can enable us to utilize the design as self-sensing actuator since the design quickly responds to change in temperature

Acknowledgements

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and Composite Systems

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