THE OHIO STATE UNIVERSITY

Quantifying the Influence of Parametric Variations on the Effectiveness of Metamaterial Energy Dissipation Mechanisms

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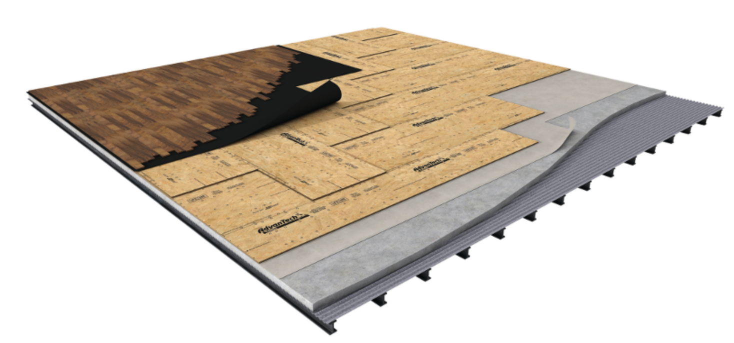
Motivation

Engineered elastomeric material systems to attenuate impact and vibration are of emerging interest for exceptional energy dissipation capabilities combined with lightweight design. These material systems may find application in personal protective equipment, construction and building materials, and more.

football helmet

Yet, by virtue of the integration of structural and material characteristics, quantitive relationships among system properties and energy dissipation characteristics are desired. This research aims to establish an experimentally-validated model infrastructure to design such metamaterials for desired vibration and shock mitigation performance.

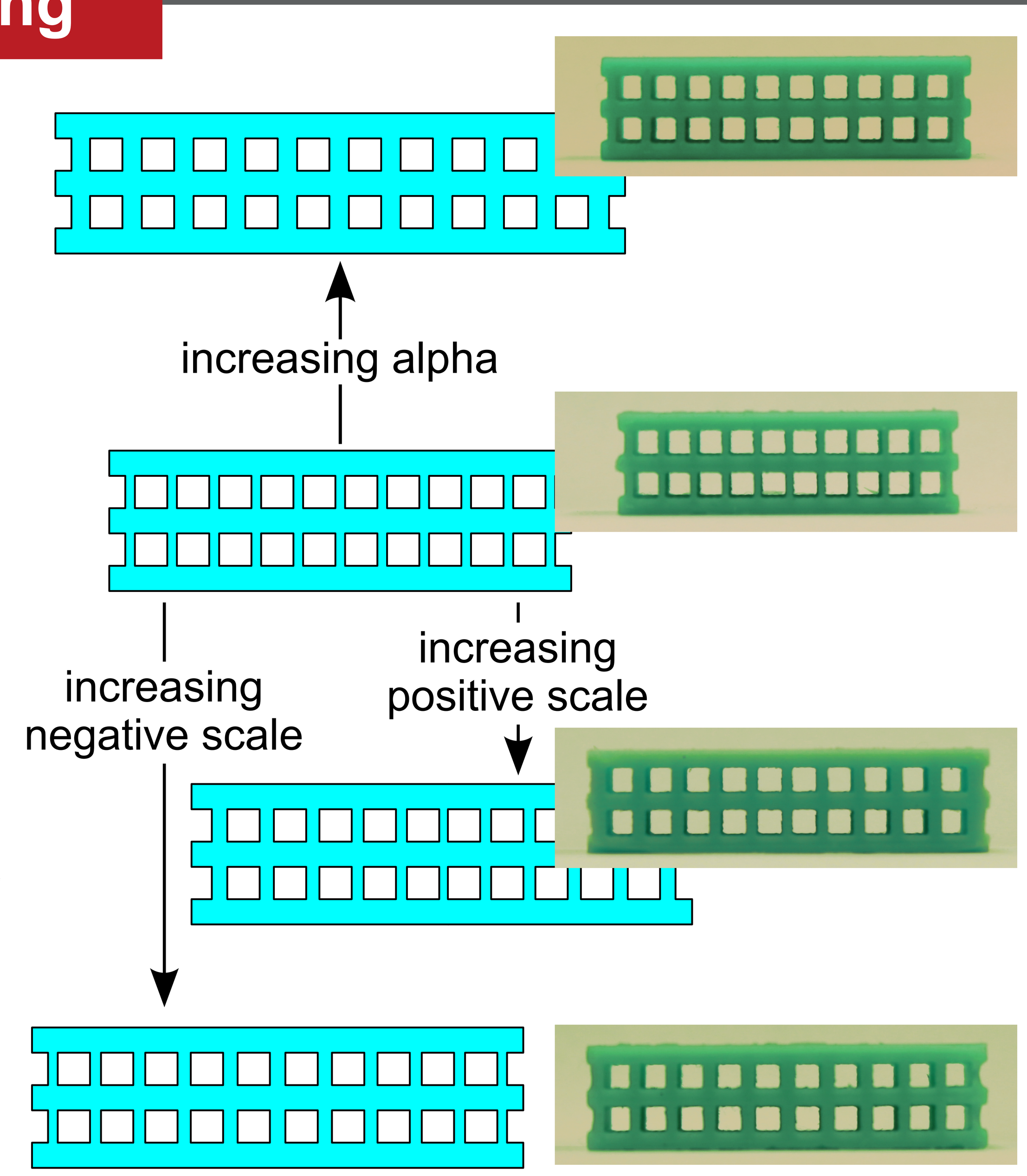


sub-flooring

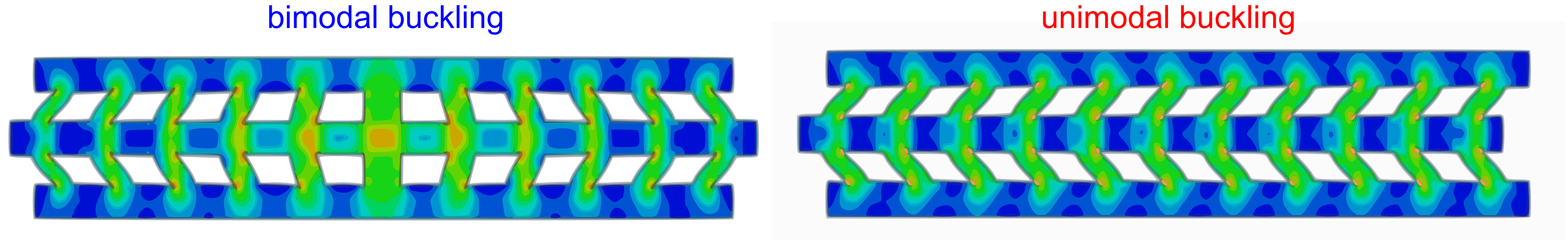
Computational Finite Element Modeling

Previous work has revealed that constrained engineered metamaterials magnify energy dissipation properties in accordance to the nearness of the constraint to criticality [1,2]. The geometric roles governing such behaviors have yet to be revealed.

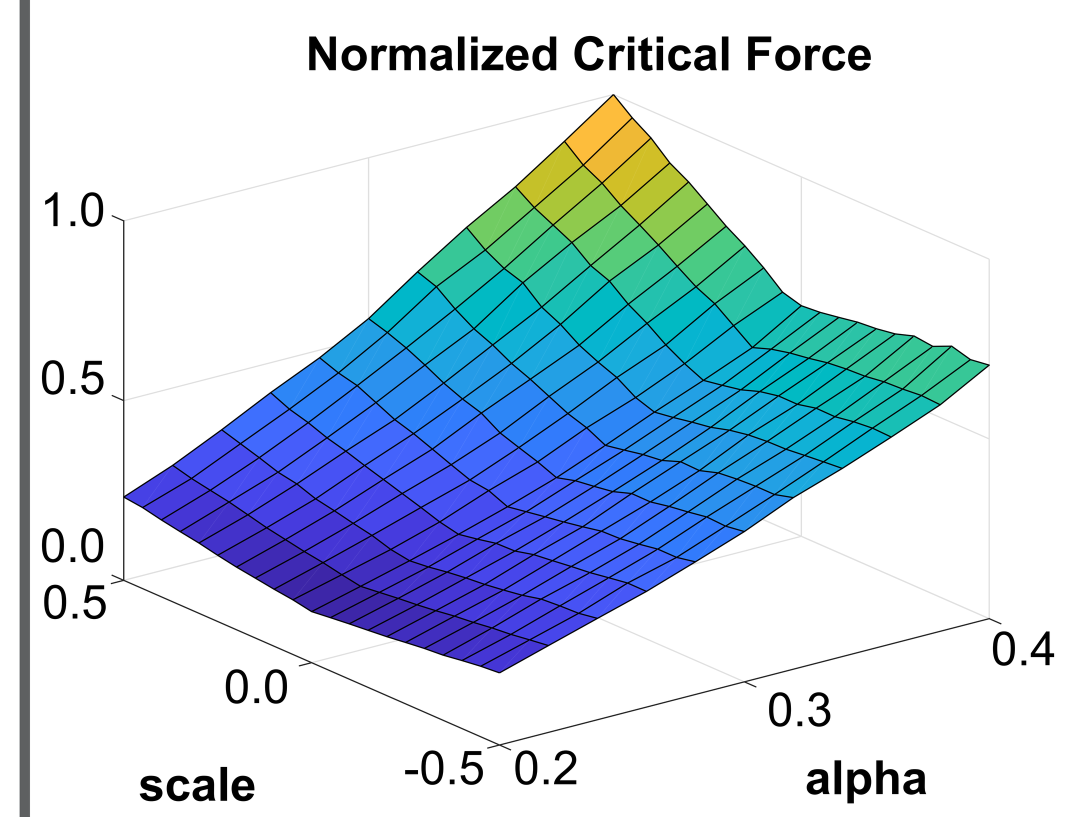
- ABAQUS Finite Element modeling is used to determine critical loading conditions
- The effects of varying thickness per length (alpha) and thickness gradient (scale) are studied in relation to **buckling behavior**, **critical force**, and **critical strain**

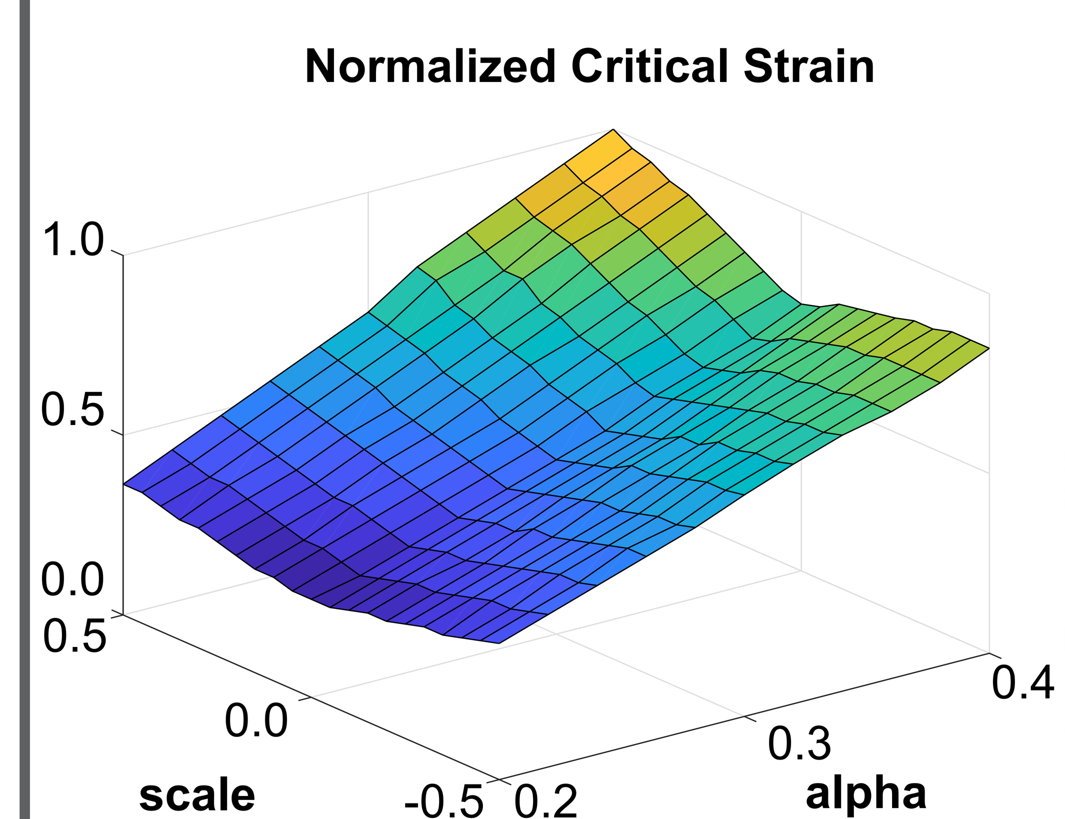


ABAQUS Finite Element result distinguishing buckling behaviors



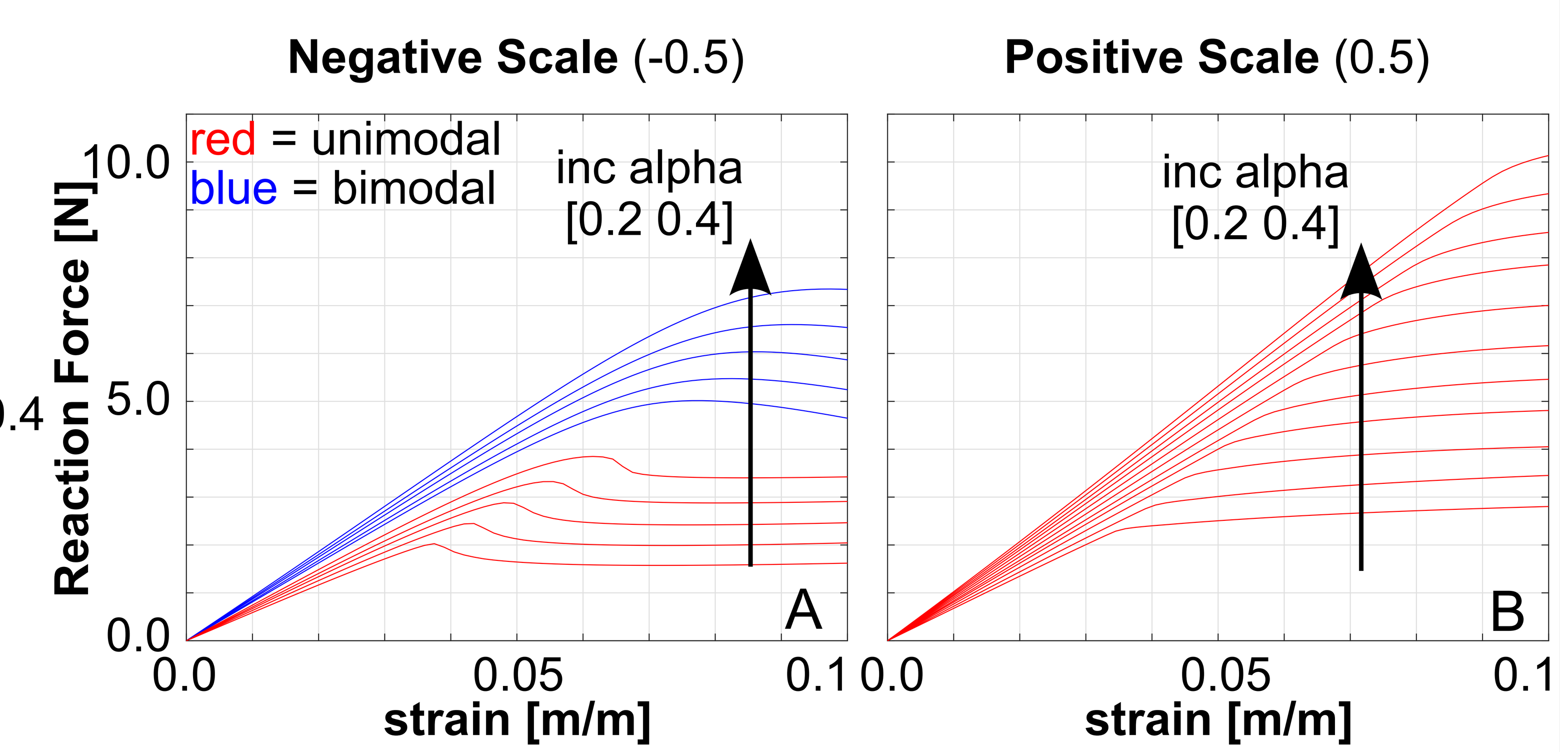
Critical Parameter Results and Evaluations





The contours indicate normalized critical point results for varying alpha and scale parameters.

- Critical force and strain trends are similar
- Trend of critical parameters with changing alpha or scale is approximately linear
- Positive scale shows greater increase in critical force/strain with increasing scale value than negative scale due to increase in avg. beam thickness
- For negative scale, bimodal buckling occurs for greater alpha
- Bimodal buckling mitigates the negative stiffness effect characteristic of buckling
- Uniform and positive scale exhibit unimodal buckling



Key Findings:

- The engineered metamaterials can be tailored to undergo collapse and energy absorption effects for a wide range of loading conditions
- Negative scale specimens mitigate negative stiffness event due to stretching of inner horizontal beams during bimodal buckling (Red vs. Blue in Fig A)
- Magnitude of scale must be great enough to achieve significant difference in thinnest to thickest beam for bimodal buckling to occur (Fig A/B are |scale|=0.5)

Ongoing Investigations

Experimental specimens are being fabricated and prepared for testing to characterize the efficacy of model predictions and energy dissipation properties

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[1] Cui, Harne, Int. J. Sol. Struct. 135:197-207 (2018). [2] Bishop, et al. *Adv. Eng. Mat.* 18:1871-1876 (2016).