Exploring the Material Property Space of Asymmetric Lattice Metamaterials

Srikar Srivatsa[1], Roshan Suresh Kumar[2], Daniel Selva[2], Meredith Silberstein[1]

[1]Sibley School of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY, USA
[2]Department of Aerospace Engineering, Texas A&M University, College Station, TX, USA

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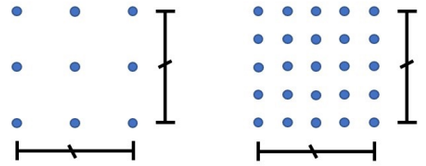
Introduction

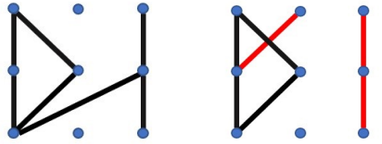
Lattice-based mechanical metamaterials can be tailored for a diverse array of applications by changing the underlying mesostructure. Most existing lattice patterns use symmetric patterns, while existing asymmetric lattice metamaterials are often distortions of symmetric lattice patterns. This study compares the metamaterial property space of asymmetrically-arranged lattice metamaterials to that of symmetric lattice metamaterials, and examines geometric traits present in both types of lattice patterns that contribute to differences between their respective property spaces.

Design Space of Lattice Patterns

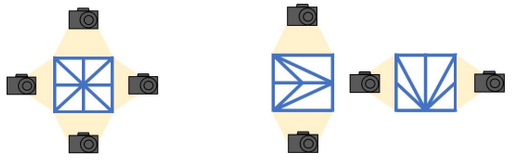
Definitions of design spaces



Feasible and infeasible designs within design spaces

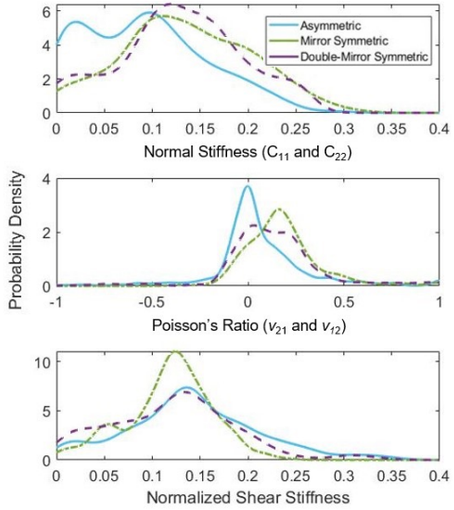


Double-mirror symmetry **Mirror symmetry**



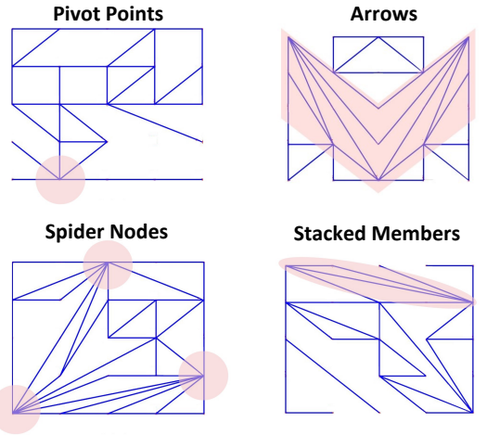
- A generative design process was used to create sets of feasible asymmetric, mirror symmetric, and double-mirror symmetric lattice patterns in both design spaces
- A reduced-order model with beam elements, constructed in ANSYS APDL, was used to simulate all the lattice patterns within linear elasticity at a unit cell scale

Metamaterial Property Spaces

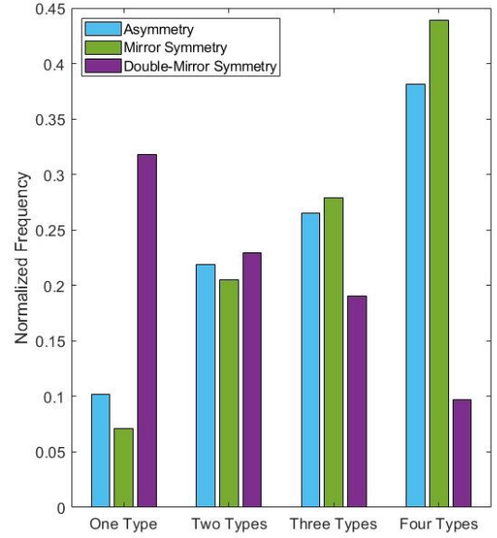


- Two-sample Kolmogorov-Smirnoff (K-S) tests show that the property spaces of asymmetric, mirror symmetric, and double-mirror symmetric designs are all distinct from each other

Design Features



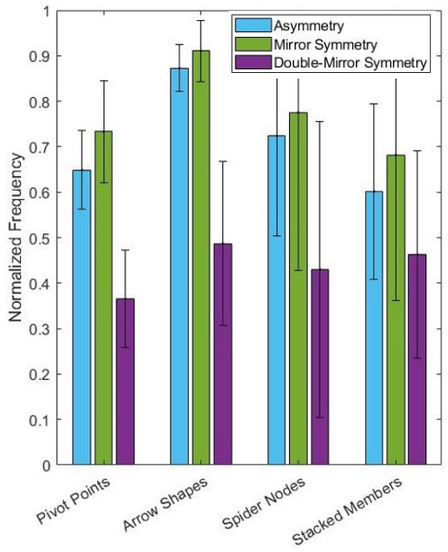
Intersectionality of Design Features



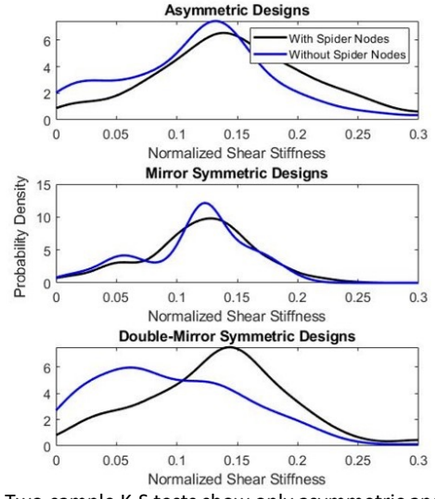
- Asymmetric and mirror symmetric designs have higher intersectionality of features than double-mirror symmetric designs

Impact of Design Features

Proportions of each design feature present



Effect of design feature on metamaterial properties



- Two-sample K-S tests show only asymmetric and double-mirror symmetric distributions are distinct

Conclusions

- The asymmetric, mirror symmetric, and double-mirror symmetric property spaces are all distinct from each other
- Design features are more likely to be present in asymmetric and mirror symmetric designs
- Only in mirror symmetric designs do spider nodes fail to impact the property space as expected
  Overlapping of features could explain how features behave differently with mirror symmetry compared to asymmetry and double-mirror symmetry

Acknowledgment

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