Buckling Analysis of HexaChiral Unit Cell

Luis Mendoza, Juan Camilo Velasquez, Juan David Navarro

The University of Texas at San Antonio, San Antonio TX, 78249

Name: *Luis Mendoza*
Status: *Sophomore, Undergraduate Student*
Department: *Mechanical Engineering*
Area of Study: *Advanced Materials*
USDA/UTSA Mentor(s): *David Restrepo Ph.D.*

AMMS Lab

The main research interest of the AMMS Lab is to advance in the fundamental understanding of nonlinear behavior and failure mechanisms observed in materials and structures, with the aim of designing new materials that exhibit unprecedented mechanical properties and functionalities. To achieve this goal, our research approach combines computational simulations, theoretical analysis, fabrication, and experimental testing. Applications of interest are in broad areas including healthcare, defense, robotics, civil infrastructure, mechanical engineering, and aerospace engineering.

Motivation or Background

Traditional mechanical energy dissipation mechanisms rely on yielding, fracture propagation, and failure. Elastic deformation and buckling allows for energy dissipation and return to its undeformed state when the loads are released. Periodic architectured materials are a noble and prominent field in materials research because they achieve extraordinary properties by the design of its unit cell. A novel hexagonal periodic material buckling behavior is studied here. The hexagonal periodic material was subjected to simple shear loading conditions, local kinks indicated the presence of localized buckling. Our hypothesis is that these local kinks correspond to the lowest energy content bukling mode of the structure, and are not caused by the imposition of periodic boundary conditions. To test this hypothesis, buckling analysis with Bloch's periodic
boundary conditions is performed.

Objectives

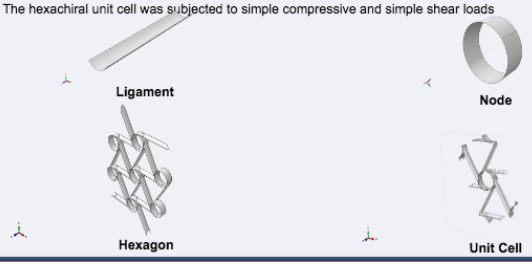
1. Developing the correct hexagonal periodic architectural material unit cell.
2. Execute buckling analysis with Bloch's periodic conditions.
3. Validate hypothesis of localized buckling.

Methodology

A novel hexagonal periodic material [1] has been proved to dissipate energy when subjected to axial compressive loads. However, it is believed that localized buckled ligaments are a results of imposing periodic boundary conditions. To verify this, Bloch's periodic boundary conditions has been used in a buckling analysis to verify the nature of these buckling behaviour [2,3]. Bloch's periodic boundary conditions impose periodicity at opposite boundaries, with a shift in the wavenumber domain [4].

The Mechanical properties used for this analysis correspond to ABS with Young's Modulus of 3.5 GPa and Poisson's ratio of 0.36. To limit the deformation in the circular nodes of the hexachiral unit cell, a stiffer material was used with Young's modulus of 3500 GPa.

The hexachiral unit cell was subjected to simple compressive and simple shear loads



Results

According to the theory, the relation between the frequency w^2 and the strain should be linear [2,3]. However, a non-linear behavior is identified when localized buckling takes place. Figure 1 shows this relation for the hexachiral subjected to compressive loads, and a local minima corresponding to buckling initiation.

Figure shows a similar behavior when the unit cell is subjected to simple shear loads

Both results suggest local buckling to be the cause of the kinks previously mentioned. Confirming our first hypothesis.

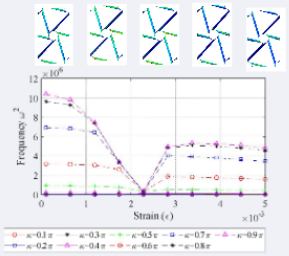


Fig. 1
Strain v. Frequency through compressive load

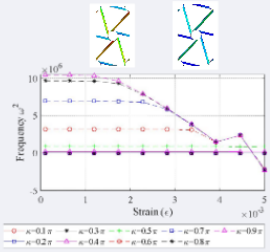


Fig. 2
Strain v. Frequency through simple shear

Skills and Experience

There were plenty skills and experiences gained through the research process. Becoming proficient in Abaqus by creating plenty of models, attaching nodes, meshing, assigning steps, and creating jobs to obtain input files.

What I Learned

The concept of Buckling Analysis and how it is related to Bloch's theorem.

How to use the infinite element method by the usage of Abaqus.

Future Plans

Parametric study is necessary to validate the effect of the geometry and the unit cell size on this hypothesis. Implementation of different materials, sizes, and quantity of unit cells could have an impact on the results obtained.

Acknowledgments

This work is supported by the USDA National Institute of Food and Agriculture, Interdisciplinary Hands-on Research Traineeship and Extension Experiential Learning in Bioenergy/Natural Resources/Economics/Rural project, U-GREAT (UnderGraduate Research, Education And Training) program (2016-67032-24984).

AMMS Lab, David Restrepo, Juan Camilo Velasquez, Juan David Navarro, Jens Knudsen, and Hayden Bilbo.

References

1. K. W. Hector, D. Restrepo, C. Tejedor Bonilla, L. G. Hector, N. Mankame, and P. D. Zavattieri, "Mechanics of Chiral Honeycomb Architectures With Phase Transformations," J. Appl. Mech., vol. 86, no. 11, Nov. 2019.
2. J. Liu and K. Bertoldi, "Bloch wave approach for the analysis of sequential bifurcations in bilayer structures," Proc. R. Soc. A Math. Phys. Eng. Sci., vol. 471, no. 2182, p. 20150493, Oct. 2015.
3. V. D. Do and P. Le Grognec, "Buckling analysis of a reinforced sandwich column using the Bloch wave theory," Thin-Walled Struct., vol. 115, pp. 323–335, Jun. 2017.
4. Brillouin, L., 1953. Wave propagation in periodic structures: Electric filters and crystal lattices, Dover Publications, 1st edn.