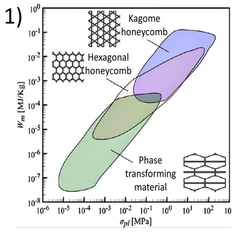
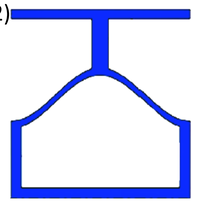
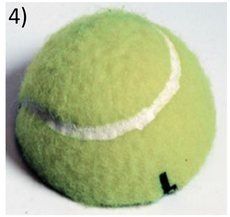
Phase Transforming Cellular Materials

Valeria Grillo[1], Yunlan Zhang[2], Kristiaan Hector[2], Pablo Zavattieri[2]
Pre-Engineering Department Ivy Tech Community College[1]
Civil Engineering Department, Purdue University[2]

Background and Motivation

- "Phase transforming cellular materials (PXCMs) are a class of materials whose unit cells exhibit multiple configurations (***metastable*** or ***bistable)*** [1]. The geometrical structure of the PXCM can change to increase the energy absorbed. The hysteretic nature of the PXCM makes the potential application of these cellular materials extremely versatile"[1]. The objective was to be able to research within the 3D realm for the purpose of constructing a 3D PXCM.

1) 

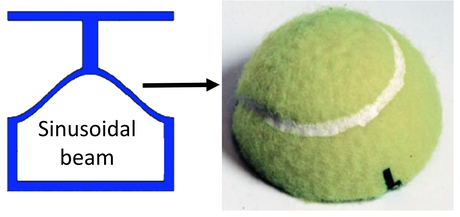
2) 
3) 
4) 

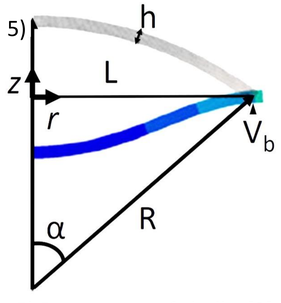
1) Ashby plot of PXCM. 2-4) Different geometric structure of PXCM)

Introduction

- A well known PXCM has a sinusoidal beam mechanism. During the summer the research group decided to test different geometries, in this case, shells were created with tennis balls.

- ✓ α = Alpha
- ✓ R = Radius from pole
- ✓ h = Thickness
- ✓ v = Poisson's ratio
- ✓ L = Lateral size.



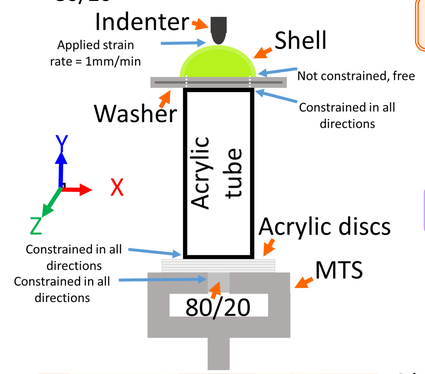
5) 

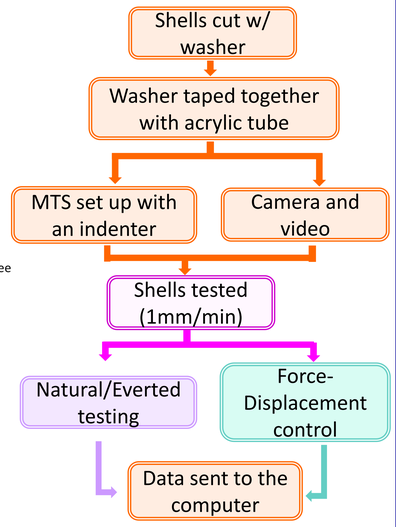
$$\lambda = [12(1-v^2)]^{\frac{1}{4}} \sqrt{\frac{R}{h}}\,\alpha$$

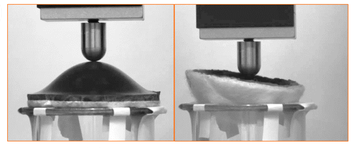
5) Parameters of shells. [2]

Experimental Methodology

- ✓ Tennis balls
- ✓ Acrylic tube/ discs
- ✓ MTS machine
- ✓ Washers
- ✓ Indenter
- ✓ Tape
- ✓ 80/20



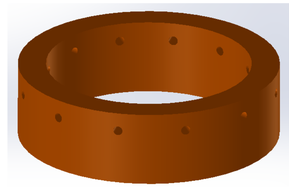


6.a) 
6.b) 

6) Set up of experiment: a) Natural state. b) Everted state.

Future Work

- Improvements to experimental set up:
  - ✓ Reduce friction of shells with acrylic tube.
  - ✓ Displacement control.

- Test all 4 regimes.
- Analytical equations.
- Create a code for shells to be implemented in tool.

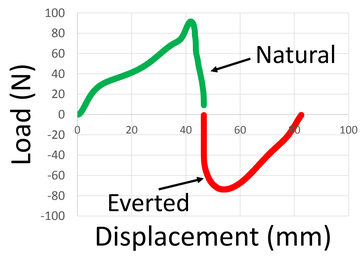
Acknowledgments and References

- Acknowledgements:
  - ✓ General Motors (GM).
  - ✓ Purdue University and Ivy Tech Community College.
  - ✓ Pablo Zavattieri , Kristiaan Hector and Yunlan Zhang.
  - ✓ Dr. David Ely.
- References:
  - ✓ [1] D. Restrepo, N. D. Mankame, and P. D. Zavattieri. "Phase transforming cellular materials". Extrem. Mech. Lett., vol. 4, pp. 52–60, 2015.
  - ✓ [2] M. Taffetani, X. Jiang, D.P. Holmes, D. Vella. "Static bistability of spherical caps". Proc. R. Soc. A., vol. 474, 2018.

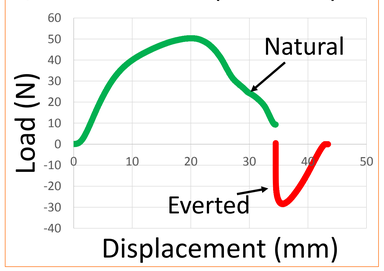
Results

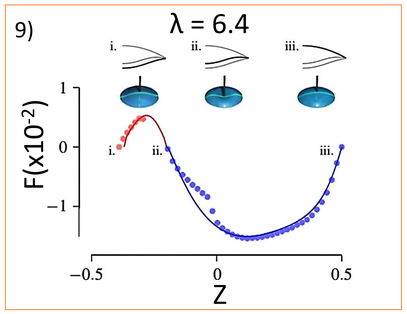
- The caps tested were part of the following regimes:
  - ✓ Monostable: $\lambda \leq 5.75$. Only natural state exist.
  - ✓ Axisymmetric snapping: $5.75 \leq \lambda \leq 7.2$. Both everted and natural states exist.
- Hysteresis in metastable shell.
- A longer indenter needed to be use with the 90° shell but worked well with 53° and 70°.

7) Bistable Shell (α = 90°)

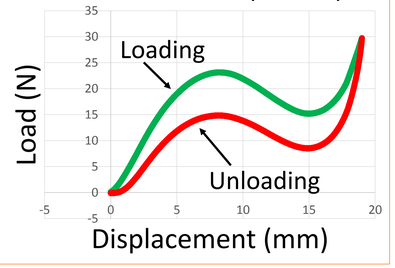


8) Bistable Shell (α = 70.3°)



9) 

10) Metastable Shell (α= 53°)



Graphs from data points collected from the computer. 7) λ = 5.93. 8) λ = 5.04 . 9) Graph from paper to compare [2]. 10) λ = 3.9

PURDUE UNIVERSITY | Network for Computational Nanotechnology DISCOVERY PARK | IVY TECH COMMUNITY COLLEGE | GM

This work is funded by the National Science Foundation, Network for Computational Nanotechnology Cyberplatform, Award EEC---1227110. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.