# MODELING AND TESTING OF BIOMIMETIC LAMINATE MATERIALS

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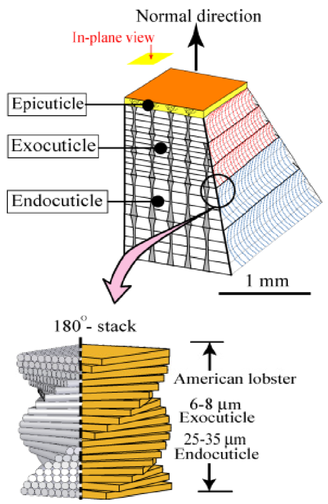
## BACKGROUND

### THE *HOMARUS AMERICANUS* SHELL




The exoskeleton of the *Homarus americanus (American lobster )* has 3 shell sections. The epicuticle is a waxy diffusion barrier on the surface. The exocuticle and endocuticle are the load-bearing portions.

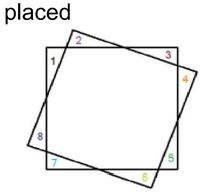
The load-bearing portions of a lobster shell are made of many uni-directional layers of chitin fibers that gradually rotate as they are stacked (i.e. a helix) .

*Objectives of this study:*
To prototype and test composite laminates with similar helical structures and compare their structural performance to conventional composite layups.

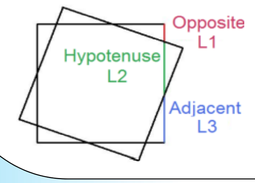
## COMPOSITE MANUFACTURING

### Manufacturing Techniques

Geometric observations were used to form a method for stacking the helix structure with square plies. 3 points where the perimeters of the plies intersect yields a unique location for the next ply to be placed

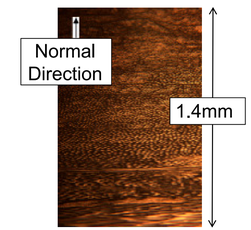


When two squares share the same center point, 8 equal triangles are formed

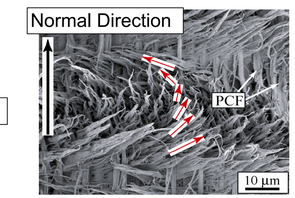



The sum of the sides of a triangle equals the length of one side of a ply (i.e. L1 + L2 + L3)

### The Mimicked Lobster Shell




Composite imitation cross section

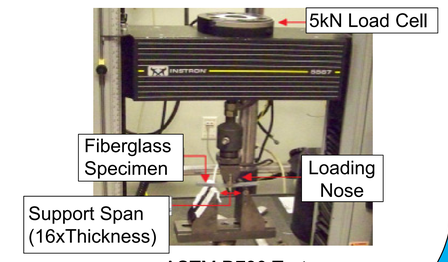



Lobster shell cross section

The biomimetic composite was created using a fiberglass prepreg to test for any practical applications. The composite imitation and lobster shell can be compared in the microscope pictures provided above.

### Testing

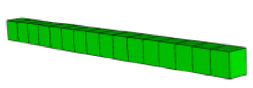
To date, two kinds of 3-point-bend tests have been performed on the biomimetic, unidirectional, and [0/-45/+45/90] composites:
1. ASTM D790 long beam test
2. ASTM D2344 short beam test




ASTM D790 Test

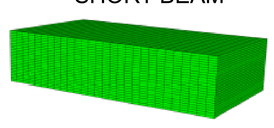
## ABAQUS FEA SIMULATION

LONG BEAM

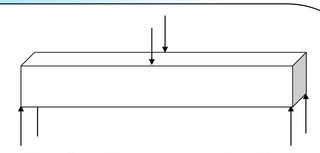


- Length/thickness ≈ 16
- SC8R Continuum Shell Elements
- 1 element through thickness
- Loaded at constant displacement to 5 mm

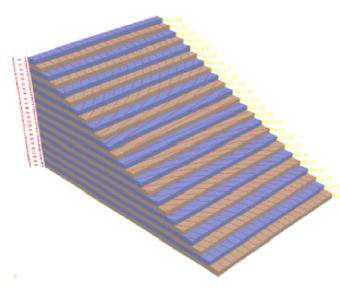
SHORT BEAM



- Length/thickness ≈ 4
- SC8R Continuum Shell Elements
- 24-30 elements through thickness
- Loaded at constant displacement to 1/2 mm

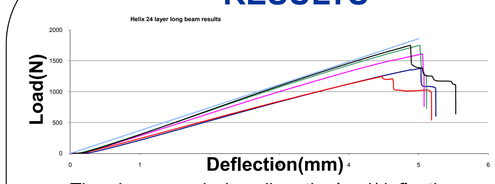


Loading Conditions: constrained in the z-direction at the bottom 4 corners, two point loads at center of the beam



Helix Lay-up cross section

## RESULTS




The above graph describes the load/deflection curves for the long beam biomimetic structure tests. The light blue line represents the FEA simulation. Five long beam (ASTM D790) and short beam (ASTM D2344) specimens were tested for every type of composite structure

**Elastic Moduli (GPa) for long beam tests**

| [0/90] | | helix | | unidirectional | |
|---|---|---|---|---|---|
| experimental | FEA | experimental | FEA | experimental | FEA |
| 25.53+/- 0.55 | 25.36 | 31.67 +/- 0.91 | 37.30 | 47.73 +/- 5.00 | 43.20 |

## CONCLUSIONS

- A method was successfully developed to manufacture helicoidally oriented composites.
- FEA results for the long beams matched experimental results well.
- FEA results for the short beam differed slightly from the experimental results.
- The helical structure demonstrated a higher elastic modulus than a conventional 0/90 layup.

## ACKNOWLEDGEMENTS

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