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Bio-inspired helicoidal composites: 3D Printing and Experiments

Michael E. Jones, Nobphadon Suksangpanya, and Pablo D. Zavattieri
Lyles School of Civil Engineering, Purdue University

ABSTRACT

Materials that are impact resistant enough for personal protection in sports, transport, and combat are not also lightweight, strong, tough, and impact tolerant. Nature can provide inspiration for novel materials that can meet these needs. The hierarchical composite of the stomatopod's, or mantis shrimp's, dactyl club has been shown to have high impact resistance and damage tolerance due to its helicoidal fiber reinforcement[1,2]. Analyzing helicoidal composites of different pitch angles (angles between adjacent rows of fibers) under quasi-static, displacement-controlled loading has provided insights into the fracture mechanisms of the composite structure and how they affect the macroscopic properties of the material. Three-point bending tests, alongside crack-twisting models, have yielded insights into key damage mitigation mechanisms in helicoidal composites. Utilizing computer-aided design to generate models and a multi-material 3D printer to fabricate the models, appropriate fiber diameter and gaps between individual rows of fibers were determined by fibrous tensile tests and plate gap tests. Helicoidal beams were then printed and tested in three-point-bending. Subsequently, specimens with twisting interfaces were printed and tested to failure. Our experimental results indicate that under the quasi-static loading condition, the composite with a 45° pitch angle was stiffest, but experienced more delamination failures. The lowest pitch angle tested, 5°, created a large, twisting crack, but maintained its shape after unloading. The helicoidal architecture forced the composite to fail in a twisting manner, becoming more resistant as the crack propagates. Future work will continue to explore the influence of pitch angles on failure modes.

KEYWORDS

Helicoidal, composite materials, fracture, 3D printing, stomatopod, mantis shrimp

REFERENCES

1. Grunenfelder, L. & Suksangpanya, N. *et al.* Bio-inspired impact-resistant composites. *Acta Biomater.* 12 (2014). doi:10.1016/j.actbio.2014.03.022

2. Weaver, J. C. *et al.* The stomatopod dactyl club: a formidable damage-tolerant biological hammer. *Science* **336,** 1275–80 (2012).