

ABSTRACT

The smashing mantis shrimp is a crustacean that uses a dactyl club to defend or to prey on other animals. This dactyl club is so strong that can achieve accelerations of a bullet of a caliber 0.22 gun and impact without breaking, so we will like to unveil the secrets behind the amazing properties of this club that withstand several high damage impacts without breaking catastrophically. The dactyl club is composed of 3 parts: the impact region, the periodic region, and the striated region.

We are first interested in the periodic region. It was found that this region is formed of a helicoidal arrangement of fibers called bouligand architecture, and that in this architecture cracks only form between fibers (at the matrix only). We thus first begin to research this bouligand composites analyzing the approximation when we have a single helicoidal crack embedded in an isotropic material in a disk with a notch under quasistatic boundary condition. We found that there is an enhancement of fracture mechanics properties when we increase the pitch angle, increase that we can see with the load-displacement curves and parameters like the area, width, and depth of the crack. In the following section, we develop a coarse-graining model, that allows multiple crack formation. This approximation tells us that as the initial crack grows the energy release rate diminishes (this is the driving force of the crack propagation) and the crack isolates allowing multiple crack nucleation and delocalization, at the same time this dissipates more energy as more crack surface is produced.

We then proceed to model helicoidal composites with Hashin damage model for intralaminar behavior and cohesive zone model for interlaminar failure under different boundary conditions, geometries, and material properties. We find that the helicoidal composites outperform the reference ones in peak load, absorbed energy, and so on.

The next part of this report is dedicated to the bicontinuous particles present in the impact region of the dactyl club. These bicontinuous particles are made of a soft phase (organic) and hard phase (HAP) that can withstand high strain rates improving their stiffness and strength. On the other hand, preliminary studies seem to suggest that they are good against cyclic loading.

Finally, we proceed to use the helicoidal composites to design structural parts. We introduce a model for simulating the fiber reinforced composites called LARC05. We do the verification and validation and then use models for fiber reinforced composites for layup composites.