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Minimum Weight Optimization of Honeycomb Core Sandwich Panels for Origami-Inspired Shelters

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1. Abstract

Deployable shelters, which expand from a small packaged size to a large usable volume, are a great asset for military or disaster relief operations for which transportability is at a premium. Origami is an exciting source of inspiration for such shelters since (1) folded panels in the deployed shape can offer flexural rigidity and (2) these folds can then be employed to package the structure into a small volume. Weight is critical for the feasibility of these shelters for both ease of transportation and erection. Honeycomb core sandwich panels are an excellent material for these rigid-walled structures since they are lightweight with a high stiffness to mass ratio. A challenge in selecting honeycomb core, however, is the wide variety of options for material selection (for the face and core) and the thickness of each component. This paper presents an optimization procedure to select configurations of honeycomb panels for rigid-walled origami-inspired shelters. There already exists a long history of structural optimization of honeycomb core panels by leading engineers. The novelty of the approach presented here includes the specific application to origami shelters, the simplified approach employed which approximates the structural behavior of the panels to avoid time-intensive finite element analyses, and the focus on selecting commercially available materials.

The aim of this optimization procedure is to select the materials and thickness for the core and the faces (the design variables) of honeycomb core panels for minimum self-weight subject to structural constraints. The structural constraints include meeting requirements for critical limit states under applied loads, including panel buckling, face stress, core shear stress, shear crimping, face wrinkling, intra-cell buckling, and deflections. The applied loads are defined by the US Army Natick Soldier Research, Development & Engineering Center and include self-weight, wind, snow and rain. Simulated Annealing, a heuristic algorithm that searches the design space based on analogy to crystal formation, was employed for this optimization procedure.

This paper demonstrates this approach for a simple origami-inspired shelter (2.4m wide, 2.4m long, 2.1m high), comprised of horizontal roof panels supported by vertical wall panels. This approach is intended as a simplified procedure to quickly obtain an initial optimized result for a configuration. Final design would require a full finite element analysis and further consideration of connection details. However, this can be a useful tool for a designer to narrow in on optimized configurations.

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