PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
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Spatial Tailoring and Optimization of Buckling Performance in Additively Manufactured and Fiber-Placed Structures

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Abstract

Additive manufacturing (AM) enables enhanced design flexibility and performance by allowing spatially tailored material properties and geometries. This study investigates the use of such technologies to improve the buckling performance of isotropic, anisotropic, and sandwich structures, an important design consideration for aerospace applications.

The first part of this dissertation presents semi-analytical and numerical methods for optimizing the buckling performance of additively manufactured panels. The second part employs machine learning techniques to generate fiber-tow path designs for the Automated Fiber Placement (AFP) process.

A generalized technique based on the Ritz formulation forms the foundation of a semi-analytical (SA) framework that captures spatial stiffness variations in isotropic, anisotropic, and sandwich structures. For isotropic plates, variations in thickness, modulus, and combined stiffness parameters are modeled using Fourier basis functions. For anisotropic composites, fiber-angle and thickness variations are represented similarly. Single-objective (SOO) and multi-objective (MOO) optimization studies demonstrate more than a 25% improvement in buckling resistance at constant weight and yield Pareto-optimal designs that balance weight and structural performance.

The findings show that substantial gains in structural performance can be achieved through spatial tailoring of stiffness and material properties. In 3D-printed structures, mesoscale properties are tuned via process parameters, while in composites, similar control is achieved through fiber-angle steering using AFP. The second part of the study develops a convolutional neural network (CNN) model to predict manufacturable fiber-tow paths from optimized ply-angle distributions.

Overall, this work establishes a comprehensive framework for stiffness-tailored, high-performance aerospace structures and advances optimization-informed manufacturing by leveraging the design freedoms enabled by emerging technologies such as AM and AFP.