DESIGN, PRINTING, AND CHARACTERIZATION OF AEROSPACE MORPHING COMPOSITES

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Multifunctional structural composite are key enablers to future aerospace systems and have the potential to improve mission range and agility without significantly adding weight or reducing internal payload volume. This presentation will discuss efforts to accelerate the design-build-characterize development loop of non-traditional composites using multiphysics design/optimization tools, additive printing of fiber reinforced composites, and in-situ characterization. Previously, multiphysics design/optimization tools were integrated and applied by AFRL for the development of structurally embedded, physically reconfigurable, liquid metal, vascular antennas arrays (SEVA2) with nearly two orders of magnitude modulation in resonant frequency and active thermal management (1). More recently, fiber-reinforced thermosetting printing of structural composites with 90% and 66% of the theoretical tensile modulus and strength of a fully aligned fiber composite have been demonstrated (2). Within this presentation, we discuss the extension of these tools to the rapid exploration, fabrication, and characterization of morphing skins that enable large fuselage bending as a means to improve aero efficiency and agility. The majority of previous efforts in the area of morphing skins have focused on the folding, shear, rotation, or extension of wings. We specifically investigate the optimal designs for composite cylinders that balance the out-of-plane rigidity needed to resist aerodynamic load, and the work needed to reversibly articulate the cylinder 25 degrees or more in any direction while maintaining a smooth outer mold line. We explore thousands of designs for more than a dozen archetypes using bio-inspiration, topology optimization, and finite element methods to arrive at a set of non-dominated designs spanning a range of radial rigidity values and works to articulate. To validate modeled results, we fabricate and characterize each archetype and show strong agreement between model predictions and measured response. As part of the optimization, graphical material selection methods are used to identify the top performing material classes from a known database. We then explore the application of the previously printed composites, embedded actuation, and shape memory polymers for the further optimization of the most promising structures. Overall, we apply advanced design, optimization, printing, and testing methods for the accelerated development of previously unexplored multifunctional morphing skin composites.

Figure 1 – Design, validation, & optimization of cylindrical composite morphing skins