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Rapid Aerostructural Design of UAV Wings With Direct Toolpath Generation

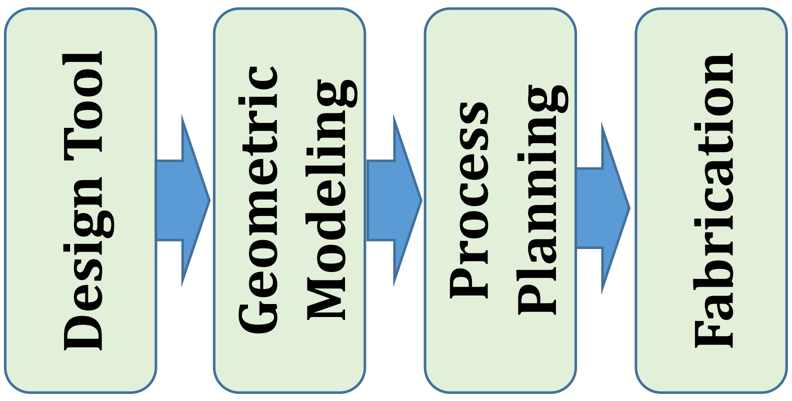
Justin Valenti and Michael Yukish

Research Task / Overview

- Design of lightweight aerospace structures is limited by AM restrictions such as: minimum feature size, geometric and mechanical anisotropy, and thermal warping
- AM provides the opportunities for greater complexity (complex curvatures, lattice structures, etc.) and mission specific designs
- A complete understanding of the workflow is required to fully leverage AM opportunities while respecting its restrictions
- A design tool has been developed that consolidates and streamlines the digital thread for AM wings while incorporating AM process and geometric constraints

Rethinking the Digital Thread

- The four steps of traditional AM workflow (pictured below) are often treated individually, allowing for poor or unmanufacturable designs to make it to the process planning or even fabrication stage, leading to part failure



- Even when all steps are considered up front, the handoff of designs between steps often leads to errors due to file conversion and human error
- Rethinking this process can help designers fully utilize AM

Goals & Objectives

Develop a complete toolchain, from design to printer, specifically for AM UAV wings.

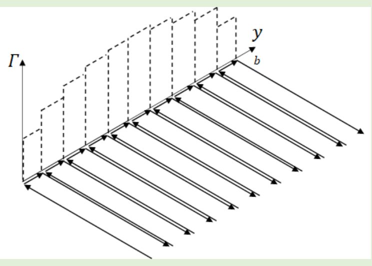
Design Methodology

- Rapid, low-order analyses are developed to allow the designer to rapidly iterate and print designs
- The wing is modeled as a simple line running from the left wingtip to the right.
- An aerodynamic design tool uses Lifting-Line Theory to generate the outer shape of a wing to provide the desired aerodynamic performance
- A structural tools used Beam-Bending Theory to generate the internal structure of the wing to carry the aerodynamic loads
- The aerodynamic and structural tools are tightly coupled to form an aerostructural design tool , which informed by the final choice of AM machine to rapidly produce a “printable” design

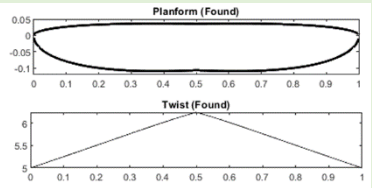
Proposed, Novel Digital Thread for AM Wings

Aerostructural Design

Aerodynamic Design

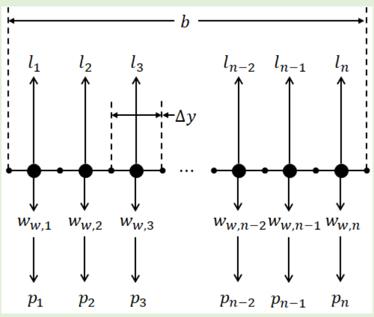


Lifting Line theory models the wing as a lattice of vortices (pictured above) and is used to calculate the spanwise distributions of wing chord and twist (example shown below)

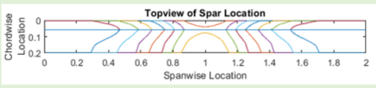


Tightly Coupled

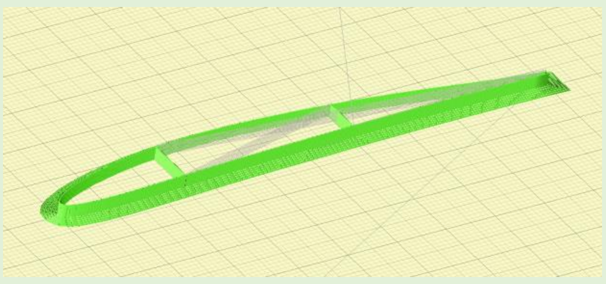
Structural Design



Beam bending theory is used to calculate the expected moments across the wing (pictured above) and is used to generate a wing structure (example pictured below) that is stiff enough to carry the loads



Direct Toolpath Generation



The aerostructural design and knowledge of the 3D printer is combined to directly generate GCode, bypassing CAD and Slicing, ensure a printable design

Conclusions

- If the specific design problem domain is known, structuring the workflow into a problem-specific digital thread speeds up the iteration
- The added upfront work pays off by allowing the designer to be flexible with the final product
- In the context of an additively manufactured UAV, this allows for the rapid re-design of a UAV for any new missions

CONTACTS

Justin Valenti, Doctoral Candidate, Aerospace Engineering, jdv5076@psu.edu
Michael Yukish, Assistant Professor, Aerospace Engineering, may104@psu.edu

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