Composite Wing Development

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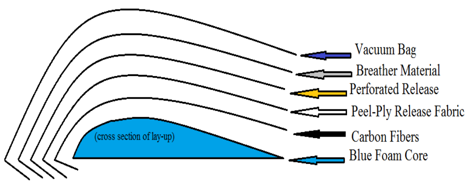
The Project

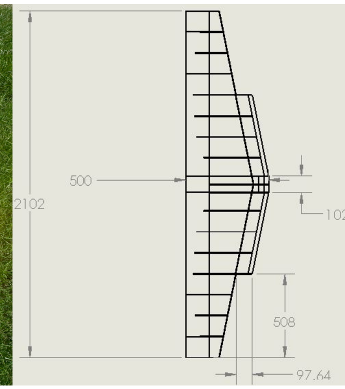
Develop an unmanned Aerial vehicle (UAV) wing with improved strength and durability using carbon-fiber composite technology

Construction Technique



- The vacuum pump holds a constant negative pressure, forcing the fibers to take the shape of the foam core, and allowing resin to flow evenly across and through the fibers.
- The vacuum bag is a plastic sheet that creates an airtight seal around the whole lay-up.
- Excess resin is soaked up in the breather material (usually cotton batting), and if there is a lot of excess resin, it flows into a trap, keeping resin away from the pump.
- The perforated film creates a barrier between the release film and breather material.
- Release fabric is usually a type of polyester fabric, whose main purpose is to keep the above layers from contacting the part. It will not stick to the part, even after the epoxy has cured.
- The laminate plies would be the actual carbon fiber fabric, covering the mold or core.

The Plane and Wing



Dimensions in mm

Finished Wing

Actual Construction

Foam core (with carbon rod contained), before carbon fiber lay-up

Foam core after being wrapped in carbon fibers, with construction layers and epoxy added, and curing under the vacuum bag

3 Main Wing Components

The main components of the enhanced wing are:

- the blue insulation foam core, used to provide the aerodynamic shape
- a carbon composite rod located in the foam core, acting as a wing spar
- and a carbon fiber composite shell for overall strength and durability

Technical Accomplishments and Lessons Learned

- A heavier, but more durable wing (~2lbs. heavier)
- Detailed build instructions for future replications
- Vacuum bag lay-up for very low cost in materials and equipment

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- Less epoxy and a more careful application, would have resulted in a lighter composite wing
- How to modify composite application techniques for the application
- How to work together with different design teams
- How to work within a tight budget

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The IEEE AESS Student Chapter at the Missouri University of Science and Technology (Missouri S&T) is developing an unmanned aerial vehicle (UAV) for student competitions, such as the UAV Outback Challenge (www.uavoutbackchallenge.com.au/). This competition, sponsored by the Australian Research Centre for Aerospace Automation, lends an opportunity for student-led teams to improve designs for autonomous, search-and-rescue vehicles. The second-generation UAV for Missouri S&T is based on a fixed-wing airframe designed in collaboration with an Aerospace Engineering Senior Design class to meet requirements of 1) a flight time of approximately one-hour, 2) a load capacity sufficient for needed on-board electronics and search-and-rescue payload, and 3) stable flight characteristics suitable to facilitate image capture. In this project, an enhanced composite wing was developed to provide greater strength and durability, than what is found in the original monokote wrapped, wood-frame wing. Generally speaking, a composite material is made up of two or more constituents, that when combined into a final product has properties more desirable than any of those properties contained in one single constituent. Carbon fibers, combined with an epoxy resin, are a very common composite used in the aerospace industry. The high tensile strength of the carbon fibers, along with the hardness and rigidity of the epoxy resin, make for a very strong, lightweight construction material.

Wing Design

The enhanced wing is the same basic shape as the original wing, but it is fabricated with a foam core covered in a carbon fiber composite shell. These composite materials allow for an extremely strong design. The main components of the enhanced wing are a blue insulation foam core, used to provide the aerodynamic shape; a carbon composite rod located in the foam core, acting as a wing spar; and a carbon fiber composite shell for overall strength and durability. Six electrical strain gauges were attached to the spar so that wing performance can be studied in the future. These gauges can be used to measure the types of deflection a composite wing undergoes both in laboratory tests and in flight. The wing span is 2.1 meters, and the wing is 50 cm at the widest point. The enhanced wing weighs 5.28 lbs., which is more than the 3.24 lbs. of the original wing. However, the durability and strength are much greater.

Composite Wing Fabrication

A custom fabrication procedure was developed and tested to meet specifications. In addition to cost constraints, a main challenge was maintaining the desired aerodynamic shape for such a large wing. There are many different ways to fabricate carbon fiber composite parts. A carbon fiber laminate structure using a vacuum bag lay-up approach, as shown in Figure 1, was used due to its simplicity and low cost. This exploded view shows the basic materials and the procedure needed to fabricate the structure using carbon fiber and a resin epoxy. The basic purpose and placement of each item is explained in the following list.

- The vacuum pump holds a constant negative pressure, forcing the fibers to take the shape of the foam core, and allowing resin to flow evenly across and through the fibers.
- The vacuum bag is a plastic sheet that creates an airtight seal around the whole lay-up.
- Excess resin is soaked up in the breather material (usually cotton batting), and if there is a lot of excess resin, it flows into a trap, keeping resin away from the pump.
- The perforated film creates a barrier between the release film and breather material.
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- The laminate plies are layers of actual carbon fiber fabric, covering the mold or core.

The fabrication steps were refined with small samples and then applied to the full-size wing. An initial sample used two-layer composite construction, but a single layer shell was shown to provide sufficient strength and reduce the overall weight.

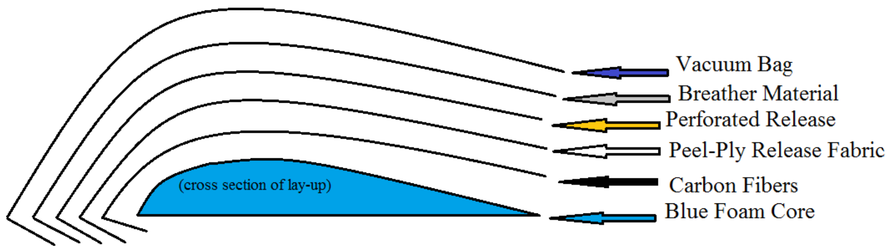

Figure 1. Carbon Fiber Lay-up Diagram

Technical Accomplishments and Lessons Learned

This enhanced wing is a secondary wing for the UAV project and has better performance characteristics. The resulting wing is slightly heavier than the original, but it is much stronger and more resistant to damage, much like what can result from a botched landing. Some “crashes” can be expected, since the auto-pilot system configuration process for small aircraft is iterative. Along with the construction of the wing, the project also developed a set of detailed build instructions, in case duplicate wings need to be built in the future. The vacuum bag lay-up technique was modified for this application and implemented using low-cost materials and equipment. In particular, the incorporation of blue insulation foam as a light-weight, inexpensive form was an effective innovation. The procedure can be used for other UAV airframe structures and other vehicle applications.

Using an external mold for the foam core to lie in during the lay-up, would improve the surface smoothness of the finished product. Also, using less epoxy, and spreading it more carefully, would have resulted in a lighter composite wing. Beyond the technical results, lessons were learned in how to use readily available resources in the wing construction, how to modify composite fabrication techniques for a specific application, and how to effectively work together with separate design teams. The project provided insight into composite design choices and fabrication on a tight budget.

Acknowledgements

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