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A Conceptual Hybrid Wing Body Design with Powered High-Lift Device

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Introduction

This aircraft is designed to be a heavy lift transport with greater cargo capacity and volume than extant designs and capable of operating at high angles of attacks as required by operation out of short runways. To this end an unconventional design is used.

Design Progression

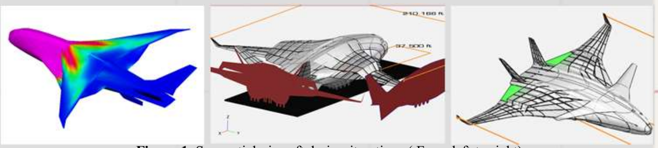

Figure 1. Sequential aircraft design iterations (From left to right)

- The design started as a relatively conventional high wing design with a high aspect ratio wing and blown flaps as well as an unconventional blended lower wing. (**Figure 1, Left**) This design limited the internal volume, however.
- The next iteration utilized a hybrid wing-body type design which required a massive vee shaped empennage to counteract the pitching moment produced by the high-lift devices. (**Figure 1, Center**) Doing so negated the extra lift produced by the blown flaps. The engines are mounted on the top of the wing to induce more circulation about the mid-wing.
- Avoiding the loss of lift required for trimming when using the high lift devices led to the current configuration, which employs closely coupled canards to improve the performance at high angles of attack and to ensure sufficient airflow to the engines mounted on the top of the wing. (**Figure 1. Right**)

Figure 2. CATIA markups for the design and the testing model

- Utilizing CATIA, a detailed markup (**Figure 2**) was created to ensure that the dimensions were realistic in that they included sufficient volume for necessary subsystems such as the landing gear and cockpit as well as the off-the-shelf engines.
- The design was then modeled in a clean configuration at a smaller scale in order to conduct wind tunnel testing to validate the results produced by simulations.

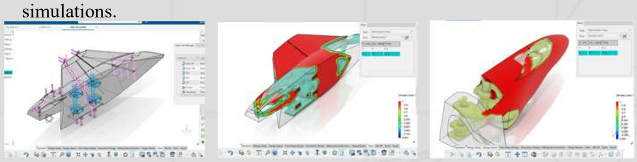

Figure 3. Examples of load scenarios and resulting geometry using functional generative design

- The model is designed to be manufactured by 3D printing rapidly and at a low cost while still being sufficiently sound for wind tunnel testing.
- Topology optimization (**Figure 3**) was conducted based on the loads predicted in OpenVsp. A piano wire internal frame was used to provided sufficient strength. Structurally insignificant material making up around 65% of the gross weight was removed to reduce the print time and cost.

Current Testing

Figure 4. Model construction showing trailing edge build up and internal reinforcements (Right)

- To conduct a safe experiment, the model is reinforced with piano wire internally and fiberglass strands on the surface which provide multiple degrees of safety as well as unloaded copper wires which prevent fragmentation in the unlikely event of a structural failure.

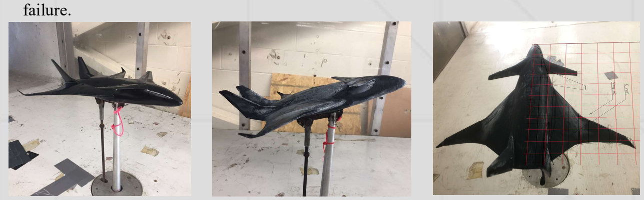

Figure 5. Model on test-stand (superimposed grid provides positional information for clay flow visualization)

- The first testing iteration was conducted in the Lehman Building subsonic wind tunnel. Here lift and drag were measured from an angle of attack of -3° to 15° at 3° increments. A mixture of kerosene and kaolin clay is used to visualize the flow patterns of the boundary layer at 15° and 18°.

Partial Results

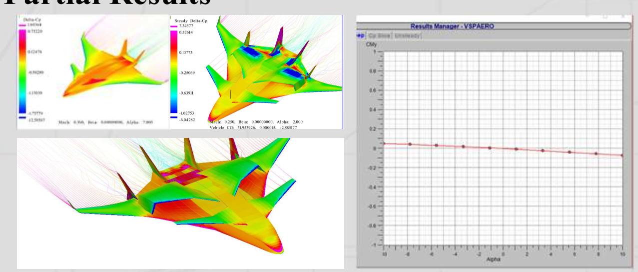

Figure 6. Partial results calculated by Vortex Lattice Method in OpenVsp

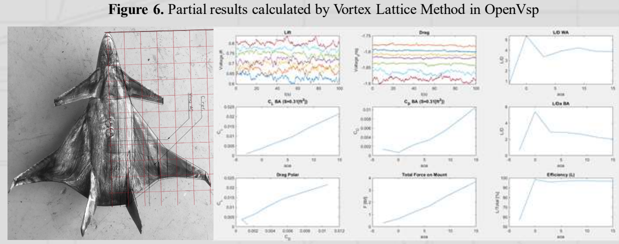

Figure 7. Boundary layer visualization at 18 ° angle of attack (left) and the initial results from wind tunnel testing (right)

Partial Results (Continued)

- The aircraft is not efficient without the engines providing extra circulation, but the likelihood of a complete engine shut down is low. (**Figure 6, Left**)
- Canard configuration can be stable by balancing the size of canard and the center of gravity. (**Figure 6, Right**)
- The lift to drag ratio is relatively low, but constant across the expected angle of attack range. (**Figure 6**)

Future Work

- Further wind tunnel testing which is more representative of the flow about the full-size model (higher Reynolds number)
- Glowing paint used to emphasize kaolin clay and kerosene flow visualization during testing. (**Figure 8**)
- Flow visualization done across the full angle of attack range to better understand flow regimen development and flow interactions.

Figure 8. Model with glowing paint

- Better simulation will be conducted using more advanced methods
- Fully blend the wing and body and evaluate performance changes
- Study impact of the ground effect in reference to final approach and take off situations
- Create a detailed mockup if a final version could be ready by summer 2021
- Results of further work presented again in November 2021

Skills Utilized

- Incompressible aerodynamics and aircraft stability principles
- Designing for additive manufacture and complementing finishing techniques
- Low-cost rapid prototyping methods
- Techniques for experimental aerodynamics testing including low-cost continuous boundary layer flow visualization

Citations

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- Gloudemans, J., McDonald, R., Moore, M., Hahn, A., Fredericks, B., & Gary, A. (2020, July 28). OpenVSP (Version 3.21.2) [Computer software]. Retrieved October 11, 2020, from http://openvsp.org/
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