Aeroelacticity of a Conventional Composite Wing Structure

Carlos Marquez, Felipe Aragon, Bruno Malo, Alejandro Aguilar, Pedro Vergara, Luis Otero

Department of Aerospace Engineering, Embry Riddle Aeronautical University

Abstract

Flutter is an interesting phenomenon that consists of vibration in a system at an uncontrollable frequency. Aircraft, due to the circumstances they usually encounter, tend to present this physical condition. Throughout history, aircraft manufacturers have studied flutter and generated models for their particular designs. However, no general analyses and methodologies have been developed for flutter. To conduct this research, a wing was designed and constructed to study excessive vibrations and aeroelastic behaviors, required for flexible flight controls. First, it was necessary to perform material testing to define the best dimensions of each component of the wing. Destructive tests were performed to determine the stiffness and flexibility of naked foam, naked foam with epoxy, and a sandwich composite component made of carbon fiber and foam. Next, the main wing was constructed and placed into the wind tunnel. During testing, flutter was observed in the wind tunnel due to a force of the fan at a speed of 300rpm. The wing generated rapid and unnatural upward and downward motions, deflecting at a precise frequency until the whole system failed. Unfortunately, this part of the experiment occurred too quickly, so it was not possible to gather enough data. For that reason, this experiment needed to be performed again in a more controlled environment. Furthermore, additional material testing is currently being done to improve the wing structure before the wing is tested again.

Importance of the Matter

- Studying the interaction among inertial, elastic and aerodynamic forces behaving on a wing.
- to design a functional wing of reduced complexity that could withstand excessive vibrations and aeroelastic behavior required for flexible flight controls

Design and Construction

- 3 sample spars of 11"x 3"x 0.4" were constructed using foam and carbon fiber around it.
- The wing design consisted of four ribs and a single spar
- The dimensions of the spar were 1in x 33in x 0.4in
- The airfoil used on the ribs was NACA 0012, with a chord of 14" and thickness of 1.8".
- The skin was modeled using a thin but strong plastic bag, maintaining the shape of the wing during testing.

Figure 1. Main Wing Skeleton Structure (1 spar with 4 ribs)

Destructive Test

- These sandwiches were tested applying a flexure test in order to determine structural properties, such as elongation and Young's Modulus.
- The beams were treated as simple beams due to the nature of the test machine. The formulas below represent the relation between a cantilever beam and a simple beam test

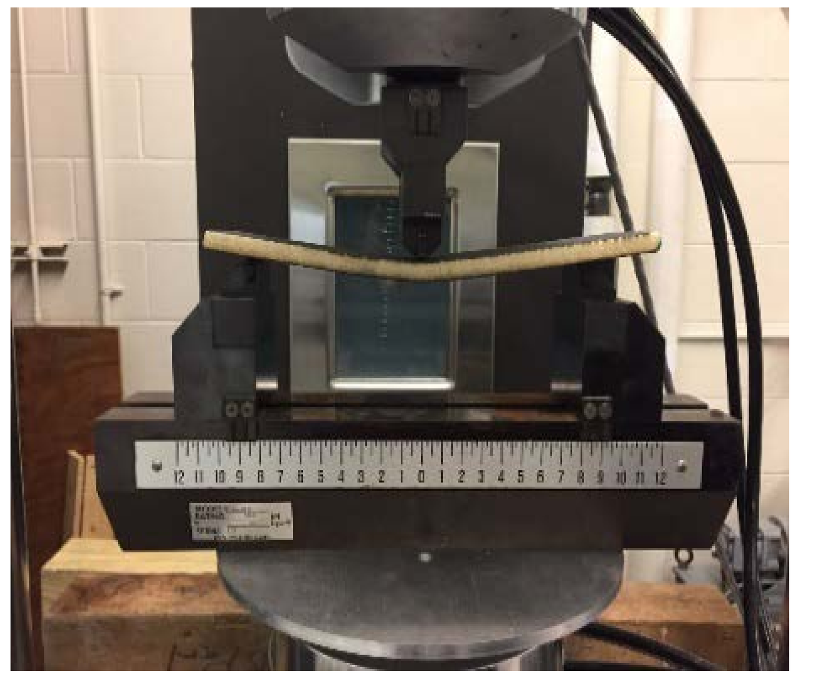

Figure 2. Destructive Test Configuration

$$V_p = 2 \cdot V_t \cdot V_p$$

$$M_{max,p} = 4 \cdot M_{max,t}$$

$$T_{max,p} = \frac{48}{3} \cdot T_{max,t}$$

- At 180 rpm the wing presented small oscillations, reaching an angle of attack of 10°.
- At 250 rpm, the wing presented flutter breaking the spar at the attachment with the mount, front tips of the ribs and the plastic skin.

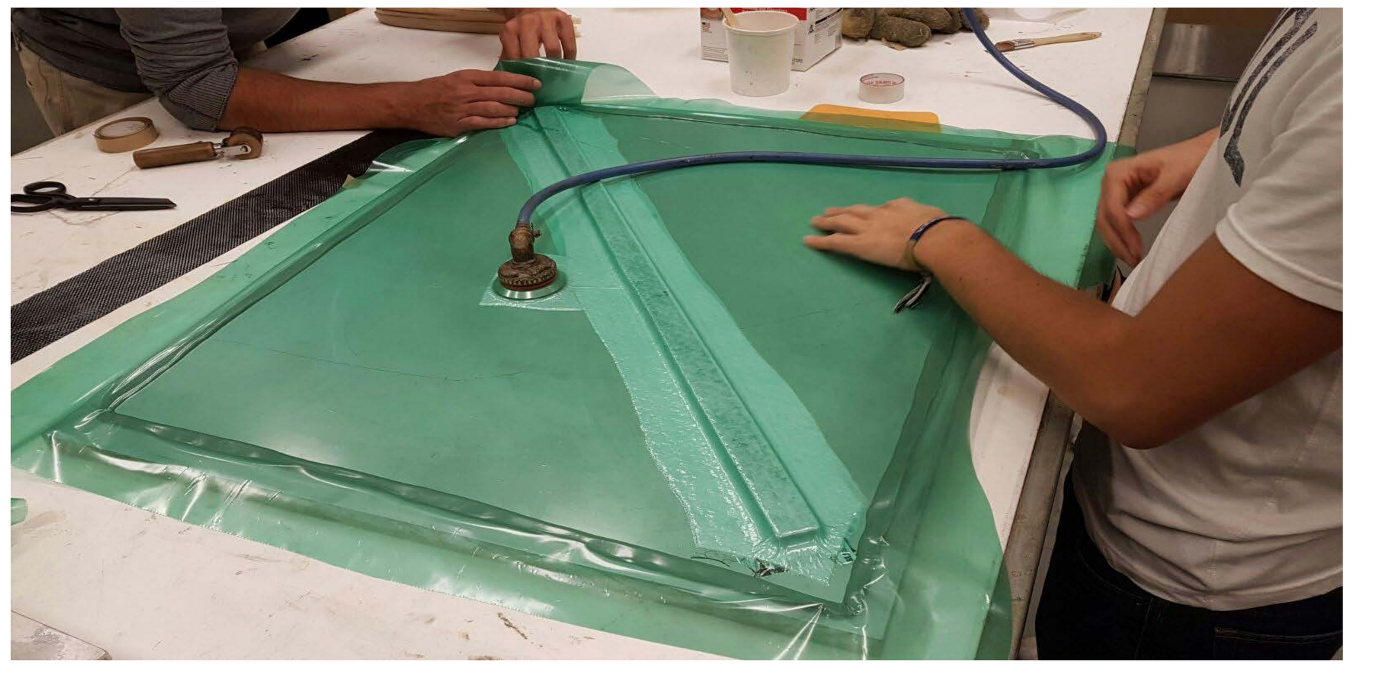

Figure 3. Construction of the Main Spar

Result and Discussion

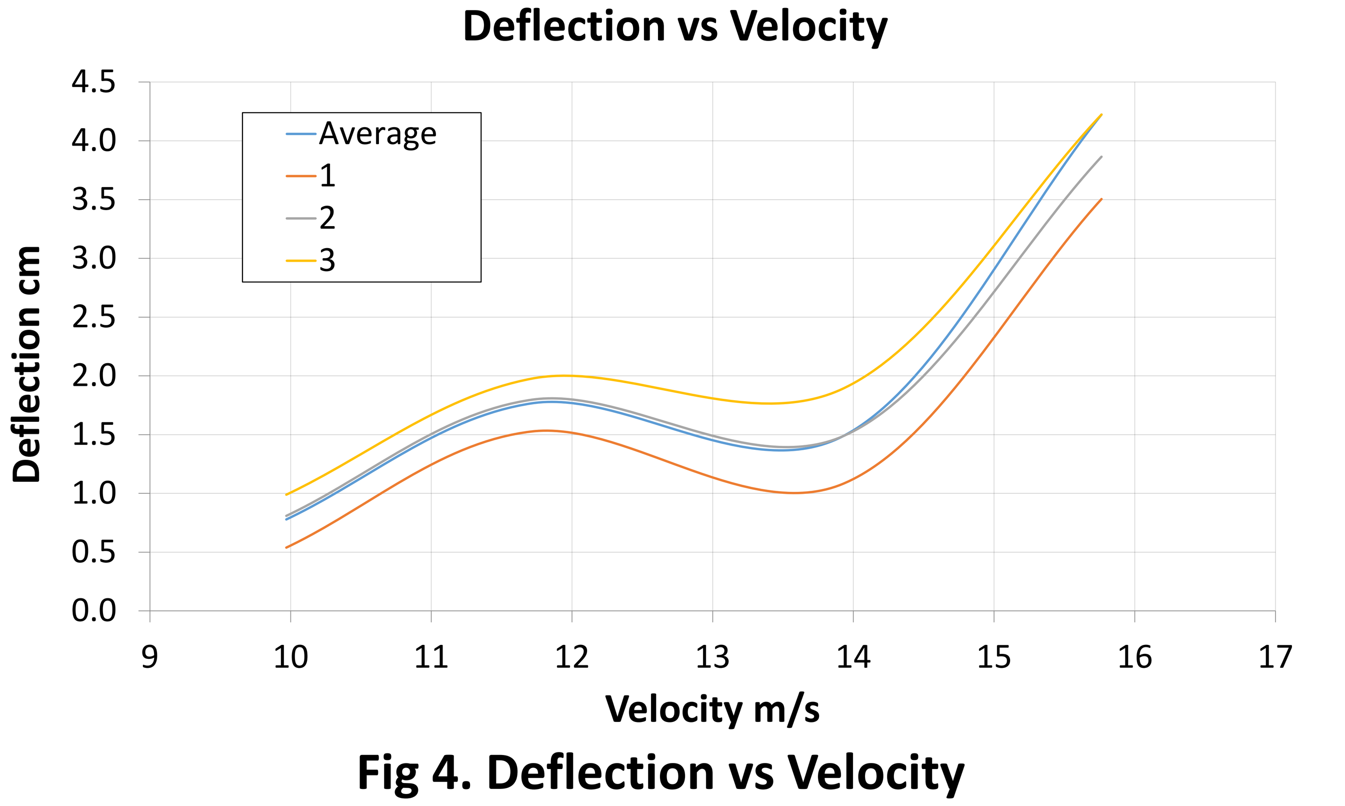

Fig 4. Deflection vs Velocity

- The sandwich acting as the spar of the wing suffers a failure at approximately 12 and 14 m/s in the wind tunnel. After this particular point, flutter takes place until the whole system fails.

Figure 5. Main Wing Configuration in the Wind Tunnel

Reference

1. Chiappa, C., Magni, J-F., Gorrec, Y. L., Kubica, F. and Doll, C., "Flexible structure control by modal multi-model approach: Application to a flexible aircraft," International Council of the Aeronautical Sciences (ICAS), A98-31461.
2. Waszak, M., "Robust multivariable flutter suppression for the benchmark active control technology (BACT) wind-tunnel model," 11th Symposium on Structural Dynamics and Control, Blacksburg, VA, 1997.