A Computational Approach for Optimizing the First Flyer Using COMSOL

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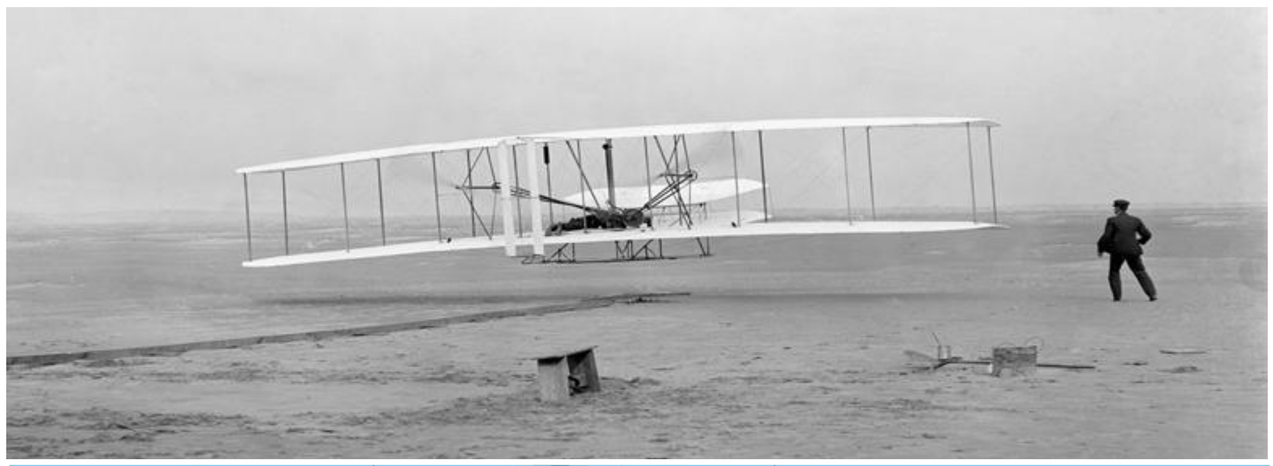
Introduction: The flight of the Wright Brothers' 1903 flyer is simulated in COMSOL. An attempt was made to increase the flight duration by reducing the weight.



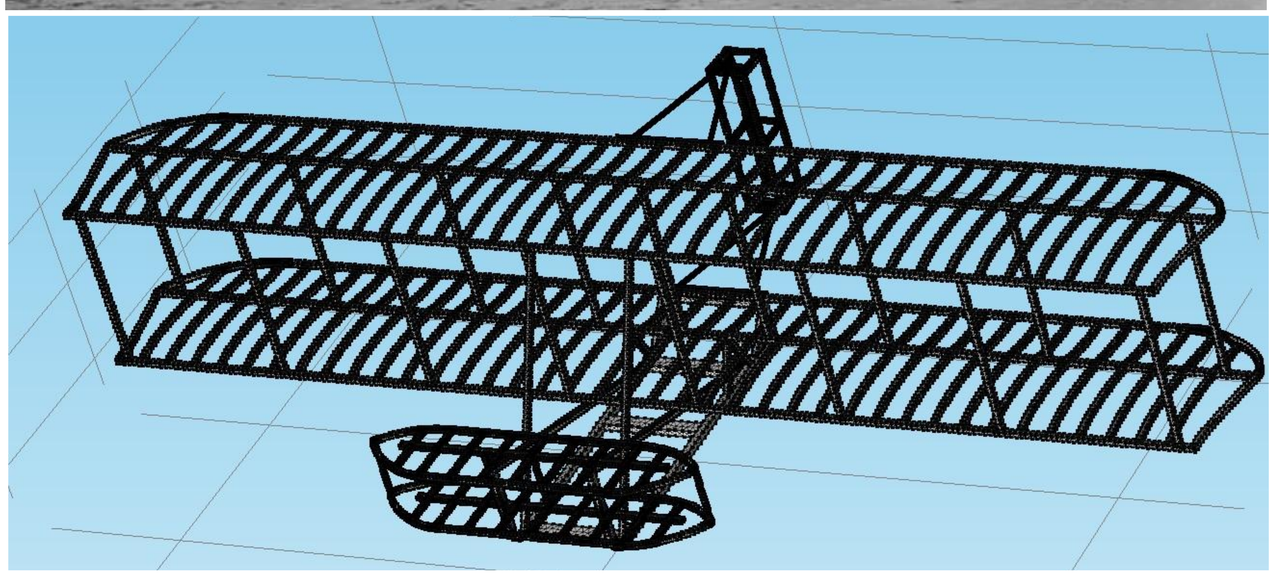


Figure 1. The first twelve seconds of the age of powered flight, Kitty Hawk, N.C., December 17, 1903 (top); The Wright brothers' original flyer meshed in COMSOL(below).

Computational Methods:

The equation of motion of a rigid airplane are derived from Newton's Laws of Motion in linear and angular form:

Conservation of Linear momentum:

$$\frac{d}{dt}\int_V \rho_A \frac{d\vec{r'}}{dt} dV = \int_V \rho_A \vec{g} dV + \int_S \vec{F}\, dS$$

And Conservation of Angular momentum:

$$\frac{d}{dt}\int_V \vec{r'} \times \rho_A \frac{d\vec{r'}}{dt} dV = \int_V \vec{r'} \times \rho_A \vec{g} dV + \int_S \vec{r'} \times \vec{F} ds$$

The longitudinal equation, below, are then integrated to obtain the flight time.

$$\dot{u} = \frac{F_x}{m} - \mathrm{Qw} - \mathrm{g}\sin(\theta)$$

$$\dot{w} = \frac{F_z}{m} + \mathrm{Qu} + \mathrm{g}\cos(\theta)$$

$$\dot{Q} = \frac{M}{I_{xx}}$$

Longitudinal Equations of Motion

Results:

Laminar, compressible flow of air over the wings of the Wright Flyer was modeled. The values for lift and drag obtained from this model were used both for the structural integrity analysis as well as the flight dynamics calculations.

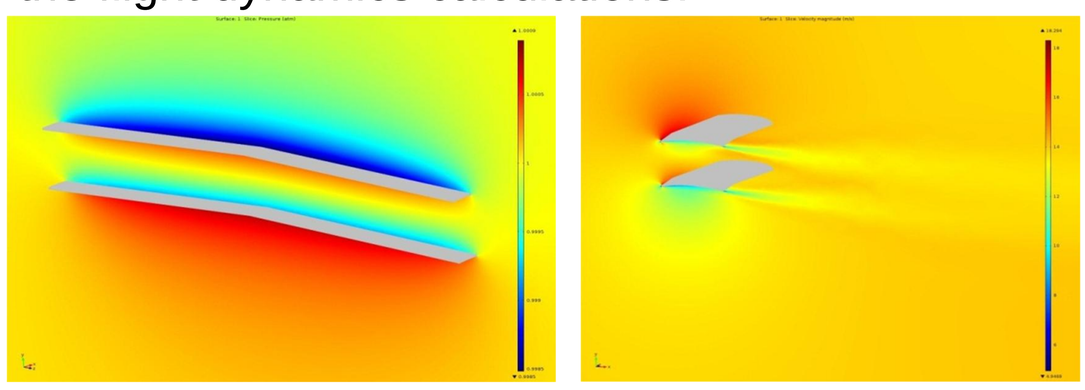


Figure 2. The pressure distribution (left) and the velocity profile (right) on the two wings.

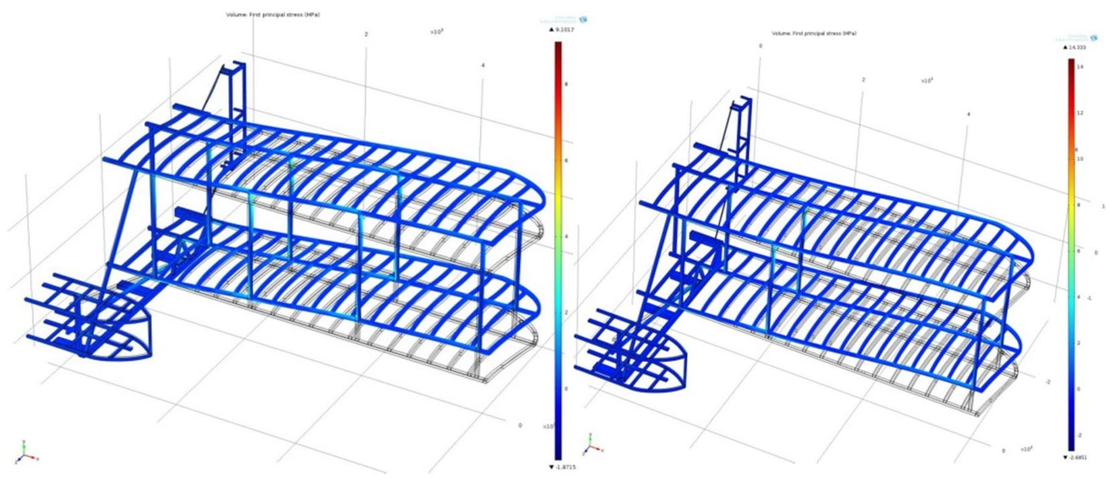


Figure 3. The principal stress for the flyer with the original 8 struts (left) and with two struts removed (right).

To ensure that the removal of the 4 struts did not compromise the structural integrity of the flyer, a structural simulation was performed at the fully loaded configuration.

Conclusions: COMSOL software package was used to ensure the structural integrity of the flyer and to compute the aerodynamic forces and moments. It was noticed that a small (2.5%) reduction in the flyer's weight resulted in a considerable decrease (16%) in flight time to cover the same range of 852 feet.

References:

1. Roskam, *J. Airplane Flight Dynamics and Automatic Flight Controls*, Part 1 (1982).
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