RWDC STATE CHALLENGE STATEMENT, 2010 - 2011

Background:

Given the anticipated increase in future fuel costs and increased emphasis on global climate change emissions, such as carbon dioxide, there is renewed interest in making airliners more efficient.

Conventional wing design is a compromise between aerodynamic efficiency and light weight because wings are designed to maintain approximately the same Spanwise Load Distribution (SLD) as they are subjected to increasing load. Unfortunately, the most efficient SLD results in a heavy wing, while the lightest SLD results in an inefficient wing at cruise.

One promising way to improve fuel efficiency is called passive aeroelastic tailoring. Aeroelastic tailoring may provide a better compromise by adding an additional degree of freedom, that is the ability to change shape under load to both allow for the most efficient SLD in cruise while also allowing the lightest weight SLD at the ultimate loading.

The Challenge:

The challenge is to design the exterior geometry and internal structure of an airliner wing using aeroelastic tailoring methods to minimize the objective function by varying specified design variables without violating constraints.

The Final Design Must:

1. Not exceed material design allowables at the ultimate load factor at the cruise design point of 36,000 ft at Mach 0.70. This is done by adjusting the wing angle of attack until lift is equal to 3.75 times the gross weight. Perform a static aeroelastic solution convergence using Creo Elements/Pro (formerly Pro/ENGINEER), FloEFD.Pro, and Creo Elements/Pro Mechanica to update aerodynamic loads on the deflected geometry and modifying the structure. This will give you the wing weight.
2. Balance the aircraft gross weight and wing lift at the cruise design point of 36,000 ft at Mach 0.70. This is done by adjusting the wing angle of attack until wing lift is equal to gross weight. Perform a static aeroelastic solution convergence using Creo Elements/Pro, FloEFD.Pro, and Creo Elements/Pro Mechanica to update aerodynamic loads on the previously sized structure to get the cruise condition deflected geometry. This will give you the wing drag.
3. Critical speed for flutter must be greater than 370 KEAS (knots equivalent airspeed) at an altitude of 30,000 feet. Perform the Creo Elements/Pro, Creo Elements/Pro Mechanica, NEi Nastran, ZAERO solution sequence to calculate flutter speed.

Objective Function:

OF = [145,360 + W(wing)] + 19 * q * S * [0.01819 + CD(wing)]

Where q = 162.92 lb/ft^2, and S = 1,400 ft^2

Design Variables:

- Wing sweep angle
- Wing twist angle

- Root and tip airfoil shapes
- Material types, thickness, and location, composite material layup fiber orientation, etc.

Constraints:

- Trapezoidal planform from root to tip.
- Planform span of 118.0 ft.
- Planform area of 1,400.0 ft^2.
- Taper ratio of 0.30.
- Dihedral angle of 6 degrees.
- Airliner design gross weight of 160,000.0 lbs.
- Wing twist change per g must be negative (washout with load).
- No winglets or tip devices.
- No flaps, ailerons, slats, or speed brakes need be designed, but loads will be provided to simulate them for analysis purposes.
- Total fuel volume sufficient for 40,000.0 lb at a density of 49.0 lb/ft^3. Fuel load confined to be within space defined by 0.15 - 0.70 chord and 0.00 - 0.85 semi-span. In addition, there must be internal structure bounding the chosen fuel volume, representing an integral fuel tank.
- Internal structure spanwise elements are restricted to be within 0.15 - 0.70 chord and 0.00 - 1.00 semi-span.

Assumptions:

- U.S. Standard Atmosphere and Standard Day conditions.
- Materials properties and design allowables will come from provided tables.
- Use airfoil coordinates from http://www.ae.illinois.edu/m-selig/ads/coord_database.html or other airfoil data sources.
- Nastran input for lumped masses for flutter solution will be provided to represent the additional weight of flight control systems.
- Reference axis system for the design variable angles will be illustrated in the supporting materials.

Tools:

- Creo Elements/Pro, Creo Elements/Pro Mechanica, Mathcad, and the Windchill collaboration site provided by PTC.
- NEi Nastran provided by NEi Software.
- ZAERO provided by ZONA Technology.
- FloEFD.Pro provided by Mentor Graphics.
- Responses to frequently asked questions will be posted and shared with all teams.
- Process automation for computing flutter speed.

Overall Technical Scoring Will Be Based On The Following Deliverables:

- Design notebook.
- Creo Elements/Pro model and 3-view of final design.
- Analysis input and output for the final configuration.