A Coupled Aero–Structural Optimization Method for Complete Aircraft Configurations

Joaquim R. R. A. Martins

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OBJECTIVES

❑ Develop a high-fidelity environment for aero-structural analysis and design of aircraft configurations.

❑ Create a full aircraft geometry outer mold line (OML) database for the exchange of information between disciplines.

❑ Couple an Euler flow solver with a linear finite element solver for aero-structural analysis and design.

❑ Establish a framework for future use in coupled sensitivity analysis.

❑ Demonstrate aeroelastic analysis and simplified aero-structural design problems.
INGREDIENTS OF THE FRAMEWORK

- High-fidelity modeling in the component disciplines:
  - Euler equations for aerodynamics.
  - Detailed Finite Element Model for structures.

- High-fidelity coupling between participating disciplines:
  - Consistency: force and moment resultant preserved.
  - Conservativeness: total work/energy preserved.

- OML geometry database for information exchanges (shape, pressure distributions, displacements)

- Sensitivity analysis
HIGH-FIDELITY AERODYNAMICS

Transonic Business Jet
FLO107-MB Solution
Baldwin–Lomax Turbulence Model
Mach = .82  240 Blocks  5.8 Million Mesh Points
Triangular plates and truss elements
Skins modeled with plates
Spars and ribs modeled with plates and trusses
Simplified but realistic and accurate
GEOMETRY DATABASE

- Un-intersected set of aircraft components
- Parametric patches from intersection of surfaces
Parametric location of CFD mesh points is identified by a triad \((n, u, v)\), where \(n\) is the patch number.
AERO–STRUCTURAL COUPLING

- Accomplished via geometry database and the use of standard calls, for ease of interchangeability of solvers.

- Geometry points are associated with nearest point on structure’s surface.

- Geometry displacements are then obtained by extrapolation of structural displacements.

- CFD mesh is perturbed based on interpolated geometry displacements.

- Pressures from CFD are interpolated in the geometry mesh.

- Geometry integrates the pressures and calculates a conservative and consistent force vector for the structural solver.
GEOMETRY POINT ASSOCIATION
DESIGN PROCEDURE

☐ Considered cruise flight conditions.

☐ Aerodynamic sensitivities obtained by solving the Euler adjoint equations, cost is similar to one flow solution.

☐ Objective function that was minimized was a linear combination of the total drag and structural weight.

☐ Used a penalty function based on the structural stresses.
Calculated structural sensitivities using analytical methods and used these to run a structural optimization.

Analyzing methods for obtaining total sensitivities of coupled systems in the all-at-once approach.

Considering the use of Collaborative Optimization in this framework.
FUTURE WORK

Design Variables
- External Geometry Variables
- Internal Structure Variables

Optimizer
- Objective: Range (Weight, Drag)
- Constraints: Stresses, etc.

Cruise
- Flow
- Geometry
- Structure

Maneuver
- Flow
- Geometry
- Structure

Weight, Stresses
Drag