Enabling Aeroelastic Certification by Analysis

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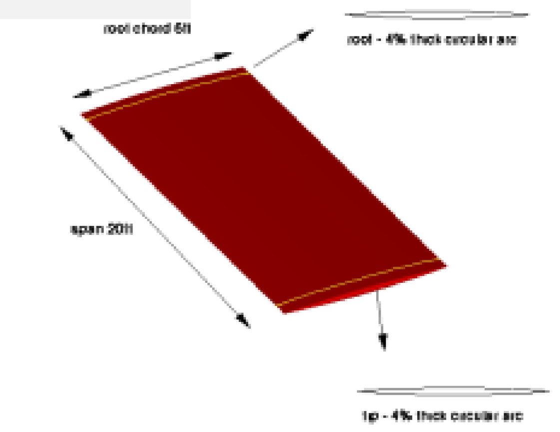
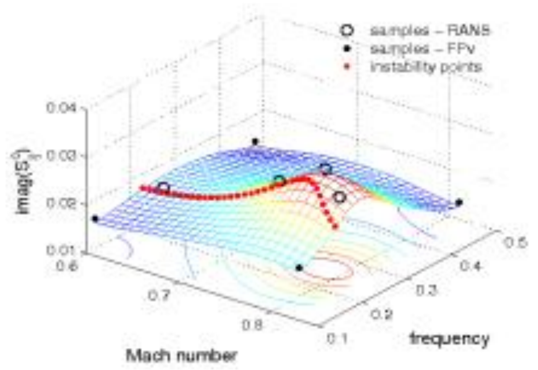
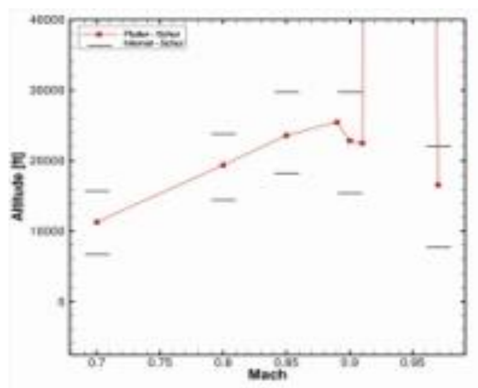
Objective

Aeroelastic stability prediction has been dominated by linear methods for the past 40 years. Nonlinearities are often destabilising and require higher fidelity models for investigation. This introduces computational costs which makes the analysis unfeasible. The objective of the Excellence Team is to establish a set of methods which enable nonlinear aeroelastic analysis in an industrial setting, accounting for structural model uncertainty .

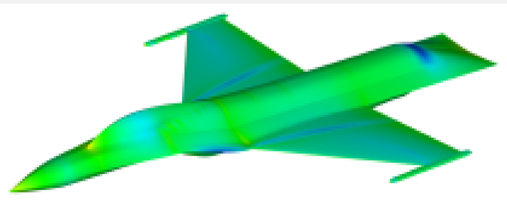
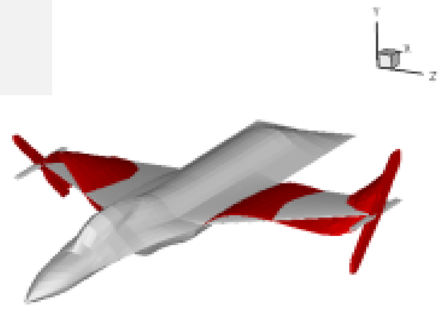
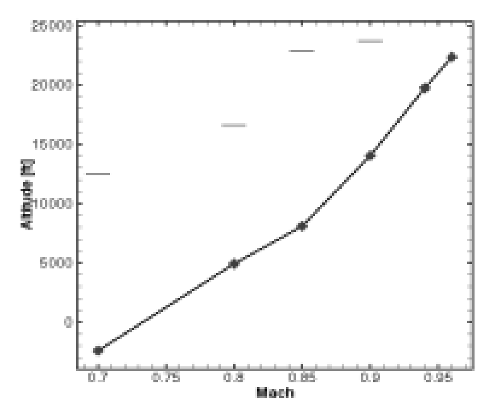
Results

Academic and industrial test cases, method implemented in Airbus codes

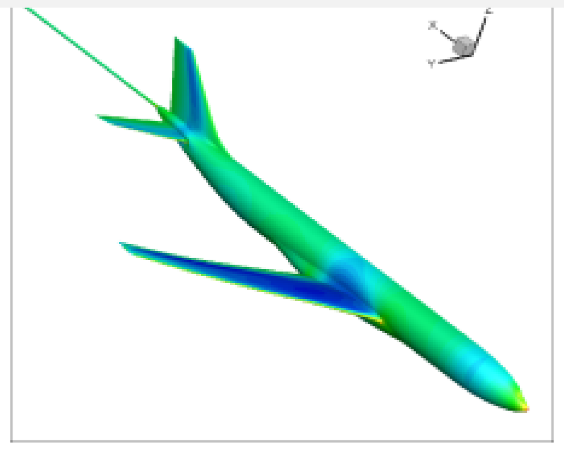
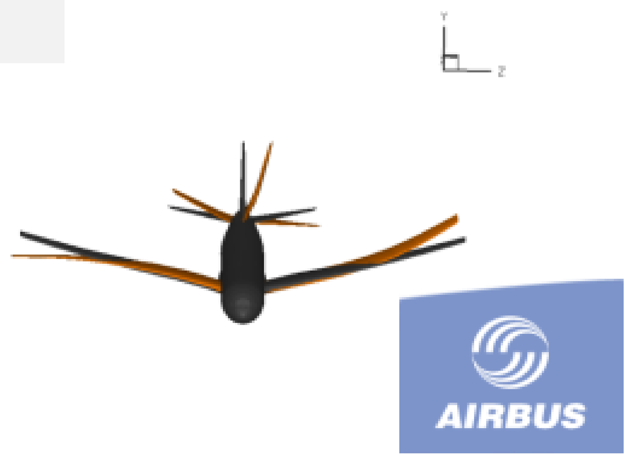
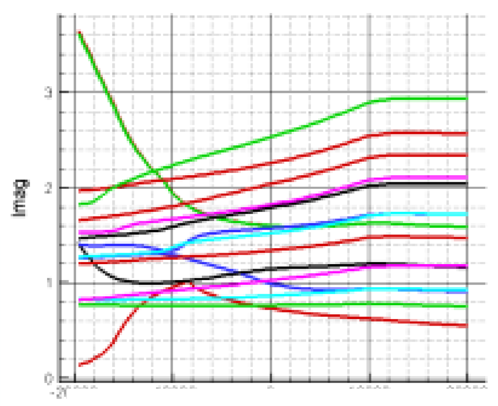
Goland

Open Source Fighter

Airbus model

Formulation

Coupled system, Subscripts f=fluid, s=structure; fluid model from CFD, structural model from a set of modes, typical dimension for aircraft models 10 millions DoF

$$\frac{d\mathbf{w}}{dt} = \mathbf{R}(\mathbf{w},\mu) \qquad \mathbf{w} = \begin{bmatrix} \mathbf{w}_f \\ \mathbf{w}_s \end{bmatrix} \qquad \mathbf{R} = \begin{bmatrix} \mathbf{R}_f \\ \mathbf{R}_s \end{bmatrix}$$

Stability of steady state from eigenvalue problem, dimension of E – order 10-100

$$\begin{bmatrix} A_{ff} & A_{fs} \\ A_{sf} & A_{ss} \end{bmatrix} \begin{bmatrix} p_f \\ p_s \end{bmatrix} = \lambda \begin{bmatrix} p_f \\ p_s \end{bmatrix} \longrightarrow \begin{aligned} E &= S(\lambda)p_s - \lambda p_s = 0 \\ S(\lambda) &= \left(A_{ss} - \lambda I\right) - A_{sf}\left(A_{ff} - \lambda I\right)^{-1} A_{fs} \end{aligned}$$

Newton's method is used to solve small order nonlinear system E=0
Kriging and sampling methods approximate S(λ,M,altitude) for approximate Jacobian

$$\frac{\partial \mathbf{E}_{approximate}}{\partial \mathbf{u}} \Delta\mathbf{u} = -\mathbf{E} \qquad \mathbf{u} = [\mathbf{p}_s, \lambda]^T$$

Define uncertainty in structure by a set of modes arising from parameters defined in intervals or by a PDF. Use eigenvalue solver to calculate realisations for a Monte Carlo simulation or to solve an optimsation problem for the interval problem. The approximate Jacobian is calculated once at a nominal structural state.

The method allows aeroelastic stability searches over the flight envelope in the presence of structural uncertainty using high fidelity models accounting for nonlinearity

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LABORATORY

Marie Curie Excellence Team
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