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1. Adjoint methods for predicting receptivity to random roughness.
2. Boundary layer and stability methods for surface deformations.

1 Motivation

Develop tools for fast and accurate analysis of receptivity and boundary layers, providing new and alternative methods for investigating the effects of random roughness and surface deformations on stability. Further developing our understanding of the complex processes of disturbance evolution.

2 Research

Adjoint methods can be utilised to immediately predict the receptivity of disturbances to many external forces (roughness, free stream noise). The incompressible and compressible adjoint system of equations have been derived and implemented within MiPSecR (developed by S. Mughal). The receptivity to many roughness distributions can be computed instantaneously to both idealised (Gaussian, cylindrical, rectangular) and random surface deformations. A thorough uncertainty quantification analysis can then be carried out, providing mean receptivity amplitudes and probability density functions.

A new method for generating boundary layer profiles for stability analysis is being derived and tested (REBL - Rans Extraction of the Boundary Layer). Velocity profiles are extracted directly from RANS solutions and output into an orthonormal coordinate system that is suitable for stability analysis. The method bypasses the traditional compressible boundary layer equation solver routines (CoBL) and is particularly useful in cases of extreme surface curvature and adverse pressure gradients where CoBL methods fail. REBL and CoBL methods are utilised for the stability analysis of both 2D and 3D flow systems with surface deformations (that characterise wing irregularities) along the chord and spanwise directions. Analysis suggests that 3D boundary layer effects have a significant impact on stability.

3 Application for industry

The adjoint method is implemented into the code MiPSecR (developed by S. Mughal) for both incompressible and compressible flows. This tool is already used by Airbus Group Innovations, who can utilise the new routines to perform a thorough parametric analysis of disturbance receptivity to random roughness.

REBL provides the user (Airbus Group Innovations and potentially Airbus) a new method for generating boundary layer profiles for stability analysis. The tool is an alternative to the compressible boundary layer equation solvers (CoBL) that can fail in regions of extreme adverse pressure gradients.