Large Eddy Simulation of Coanda flaps

Overset LES for the investigation of sound sources in Coanda flap

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In Short

- Scale resolving simulations of sound generating mechanisms on Coanda flaps.
- Overset LES of high lift generating Coanda flaps.

The code PIANO (Perturbed Investigation of Aerodynamic NOise) was developed by Technical Acoustics department of DLR 1 . PIANO in its classical version is used to simulate sound propagation by solving Linearised Euler Equations (LEE) and subsequently Perturbed Nonconservative Nonlinear Euler Equations (PENNE). The fluctuating viscous terms are added to the PENNE resulting in full Navier-Stokes equation in the perturbed form. This makes viscous-PIANO suitable for DNS/LES 2 computations and hence not only sound propagation but also sound generating mechanisms near the solid wall can be analyzed.

The viscous-PIANO code solves the Navier-Stokes equations in the perturbed form on a structured grid using a higher order, state of the art Dispersion Relation Preserving scheme (DRP) 3 with 7 point stencils for spatial discretization and Low Dispersive Low Dissipative Runge Kutta (LDDRK) 4 for temporal discretization. It is a well established fact that the effective wave number resulting from the numerical approximation is same as the physical wave number only for long waves. Hence the unphysical short waves need to be damped out. For this purpose, artificial selective damping (ASD) is applied for the whole flow field making the solution free from spurious waves.

The fluid flow on a jet equipped Coanda flap is one of the most intriguing fluid dynamic problems and hence requires a high fidelity simulation to understand the intricacies involved in the lift generation as well as the nature of sound sources at the flap curvature and the flap edge. In the framework of *SFB880-Fundamentals of high lift for future civil Aircrafts* 5 , the current project aims to perform overset LES on the Coanda flap using the viscous-PIANO code. The formulation of the Navier-Stokes equation in the viscous-PIANO code allows to compute perturbed quantities on top of time invariant background flow obtained from RANS simulations and thus paving way to an overset LES/DNS approach. This approach gives liberty to use the computationally demanding but accurate LES only in the area of interest and makes it feasible in practical applications.

Generating accurate inflow turbulence is one of the ever existing challenges in Hybrid RANS-LES approach. The realistic inflow turbulence for the overset LES in the current project is realized through a statistical tool called Fast Random Particle Mesh (FRPM) 6 . The turbulence data from RANS such as turbulent kinetic energy, length scales, time scales are interpolated to the FRPM region and based on that, the FRPM generates 4D (varying in space and time) turbulent structures suitable for the overset LES as illustrated in figure 2 .These structures further convect with the background flow velocity and interacts with the blunt geometrical edges. The trailing edge noise generation is believed to be a response to the edge scattering of such convecting structures and vortex shedding. This approach is applied and extensively validated on a trailing edge of NACA 0012 profile 7 . The overset domain for Coanda flap simulation is illustrated in the figure 1 .

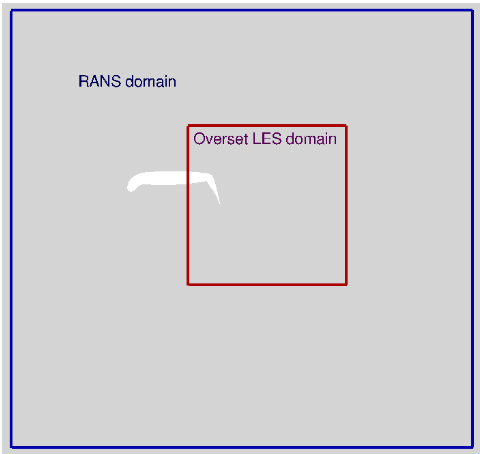

***Figure 1:** A schematic diagram of overset LES domain for the scale resolving simulation of the Coanda flap.*

A 2D overset LES of the Coanda flap has been already carried out to get accustomed to the practicality of the code, grid generation, to identify potential challenging aspects in the simulation and to test the post-processing routines. The inflow turbulence generator FRPM is designed based on the *k-w SST Menter* modeled RANS simulations. The instantaneous non-dimensional vorticity fluctuation is presented in figure 2 .

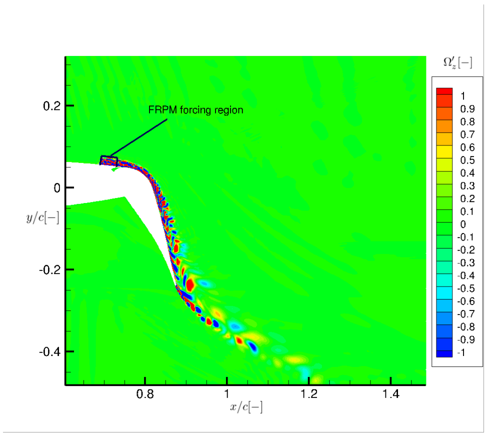

Figure 2: *Instantaneous vorticity fluctuations contour from a 2D overset simulation depicting FRPM forcing of the inflow turbulence at the entrance and vortex shedding at the flap edge.*

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More Information

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