Large Eddy Simulation of Coanda Flaps

Overset-LES for the Investigation of Sound Sources in Coanda Flaps

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In Short

- High fidelity aerodynamic simulation of a high lift device
- Scale resolving simulations of sound generating mechanisms on 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 appropriate equations, e.g., Linearised Euler Equations (LEE) or Perturbed Nonconservative Nonlinear Euler Equations (PENNE). The fluctuating viscous terms have been added to the PENNE resulting in compressible 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 analysed.

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) [5] with 7 point stencils for spatial discretisation and Low Dispersive Low Dissipative Runge Kutta (LDDRK) [6] for temporal discretisation. 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 [7], 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 back ground flow obtained from RANS simulations and thus paving way to an Overset-LES/DNS approach.

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 stochastic tool called Fast Random Particle Mesh (FRPM)[8]. The turbulence information 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 NACA0012 profile [3] [4]. A 2D slice of the Overset-LES grid is illustrated in the figure 1.

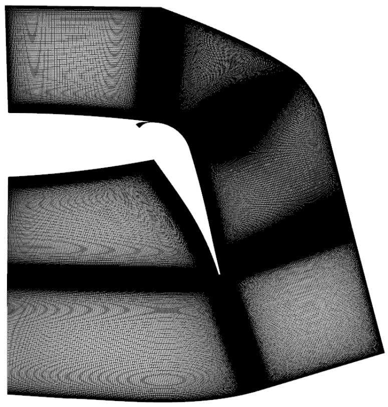

***Figure 1:** A 2D slice of the Overset LES grid of a Coanda flap*

A 2D Overset-LES of the Coanda flap has been carried out to get accustomed to the practicality of the code, grid generation and to identify challenging aspects in the simulation and to test the post-processing routines. The inflow turbulence generator FRPM is based on the turbulence information from a k-ω SST Menter modeled RANS background flow. A snapshot of contours of the vorticity fluctuations on the Coanda flap from a 2D simulation and FRPM patch (black rectangle) at the inflow forcing region is shown in figure 2.

An under-resolved 3D Overset-LES simulation is carried out. The iso-surface of the Q-criterion coloured with the magnitude of total velocity is shown in figure 3. The isotropic turbulence forced at the inflow region, advects with the mean flow velocity be-

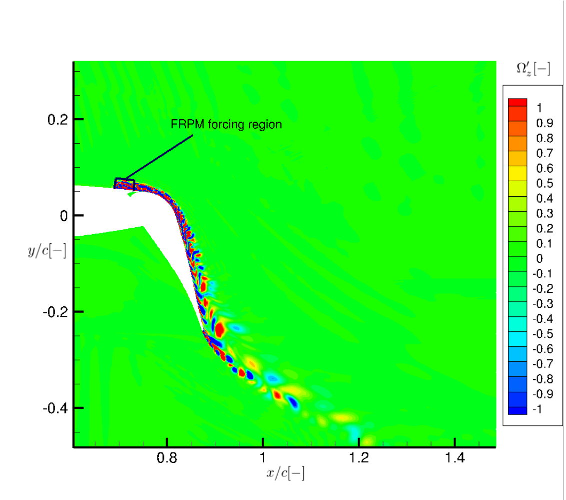

Figure 2: *A snapshot of contours of the vorticity fluctuations (Ω') on the Coanda flap; The black rectangle represents the FRPM forcing region.*

coming anisotropic. The flow acceleration over the curved surface and the attached flow over the flap is also evident in figure 3. From these simulations, three noise sources are identified, i.e. 1. Classical flap trailing edge noise resulting from the turbulent trailing edge and the flap trailing edge interaction. 2. Curvature noise resulting from the acceleration gain for the turbulent eddies convecting over the curvature of the flap. The third sound source, i.e. Coanda jet mixing noise is not simulated because of the presence of computationally demanding length scales. Moreover, the resulting upward directed high frequency noise from the jet is likely to get damped in the atmosphere.

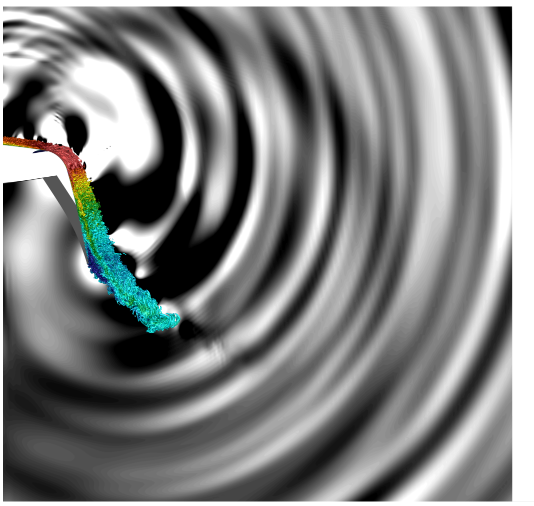

Figure 3: *The iso-surface of the Q-criterion coloured with the magnitude of total velocity. The resulting pressure field is represented by gray scale.*

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http://www.tu-braunschweig.de/sfb880

More Information

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Funding

DFG Sondernforschungsbereich (SFB) 880