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VALIDATION OF HYBRID NUMERICAL METHODS FOR AEROACOUSTIC SIMULATIONS IN AN INDUSTRIAL ENVIRONMENT

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Abstract. Airframe noise from deployed slats is considered to be the main contributor to the overall aircraft noise during approach and landing of modern airliners. Since it is generated in the vicinity of edges such as the slat trailing edge, recent slat designs attempt to achieve noise reduction by decreasing the flow velocity in this area through optimized slat positions with special focus to the slat gap. The main challenge for aircraft design is to combine noise reduction methods with aerodynamic performance requirements and therefore accurate but also fast numerical prediction methods are necessary.

The goal of the present task is to demonstrate the capability of Computational Aeroacoustics (CAA) to predict slat noise in dependency of angle-of-attack (AoA), position settings, shape deformation and flight velocity in a timeframe compatible to industrial design needs. Therefore experimental data, measured by Pott-Pollenske et al. in the Large Low Speed Facility DNW-LLF of the German-Dutch Wind Tunnel foundation within the EU co-financed project OPENAIR, are compared to simulation data of two hybrid CFD/CAA approaches. Here the acoustic predictions rest on time-averaged steady flow solutions provided by Reynolds Averaged Navier-Stokes (RANS) simulation. In a subsequent acoustic step this steady flow data is translated into synthetic fluctuations of turbulent velocity or vorticity by DLR's aeroacoustic simulation tools PIANO and DISCO to simulate the broadband turbulent sound field radiated from the high-lift system.

In both the structured CAA code PIANO and the unstructured DISCO code RANS solutions provide the non-uniform mean flow around the high lift system as well as the time-averaged quantities k and ω (turbulence kinetic energy and rate of turbulence dissipation). The 2D CAA simulation is conducted in the time domain. The Fast Random Particle Method (FRPM) is used to compute the unsteady turbulent source term on the right-hand side of the Acoustic Perturbation Equations for the prediction of sound generation and propagation in space and time. The simulation takes into account refraction of acoustic waves in the non-uniform mean flow as well as the reflection and scattering of sound waves at the complex geometry and provides narrow band spectra of the generated sound. While the finite difference code PIANO works on block-structured body-fitted grids (Figure 1) and already demonstrated good prediction capabilities in the past, the DG (discontinuous Galerkin) code DISCO is introduced, which works on unstructured grids consisting on triangles (Figure 2). The unstructured approach additionally enables faster design loops due to reduced meshing time and as such enables to simulate large numbers of parameter variations on complex geometries.

The underlying wind tunnel campaign data consists of two separated parts. At first the effect of the slat position by means of gap and overlap variations was investigated and it could be observed that a slat gap reduction leads to a remarkable slat noise reduction. In the second part the slat gap was manipulated by an adapted deformed slat shape to provide an additional degree of freedom for the aerodynamic as well as the aeroacoustic optimization. The assessment of the prediction capability of the hybrid CFD/CAA approach was conducted on six geometry variations (Figure 3) including the reference geometry (black line), gap and overlap setting variations (coloured lines) and one adapted setting (grey line). Simulations at various AoA and flow velocities equivalent to experimental settings have been computed for all selected cases.

The computational results show a good agreement with respect to the overall spectral shape (Figure 4) compared to the measured ones. While the effect of slat gap variation could be predicted in good qualitative and quantitative agreement to the measurements, the effect of overlap increase is indifferent in both measurements and simulations. The noise reduction potential of the adapted slat is well predicted by the simulation. Questions still remain regarding the effect of AoA on slat noise radiation while simulations show an increase in level with increasing AoA in a frequency range of 3 kHz to 12 kHz whereas no effect is visible in the measurement results. It is suspected that measured spectra might contain other noise sources than the slat in this frequency regime. The DG based CAA code with the same stochastic noise source modelling provides qualitative and quantitative similar results to block-structured-mesh CAA simulations.

It can be stated that by applying the 2D RANS/CAA approach to high Reynolds number high-lift systems, one is capable to efficiently predict sound emission differences caused by variations of the slat position, slat shape, and inflow velocity. First tests show that the DISCO code is capable to achieve satisfying results on an unstructured mesh in short time and may be used in industrial environment in the near future.

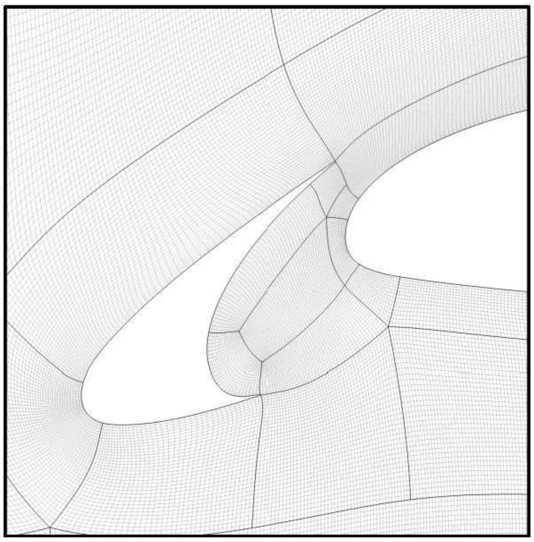

Fig. 1. Block-structured body-fitted grid for PIANO computations

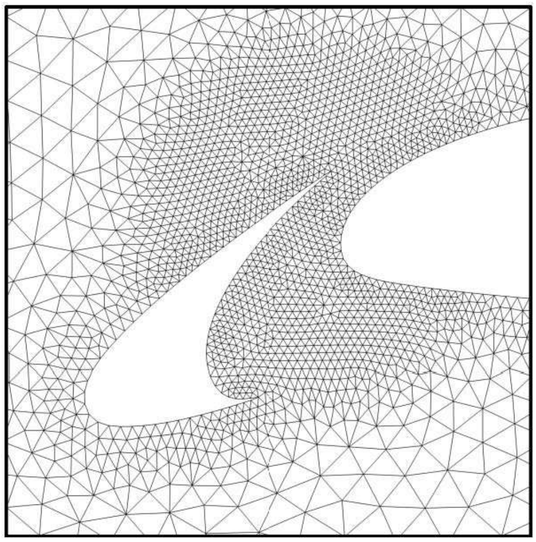

Fig. 2. Unstructured triangular grid for DISCO computations

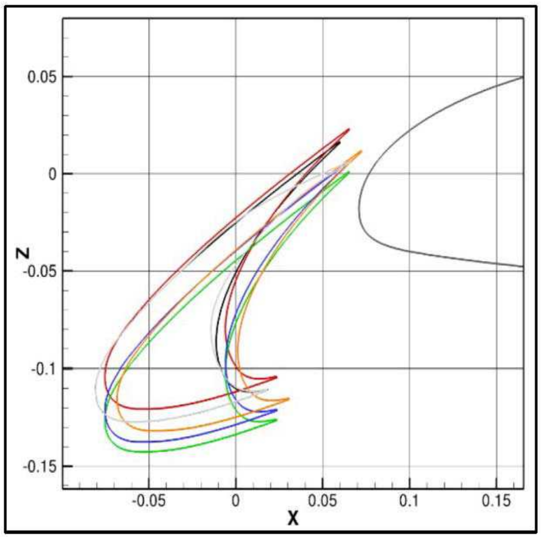

Fig. 3. Geometric setting variations (black: reference, red: SO1, green: SO2, blue: SO3, orange: SO4, grey: adapted

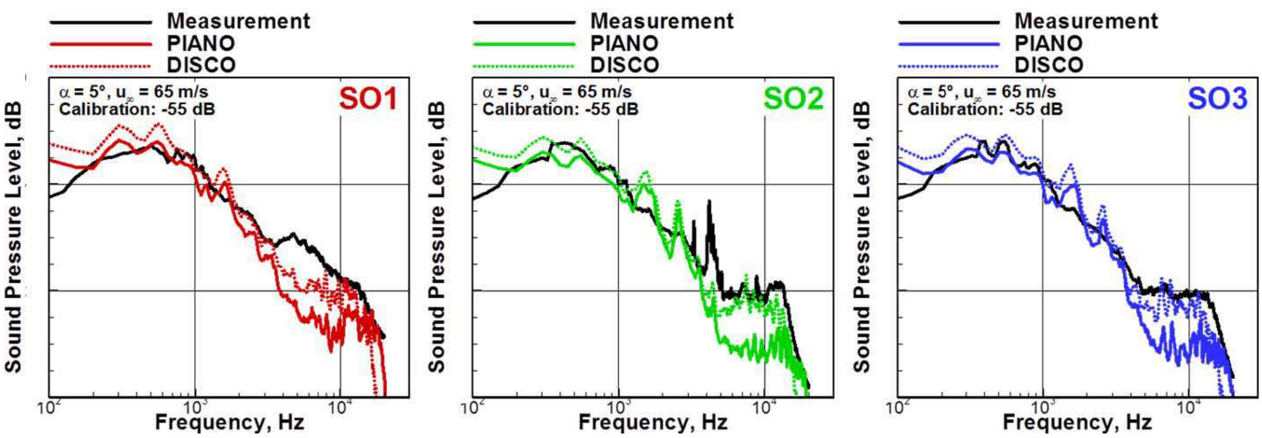

Fig. 4. Comparison of PIANO and DISCO simulations with DNW-LLF test results

Keywords: airframe noise, high-lift systems, aeroacoustic simulations.