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On the estimation of the spanwise coherence of a flat plate

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Regarding aeroacoustics, pressure and velocity fluctuations are the main quantities of interest for determining the acoustical sources. Especially the spanwise coherence of the wall pressure is of importance for the estimation of, for example, trailing edge noise and vibro-structural problems. Several authors, such as Amiet [1] and Howe [2] have discussed difraction theory regarding trailing edge noise. Here, the power spectral density and spanwise coherence length of hydrodynamic pressure fluctuations where used to estimate the acoustic far field spectrum. Amiet [1] and Howe [2] assumed that the incident pressure fluctuations on the wall below the turbulent boundary convect over the trailing edge, which acts as an impedance discontinuity, where the fluctuations are scattered in the form of acoustical waves. This theory forms the basis of multiple experimental and numerical studies, such as the LES study of Christophe [3] or the surface pressure measurements of Brooks and Hodgson [4].

This study focuses on the very first part of capturing trailing edge noise; the physically correct simulation of the spanwise coherence length of the hydrodynamic pressure fluctuations on an infinite flat plate with a low Mach number flow. It will be further extended to a study with a finite flat plate, simulating trailing edge noise and capturing the acoustic field and the spanwise coherence in the jet shear layer.

For the numerical approach, two methods are considered: a finite volume Navier Stokes (NS) method and a Lattice Boltzmann Method (LBM). The transient, incompressible NS equations are solved using a Large Eddy Simulation (LES) with two different kinds of Smagorinsky closure models. As an alternative, the LBM is used. These simulations are by nature explicit, transient and compressible and are based on tracking the advection and collisions of fluid particles. The flow results of both methods are validated with experimental data for an infinite flat plate [5] and a beveled flat plate [6], in particular, streamwise and spanwise coherence data to conclude about the quality of the acoustical sources. As a post-processing step, velocity and pressure source data are taken from the fluid simulation to obtain the acoustic field. Using a computational free field and tailored made Green's function, the acoustic field is produced.

An infinite flat plate model is numerically generated using the recycling method of Lund et al. [7]. Data at a station downstream is extracted, rescaled to account for the boundary layer growth and applied at the inlet. Reynolds numbers of 6,800 are reached with respect to the boundary layer thickness. The beveled trailing edge geometry, used to analyze the trailing edge flow consists of a set of models with varying radius of curvature and inflow conditions. With a fixed trailing edge of 25 degrees, the radius of curvature varies between $0t$, $4t$ and $10t$, with t indicated as the thickness of the plate. Together with two different flow conditions (Re = 2.7E5 and Re = 5.4E5) it forms the complete set of simulations of the beveled trailing edge.

With respect to the preliminary results of the spanwise coherence of the wall pressure fluctuations in the turbulent boundary layer, depicted in Fig. 1, the conclusion can be drawn that a high resolution in spanwise direction is recommended to capture any coherence. Clearly a peak around St = 0.25 is present, indicating a specific size of coherent structures in spanwise direction. The fast decay of coherence is notable, and also present in literature [5]. Similar results for the beveled flat plate will be presented in the final paper, as well as directivity plots for acoustic sound pressure level, extracted from the fluid simulation.

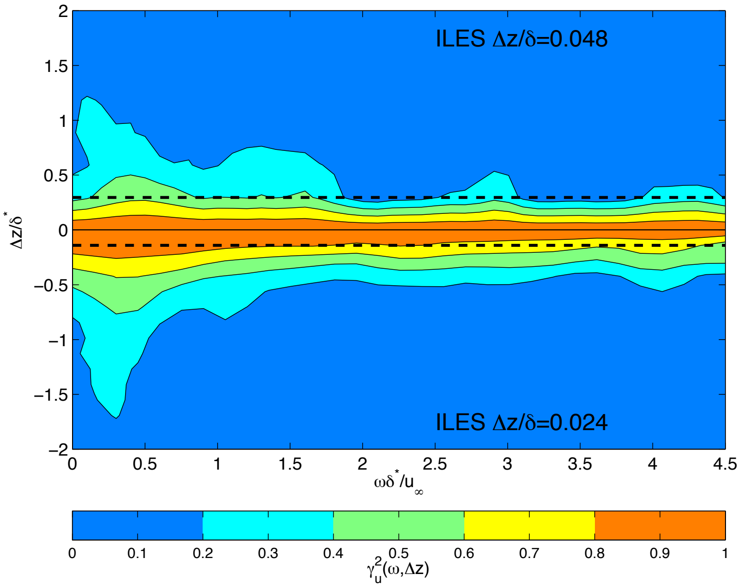

Figure 1: Comparing mesh density for spanwise coherence function of pressure fluctuations on the wall of a zero gradient infinite flat plate

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