Prediction of Wall Pressure Fluctuations using the Lattice-Boltzmann Method

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There is an increasing interest in the research field as well as in the industry to simulate aeroacoustic phenomena. Beside the prediction of resonant-acoustic phenomena like sunroof buffeting the computation of wall-pressure fluctuations (WPF) is focused, because they are a source of the excitation of structures (e.g. the hull of cars) and are therefore input for structural vibro-acoustic codes.

Flow field unsteadiness includes a wide range of spatial and temporal scales. Low frequency contributions of the spectrum are associated with the unsteady aerodynamic flow structures, while the higher wall-pressure fluctuations are associated with aerodynamic noise generation. Those are generated due to turbulence, e.g. in free shear layers, wake-regions, boundary layers. Consequently, capturing the WPF over a wide spectrum requires the direct simulation of as many as possible small-scaled vortices. The limit of the achievable fluctuations is defined by the cut-off frequency, which is dependent on the grid resolution and the degree of dissipation of the numerical method.

In this work the commercial CFD program PowerFLOW (EXA) [3] is used to simulate a flat plate in a turbulent regime. Contrary to conventional CFD methods, PowerFLOW uses a simplified kinetic model, the lattice Boltzmann method (D3Q19) with the Bhatnagar-Gross-Krook (BGK) approximation. The accuracy in the time evolution and the compressible nature of this implementations supports the simulation of aeroacoustic phenomena.

A progressive grid refinement study has been conducted to investigate the cut-off frequency. For that purpose a streamwise portion of the flat plate turbulent boundary layer is simulated. An appropriate unsteady boundary condition initiating the turbulent fluctuations based on the work of Yao-Sandham [2] is implemented and discussed. Autospectra and wavenumber-frequency spectra are generated from the simulation results and compared to experiments and theoretical considerations [1].

References:

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