Calculation of sound generation and radiation from turbulent flows

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The Lattice-Boltzmann-method (LBM) is known to be capable of simulating acoustic problems. However, only a few authors investigated the application of LBM in flow acoustics in detail. Skordos[1], Buick et. al.[2] and Haydock and Yeomans[3] studied flow acoustic problems using numerical experiments, while Lallemand and Luo[4] provide theoretical results on acoustics, but do not discuss the details of sound propagation results. This work follows the ansatz of linearizing the equilibrium distribution function with subsequent von-Neumann-analysis. The resulting eigenwert problem is solved numerically with Mathematica. It is shown that for the D2Q9-LBGK scheme dissipation of sound energy, though strongly anisotropic, is of the same order of magnitude as predicted by the theory for mono atomic gases, and is therefor negligible for all current applications in the audible frequency range. In contrast to that, phase speed errors exceed 1 % of the nominal value if waves are sampled with less than 12 points per wave length. If more grid points per wave length are used, the variation of phase speed error with respect to the propagation direction is negligible. Convection effects on sound waves (Doppler effect) are shown to be captured correctly. Compared to highly specialized DRP-FD schemes which are available for the solution of Euler's equations, a high resolution is needed for LBM to deliver accurate acoustic results.

In a second part two flow acoustic problems are investigated. A 3d-simulation of the flow above a Helmholtz resonator embedded in a flat plate is carried out using the commercial code PowerFLOW. The resonance is excited by a feedback mechanism which couples the transport of flow disturbances in the boundary layer to acoustic oscillations of the air inside the cavity. The results show good agreement with experimental data published in the literature[5]. The second, 2d test case is the generation of sound at the trailing edge of a flat plate. Vortexes are generated by a vibrating ribbon in the boundary layer above the plate and convected downstream across the trailing edge. Each passing of a vortex at the trailing edge triggers the generation of a sound wave, which propagates upstream. The directivity is that of a dipole normal to the plate located at the edge. The scaling of the observed sound intensities with respect to mean flow velocities is compared to theoretical predictions of trailing edge noise.

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