Hybrid aeroacoustics using Helmholtz decomposition

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In modern transportation systems, passengers' comfort is greatly influenced by flow induced noise. As a consequence, manufacturer include the reduction of typical noise sources into their product development framework. In general, the product development requires a fast, adaptive, and computational efficient source computation method. Preferably, this requirements select hybrid aeroacoustic method. The computation of flow and acoustic is separated in hybrid aeroacoustic and restricted to a forward coupling of flow onto the acoustic field. A separate acoustic simulation allows us to include acoustic properties at the boundaries, like impedance conditions.

Referring back to flow induced noise, aeroacoustic feedback triggers vortical flow instabilities. This instabilities and the feedback loop must be resolved by a compressible flow simulation of the aeroacoustic application. Typical hybrid aeroacoustics is limited to incompressible flow simulation, since a compressible flow simulation models already acoustic propagation. The main purpose of our approach is to connect the computational efficient hybrid aeroacoustic workflow with the compressible flow simulation that resolves aeroacoustic feedback, and is based on Helmholtz decomposition of the flow field.

Compared to ordinary hybrid aeroacoustic approaches, the main three steps of our approach include an additional filter step. First, we perform a compressible flow simulation, which incorporates two-way coupling of the flow and acoustics. Second, we filter the aeroacoustic sources by the Helmholtz decomposition, such that we obtain a pure non-radiating, vortical field that computes the sources. Finally, we compute the acoustic propagation.

The method is applied to the "cavity with a lip", a generic model of a vehicle door gap. Previous investigations[1] show that only a compressible flow simulation resolves the correct shear layer instability. The application example of the cavity in 3D includes variations of the free-stream velocity, the boundary layer thickness, and the applied turbulence model URANS and DES. A final acoustic simulation based on vortex sound validates the hybrid aeroacoustic method.

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[1] Farkas and Paal, *Period. Polytech. Civil Eng.* **337**, 59 (2015).