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Aeroacoustics of confined flows and the radiation to the surroundings

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Plenary Abstract

Acoustic comfort in modern product development has significantly gained importance in recent times. In the high-end passenger transportation sector, acoustics especially plays a significant role. The current trend toward e-mobility further contributes to the importance of acoustic design. Noise from auxiliary aggregates can become unpleasant due to the absence of combustion engine noise. Ideally, acoustic aspects are already considered during the design phase by means of numerical simulations. When aeroacoustic effects are involved, the hybrid approach is an efficient way to limit the computational effort and overcome the challenge of the disparity of scales in computational aeroacoustics. In doing so, in the first step, the main flow structures are resolved by an incompressible flow simulation within the flow guided structures. The acoustic source terms are simultaneously computed during the flow simulation and conservatively interpolated on the acoustic grid. In our case, we use the Perturbed Convective Wave Equation (PCWE), and therefore the acoustic source term is the substantial derivative of the incompressible flow pressure. In the second step, the PCWE equation, being solved within the flow guided structures, is directly coupled to the mechanical equations describing the mechanical vibrations of the flow guided structures, which directly couple to the standard wave equation to compute the radiated sound efficiently. This approach also allows to consider the interaction of the incompressible flow pressure on the mechanical vibrations of the flow guided structures. Therefore, in the second step of our computational scheme, we consider this as a pure forward coupling from the flow to the mechanical structure. Since the mechanical vibrations in most applications are small, a full flow-structural-interaction (FSI) simulation is unnecessary, and our approach is highly efficient. In addition, our scheme allows us to separate the two mechanisms leading to the radiated sound: (1) excitation of the flow guided structures by the incompressible flow pressure; (2) excitation of the flow guided structures by the flow-induced sound, being a result of the confined flow.

In our presentation, we will provide an overview of different formulations of aeroacoustics for confined flows and discuss their advantages and restrictions. Furthermore, we will present the latest results of the application of our hybrid approach to different practical applications, e.g., half-moon-shaped orifice in a circular pipe and a diverging and remerging pipe flow obtained by combining two T-junctions. In doing so, we provide details of the flow simulations, the acoustic source terms, and the radiated sound. For both applications, we have built a test-rig and performed measurements inside and outside the flow guided structures. Computations and measurements are in good agreement and demonstrate the applicability of our developed hybrid aeroacoustic approach, being capable to also simultaneously compute the radiated sound.