Prediction of airfoil tonal noise using URANS computations and its mitigation

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Abstract:

Laminar boundary layer vortex shedding is one of the main sources of airfoil self-noise. It occurs at moderate Reynolds numbers and angles of attack, where a relatively large region of laminar boundary layer is developed over an airfoil. The airfoil tonal noise, which is a result of laminar boundary layer instabilities, is critical in designing low-noise airfoils. The identification of tones and calculation of noise levels require a high-fidelity aerodynamic model, capable of resolving the laminar boundary layer, accurately predicting the transition region, formation of instabilities and their propagation downstream. Whereas the typical computational aeroacoustics (CAA) procedures require scale-resolving simulations, the aforementioned physics may be as well captured using the unsteady RANS model. Current work presents the approach to modeling of tonal noise using relatively cheap URANS simulations. The general case of asymmetric S834 airfoil was investigated at Reynolds number of 5×10^5. Hence, the tonal noise mitigation was performed using zigzag tape to trip the boundary layer. A hybrid aeroacoustic approach using Lighthill analogy was adopted to calculate noise levels for both cases, which compared to experimental results from the literature confirmed the usefulness of the presented approach.

It was found that airfoil tonal noise analysis requires a 3-dimensional aerodynamic model to allow adequate modeling of boundary layer trip. While the 2-dimensional model gave correct transition location, the vortex shedding frequency was different to 3-dimensional case. The mesh sensitivity study revealed the importance of appropriate mesh refinement, which is required to capture formation of instabilities, as well as the frequency and amplitude of force oscillation on the airfoil surface. The critical aspects regarding modeling of airfoil tonal noise were summarized.