# Leveraging flow-induced vibration for manipulation of airfoil tonal noise

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Suppression or reduction of airfoil tonal noise has been an attractive field of study for aeroacoustic research community due to its wide application in low Reynolds number flow problems such as Micro Air Vehicles or wind turbine etc. Over the years, a number of tonal noise reduction strategies have been proposed and tested over an airfoil such as leading edge modifications, trailing edge serrations, perforations and brushes, etc [1-3]. However, most of these noise reduction mechanism are associated with the degradation in aerodynamic performance of the airfoil due to geometrical modifications. Furthermore, implementation of these mechanisms are not feasible in practical situations due to complexities involved in manufacturing.

A novel idea for reduction in airfoil tonal noise using flow-induced vibrations is explored by using a flush-mounted elastic panel over the suction surface of an airfoil. The fundamental aim of this study is to reduce the tonal noise while maintaining laminar boundary layer over the airfoil with minimum or no penalty on the aerodynamic performance of airfoil. Fluid-structure interaction of an elastic panel modifies the hydrodynamic characteristics of flow over the airfoil which subsequently modifies the panel response and eventually results in reduction of tonal noise.

Flow around a NACA 0012 at an angle of attack $\alpha = 50$ and $Re = 5x10^4$ is chosen as baseline in this study due to its rich information available in existing literature. In the choice of methodology, direct aeroacoustics simulation (DAS) is employed using Conservation Element and Solution Element (CE/SE) method to solve the unsteady compressible N-S equations. Though DAS provides complete physical insights of aeroacoustics, it poses certain limitations due to the high computational time and resources required for its application. Hence, a more feasible solution is sought by using Linear Stability Analysis (LSA) which can effectively provide qualitative hydrodynamic instability characteristics convected in shear flows. A weak pulse is introduced at an upstream location of airfoil which initiates a disturbance in flow field once it interacts with the leading edge of airfoil. For LSA, time-averaged solution is set as base flow for stability analysis in this study which is extracted from DAS of baseline rigid airfoil.

A flush mounted thin elastic panel over the suction surface of airfoil is considered to analyze the mechanism of fluid-structure interaction and vibrational response of panel in noise reduction. A panel of length 0.05c at a location of 0.4c from the leading edge is chosen. Panel parameters such as internal tension, thickness, and density are carefully selected to ensure that the natural frequency of panel in the presence of flow field is similar to the first dominated frequency of naturally evolving boundary layer disturbance on airfoil suction surface so that a resonance condition is achieved.

Analysis revealed a prominent reduction in magnitude of velocity fluctuations around the airfoil trailing edge for airfoil with elastic panel. Furthermore, a significant reduction in pressure fluctuations around the airfoil at a radius of 2.5c is also observed as shown in Fig 1. A comparison of sound pressure level comparison with the baseline rigid airfoil showed promising reduction in tonal noise of airfoil with elastic panel. To gain further insights on the sensitivity of panel parameters on its vibration behavior and magnitude of reduction in tonal noise, a parametric study is also carried out. Contributions of panel density and thickness are found to be dominant in noise reduction. A maximum sound pressure level reduction of **2.72 dB** is achieved for the current flow conditions through the proposed strategy.

## References


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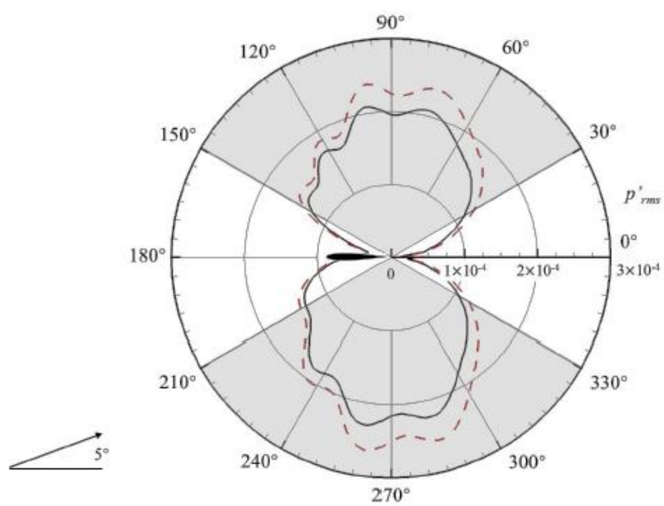


**Figure 1: Azimuthal $p'_{rms}$ comparison. - - -, airfoil with elastic panel; ---, rigid baseline airfoil**