Investigation of aeroacoustics and flow dynamics of a NACA 0015 airfoil with a Gurney flap using TR-PIV

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Keywords: Aeroacoustics, Causality correlation, Gurney flap

HIGHLIGHTS

• The tonal peaks in a Gurney flap correspond to the vortex shedding frequency.
• No prominent secondary mode of shedding was found in a Gurney flap flow in contrast to earlier observations. This difference is attributed to the turbulent boundary layer in the present investigation.
• High values of correlation between the acoustic fluctuations and vertical velocity fluctuations of the flow are found in the downstream region of the Gurney flap. Nearly zero correlation is found in the upstream recirculation region indicating that the downstream region of the flap is responsible for the noise generation in case of a Gurney flap.

ABSTRACT

The present study employs simultaneous planar TR-PIV and microphone measurements to obtain the flow dynamics and aeroacoustic causality correlation associated with a Gurney flap of various sizes in case of low Mach and high Reynolds number flows. The objectives are to investigate the secondary shedding mode for the case of a turbulent boundary layer and to understand the mechanism of noise generation by identifying structures that are highly correlated with far field pressure fluctuations. The instantaneous velocity and vorticity fields show the flapping motion of the wake and the coherent vortex shedding process. The tonal peaks are clearly audible and correspond to the vortex shedding frequency. The PSD of the flow fluctuations and acoustic spectra did not indicate a secondary mode of shedding in case of turbulent boundary layer. The Strouhal numbers of the vortex shedding are found to be close to that of a bluff body in a flow. Causality correlation between pressure fluctuations in the far-field and the near field fluctuations indicates that the vertical velocity in the wake of the model is highly correlated with the far-field pressure fluctuations. This study provides an example of the potential of the causality correlation technique in identifying flow structures/regions highly correlated with noise in case of complex high-lift devices, making it possible to design flaps with lower acoustic emissions.

Contour plot of $R_{\upsilon' p'}(\tau)$ indicating high correlation between acoustic fluctuations and vertical velocity in the wake