Tomographic Particle-Image Velocimetry Analysis of the Influence of Artificially Introduced Sound Waves on Transonic Buffet Flow

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HIGHLIGHTS

- TR-Tomo-PIV is performed in the trailing-edge region of a supercritical airfoil flow with self-sustained shock wave oscillations on the suction side, i.e., buffet.
- Variable artificial sound waves are introduced to the buffet flow field in the trailing-edge region of the airfoil to analyze in how far the feedback loop that leads to the buffet flow and of which the trailing-edge noise represents the upstream propagating part can be influenced.
- The three-dimensional Lamb vector that appears as the major source term for vorticity driven sound in acoustic analogies is analyzed.
- The variation of the frequency of the overlaid sound waves has no impact on shock oscillation frequency and only weekly influences the sound source field in the trailing-edge region.
- When the sound pressure level of the overlaid sound waves varies with a frequency near to the natural buffet frequency, the shock oscillation seems to lock into the excitation frequency and the sound source field in the trailing-edge region is changed.

ABSTRACT

The origin of buffet is still not fully understood, yet. According to Lee’s theory, the trailing-edge noise is the main feature of the buffet phenomenon. The scope of this study is to investigate how the feedback loop that leads to the buffet flow and of which the trailing-edge noise represents the upstream propagating part can be influenced by artificial noise that is introduced to the flow in the trailing-edge region of a supercritical airfoil under buffet flow conditions. For this, sound waves with a well defined frequency \( f_m \) and variation of the sound pressure level (SPL) with a frequency of \( f_m \) are generated by a loudspeaker downstream of the airfoil. Time-resolved tomographic particle-image velocimetry as well as unsteady pressure measurements are used to investigate the unsteady transonic buffet flow field with and without artificial sound waves to quantify their influence on the buffet phenomenon. Emphasis is put on the analysis of the three-dimensional Lamb vector that appears as the major source term for vorticity driven sound in acoustic analogies. The airfoil is investigated at a freestream Mach number of \( M = 0.73 \), an angle of attack of \( \alpha = 3.5^\circ \), and a chord based Reynolds number of \( Re = 1.89 \cdot 10^6 \). The results show how the shock oscillation and the natural sound source in the trailing-edge region are influenced by introducing artificial sound waves. This is exemplarily shown in the figure below that presents the phase-averaged contourplots of the absolute Lamb vector perturbation for the reference case, where no sound is emitted by the loud speaker and for one case, where sound waves are overlaid to the flow field.

a) Reference case, shock downstream
b) Reference case, shock upstream
c) \([f_m, f_m] = [1100 \text{ Hz}, 165 \text{ Hz}], \) shock downstream
d) \([f_m, f_m] = [1100 \text{ Hz}, 165 \text{ Hz}], \) shock upstream