Modal Analysis of the Wake of a Supercritical Two-Dimensional Airfoil in Transonic Buffet Conditions

Y. Y. Kwong[*], C. J. Schauerte[*] and A.-M. Schreyer[*]

Under certain conditions in transonic regime, large amplitude self-sustained periodic shock oscillations (transonic buffet) can form. When the buffet frequency is in sync with a structure Eigenfrequency, structure can be damaged due to vibrations, thus limiting the flight envelop. Previous buffet studies [1] [2] [3] focused mainly in the shock neighborhood of the airfoil, and not much attention has been paid to the wake region behind the airfoil. However, the buffet-induced disturbances can propagate downstream in the wake and affect the tailplane aerodynamics, giving rise to a very complex flow that has not yet been understood. Hence, this study focus on the investigation of dominant coherent structures and dynamics in the developing airfoil wake.

A 2D OAT15A supercritical airfoil model is studied experimentally with Focusing Schlieren visualizations and Particle Image Velocimetry (PIV). The wake development has been studied in detail for fully developed buffet conditions [4] (Ma = 0.72 & AoA = 5°). The PIV data was analyzed with a binning system breaking down the buffet cycle into 8 phases, in order to understand the flow dynamics evolution within a cycle. Proper Orthogonal Decomposition (POD) and spectral POD were then applied to the data to analyze coherent structures and dynamics in the wake flow.

POD modes showing similar patterns are detected in all phases, but with different sizes depending on the phase corresponded shock motion. Those modes correspond to thickening of shear layer, contradicting motions of separated layer and boundary layer, separated layer elongation in downstream direction and vortex shedding behavior (Figure 1). Several frequencies in the range of 2900Hz and 4200Hz (corresponding to Strouhal number based on chord length of 1.85 and 2.68 respectively) are detected as vortex shedding frequency from time-resolved (9kHz) Schlieren recordings by means of Spectral POD. We will present the results of the POD analysis in detail, discussing modes and structures that are present throughout all phases of the buffet cycle, as well as structures that are only relevant within specific phases.

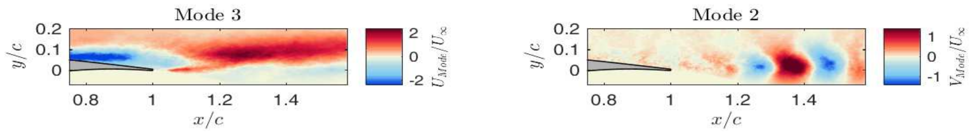

Figure 1: (a) Mode corresponding to separated layer elongation. (b) Mode showing vortex shedding.

[*]Institute of Aerodynamics, Rheinish-Westphalian Technical University, Aachen, Germany

[1]D'Aguanno et al., *Experiments in Fluids* **62**, (2021).

[2]Jacquin et al., *AIAA Journal* **47**, 1985, (2009).

[3]Deck, *AIAA Journal* **43**, 1556, (2005).

[4]Schauerte and Schreyer, *20th International Symposium on Application of Laser and Imaging Techniques to Fluid Mechanics* (2022).