Modes of noise sources around a leading edge slat and the feature with angle of attack

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1. Introduction

Noise generated from a leading-edge slat represents a complex aeroacoustic problem and the underlying mechanisms have received extensive exploration over the past decades. In general, the slat noise decreases with AOA increasing within a range from low to moderate values of AOA typical for landing conditions. The mechanism, which governs the AOA-dependent feature of the slat noise, is the focus of the study.

2. Setup

The profile of the two-dimensional airfoil model was the EUROPIV 1 geometry. The model consisted of a slat and a main element. The deflection angle of the slat was set to 30 degrees. The horizontal gap and overlap were -2.4% and 2.7% of the chord in the stowed configuration respectively. The main element chord (c_m) was 0.35 m and the slat chord was 0.088 m (c_s). A delayed detached eddy simulation was performed. The computational domain extended from -10 c_m to 10 c_m in both the x and y directions and an extension of 0.41 c_s and 37 grid points were used in the spanwise direction. The grid consisted of 71 blocks and a total of 5×10^6 points in the entire three-dimensional domain. A dual time-stepping algorithm was used with 20 subiterations within each time step of 7.14×10^{-4} flow time unit (time non-dimensionalized by c_m/u_∞). The far-field noise was predicted using the FW-H equations. To gain an insight into the flow field around the slat, the velocity field around the slat was measured using a TSI particle image velocimetry (PIV) system. The measurements were conducted in a 0.9 m × 0.6 m wind tunnel. The AOA and freestream velocity were set to 8 degrees and 25 m/s respectively. To capture the dynamics of the flow field around the slat, a fast camera system (LaVision Highspeedstar6) was employed. The sampling rate was set to 5000 frames per second, and 500 images in total were captured over 0.1 s. A video was made using all the images in order to examine the dynamics of the flow.

3. Results and Discussions

As shown in Figure 1, the patterns of slat noise spectrum at AOAs larger than 6 degrees behave similarly although the slat noise level decreases with AOA increasing at entire frequency range. This result is in accordance with the conclusion presented by Choudhari *et al.*. Physical variants, such as TKE values and pressure fluctuations, were used to locate the noise sources in the vicinity of the slat. The distribution of the pressure fluctuations (Figure 2) indicates that the regions near the trailing edge of the slat and the leading edge of the main element are the crucial regions radiating noise into far field. The comparison of the variant values at various AOA shows that those values decrease with AOA increasing. This can account for the AOA-dependent slat noise feature. Furthermore, a proper orthogonal decomposition (POD) technique was applied on the pressure fluctuations. The first mode behaves as a pressure dipole with its axis approximately aligned from the trailing edge of the slat to the leading edge of the main element. The second mode reveals that the intense pressure fluctuation in the reattachment region is closely associated with a kind of flow interaction in the slat cove region.

The PIV measurements show that the instantaneous velocity field appears to be much complex (Figure 3), wherein several vortical structures are present in the slat cove and the vortical structures only appeared in a portion of the images. A video was made using all the images captured by the fast camera system to examine the dynamics of the flow. The flow in the slat cove presents complex unsteady process. A crucial feature was found by observing the video. The flow convected from the stagnation line on the main element intermittently alters its velocity magnitude and direction, also large scale vortical structures are intermittently generated in the region C (Figure 3). The large scale vortical structures are assumed to be a result of the unsteady interaction between the free shear layer shed from the slat cusp with the flow convected from the stagnation line on the main element.

4. Summary

The flow in the slat cove showed complex unsteady process, and intermittently generated vortical structures were observed. The vortical structures are assumed to be resulted from the unsteady interaction between the free shear layer shed from the slat cusp and flow convected from the stagnation line on the main element. As the vortical structures approach the reattachment region, intense pressure fluctuations are generated. This process can account for the generation of the slat noise. As AOA increased, the size of the circulation region becomes small, and the shear layer deviates away the surface of the main element, hence the interaction becomes weak. Weak interaction leads to less intense pressure fluctuations in the regions of noise generation. This determines the AOA-dependent feature of the slat noise.

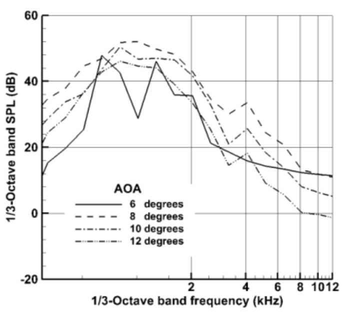

Figure 1: Computed noise SPL.

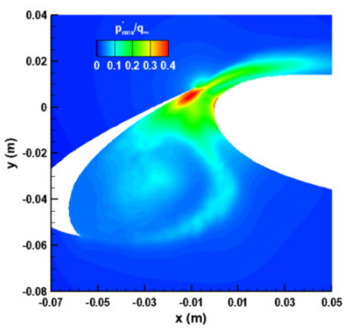

Figure 2: RMS of computed pressure fluctuations.

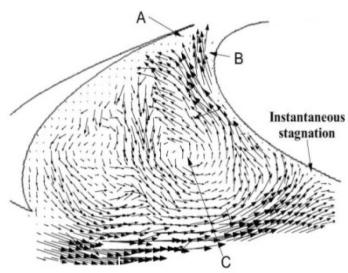

Figure 3: Velocity fields in the vicinity of slat.