Transonic airfoil buffet at high Reynolds number by using wall-modeled large-eddy simulation

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In this study, a state-of-the-art wall-modeled large-eddy simulation (WMLES) (Kawai and Larsson, 2012) is applied to the transonic buffet flow over an OA T15A supercritical airfoil at high Reynolds number. Reynolds number and the angle of attack are \(Re_c = 3.0 \times 10^6\) and \(\alpha = 3.5\) deg. Two Mach numbers of buffet condition \((M_\infty = 0.73)\) and non-buffet condition \((M_\infty = 0.715)\) are computed. Computational results are compared with the experimental data (Jacquin et al., 2009) and the results of zonal detached-eddy simulation (DES) (Deck, 2005). To understand the buffet phenomena, the flow physics are investigated and discussed. At last, a new self-sustained oscillation mechanism is proposed and investigated from the obtained results.

Figure 1 shows the averaged pressure coefficient. Zonal DES can predict the shock oscillation by tuning the size of RANS region. However, the region in which the shock wave oscillates is estimated more upstream than experiment. Furthermore, the separation near the trailing edge is predicted larger. WMLES at the buffet condition \((M_\infty = 0.73)\) can predict the shock oscillation and \(C_p\) slope which is observed at the oscillation region in the experiment is also obtained. In addition, the reattachment behind the shock wave and the small separation near the trailing edge are precisely predicted.

We propose the new self-sustained oscillation model. In the proposed model, we consider that the pressure fluctuation due to separation of the shear layer drives the shock wave. When the pressure ratio between forward and backward of the shock wave changes, the shock wave should become weak or strong and moves forward or backward to balance the equations across the shock wave. When the shock wave is at the most downstream, relatively large separation occurs and the flow area decreases. Therefore, the flow velocity increases and the pressure behind the shock wave decreases. As a result, pressure ratio decreases and the shock wave should weaken. Then, the shock wave moves upstream. On the other hand, when the shock wave is at the most upstream, the separation disappears and the flow area increases. Therefore, the flow velocity decreases and the pressure behind the shock wave increases. As a result, pressure ratio increases, and the shock wave should become strong and moves downstream. Figure 2 shows the time history of the shock wave position, span averaged pressure and local Mach number near the trailing edge and the separation size. The possibility of the proposed model is confirmed from the results.

![Figure 1](image1.png)

Figure 1. Averaged \(C_p\) along the airfoil compared to the experiment and the Zonal DES.

![Figure 2](image2.png)

Figure 2. Physical quantities fluctuation during shock wave oscillation. Grey lines are the raw data. Black and colored lines are the interpolated data by cubic spline. Black line is shock wave position 0.2c away from the wall. Red and blue lines are pressure and local Mach number near the trailing edge. Green line is shear flow thickness.

REFERENCES

