INVESTIGATION OF BUFFET AND BUFFETING CHARACTERISTICS IN BENCHMARK SUPERCRITICAL WING CONSIDERING AEROELASTIC EFFECTS

Yuming Zhang, Yuting Dai* and Chao Yang

*School of Aeronautic Science and Engineering
Beihang University,
Beijing 100191
China

ABSTRACT

Transonic wing buffet refers to the flow instability phenomenon caused by the interaction between shock waves and the boundary layer on the wing during transonic flight. Buffet can adversely affect aircraft controllability and flight performance, and may even lead to structural fatigue or failure. Therefore, transonic buffet has remained a prominent and challenging research topic in the field of aeronautics. However, the underlying multi-disciplinary physical mechanisms, particularly those related to aeroelastic interactions, are not yet fully understood.

This paper investigates the fluid–structure interaction (FSI) characteristics of the NASA Benchmark Supercritical Wing (BSCW) under buffet conditions, as shown in Fig. 1. The BSCW was originally a straight wing with a supercritical airfoil developed by NASA for transonic flutter prediction experiments[1]. It has a span of 32 inches and a chord length of 16 inches. This model has served as the primary research subject in three Aeroelastic Prediction Workshops (AePWs) organized by AIAA, during which extensive experimental and computational studies were conducted. These efforts have yielded a wealth of numerical simulation results and experimental data for the wing in the transonic regime[2]-[5]. The research objectives are to: (1) establish a comprehensive analysis of the BSCW buffet characteristics; and (2) investigate the buffet characteristics under prescribed wing modal motions and buffeting characteristics under FSI.

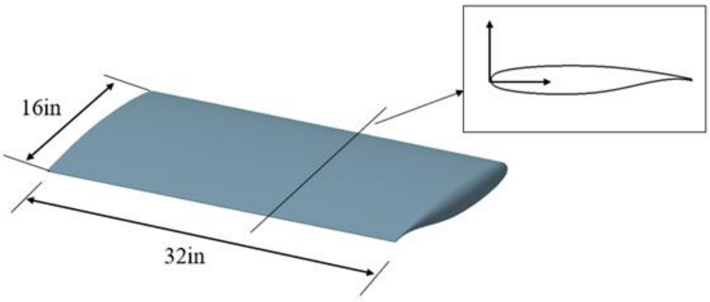
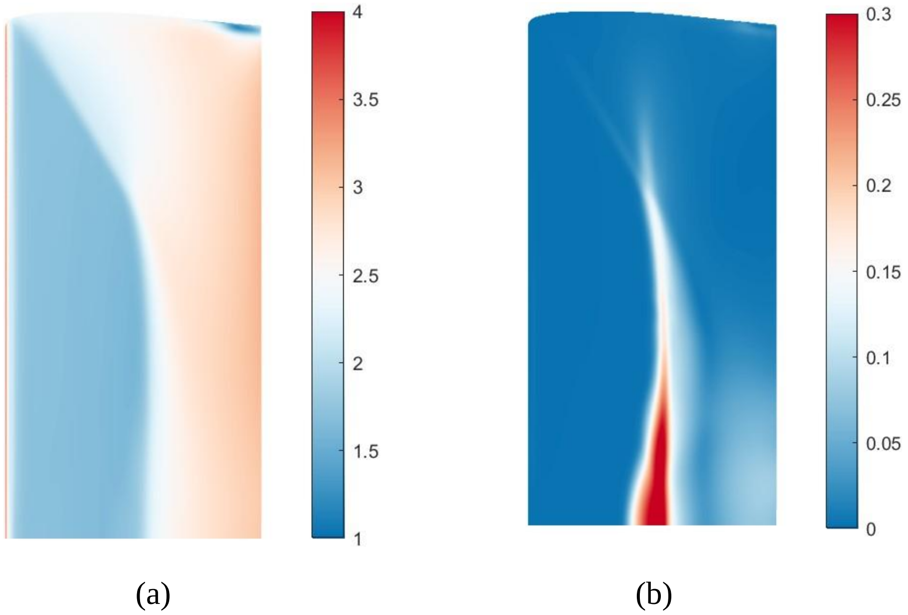


Fig. 1 Model of the BSCW

The study employed high-fidelity CFD simulation techniques, utilizing a density-based solver to analyze the wing model under flight conditions of 0.8 Mach and an angle of attack (AoA) of 5 degrees. Initially, the Transition-SST model and steady-state solver mode were used to obtain an initial flow field, followed by a transient solver mode with the Kω-SST turbulence model to solve the Navier-Stokes equations. The computational time step was set to 2e-5 seconds. The buffet simulation results of the BSCW are compared with experimental data to validate the reliability of the computational methodology. The mean surface pressure distributions and pressure fluctuations' root mean square (RMS) distributions at buffet conditions are shown in

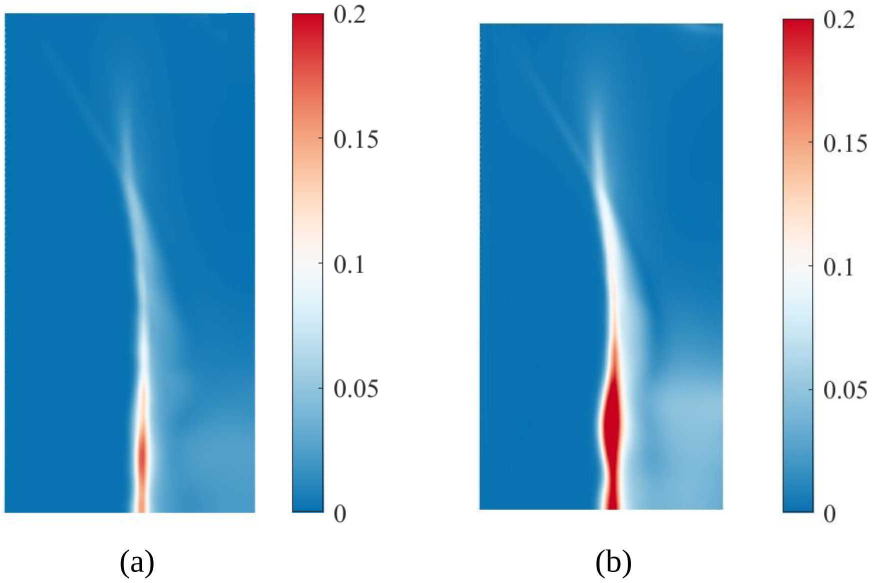
Fig. 2. The results indicate that for this low aspect ratio wing, the tip effects are dominant, decreasing the local AoA, reducing the buffet strength, and shifting the mean shock front forward toward the leading-edge (LE) at the tip region. Hence, the buffet characteristics of the BSCW are predominantly two-dimensional in nature, but significantly influenced by the tip flow.



(a) (b)

Fig. 2 Pressure coefficient contour on the upper wing surface. (a) mean pressure coefficient (b) RMS pressure coefficient

Subsequently, the BSCW wing was subjected to prescribed sinusoidal first bending and first torsion modal motions to investigate their respective effects on the buffet flow field. RMS contours of the unsteady pressure coefficient on the wing upper surface under both motion conditions are shown in Fig. 3. As shown in the figure, the prescribed sinusoidal modal motion has a mitigating effect on the buffet of the BSCW.



(a) (b)

Fig. 3 RMS contours of the pressure coefficient under the two motion conditions (a) prescribed first bending motion (b) prescribed first torsion motion

Additionally, a high-fidelity FSI CFD simulation is performed on the BSCW wing, which incorporates the first bending mode at 15.3 Hz and the first torsion mode at 40.9 Hz. Then, the buffeting response of the BSCW under fluid-structure interaction is compared with the forced vibration response calculated based on the buffeting flow field of the rigidly fixed wing. The findings demonstrate that the difference in wingtip acceleration response between the two methods is within 10%, while the forced vibration approach reduces computational time by over 60%.

Reference

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