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Session:

Vortex breakdown flows around a double-delta wing during pitching motion based on DDES

Liu Jian[1,2], Sun Haisheng[2], Xiao Zhixiang[1*]

[1]School of Aerospace Engineering, Tsinghua University, Beijing, 100084 China

[2]China Aerodynamics Research and Development Center, Mianyang, 621000 China

Description of the Case and Numerical methods

It is well known that strong hysteresis occurs when a delta wing is under pitching state at high incidence[1]. A double-delta wing during pitching motion is selected to be investigated, which is dominated by expression: $\alpha(t)=\alpha_o+\alpha_m sin(2kt)$. In which, $\alpha(t)$ is instantaneous incidence, α_o is balanced incidence, α_m is amplitude, and $k=\omega C/2U_\infty$ is reduced frequency. Here, the free stream velocity U_∞ is 40m/s, the Reynolds number is 1.3×10^6 and α_o is 36°. The model is made up of two delta wings[2], whose sweep angles are 80° and 65° respectively. The total grids number is about 10M, the grid scale in the leeward side where vortex breakdown appears is about 0.02C and set to be homogeneous and isotropic, as showing in Fig.1.

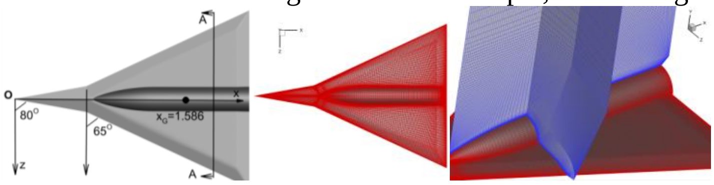

Fig. 1 Model and Mesh of 80°/65° double-delta wing

The turbulence modelling method is DDES[3] base on k-ω-SST. An adaptive dissipative scheme[3] based on 5th order WENO interpolation is used to reduce numerical dissipation in the post-breakdown regions.

Initial Results and Discussion

The movement of burst point lags behind the incidence, as showing in Fig.2. The frequency is identical with the transformation of incidence, and the phase lag is 95° and approximate to be a quarter of one period.

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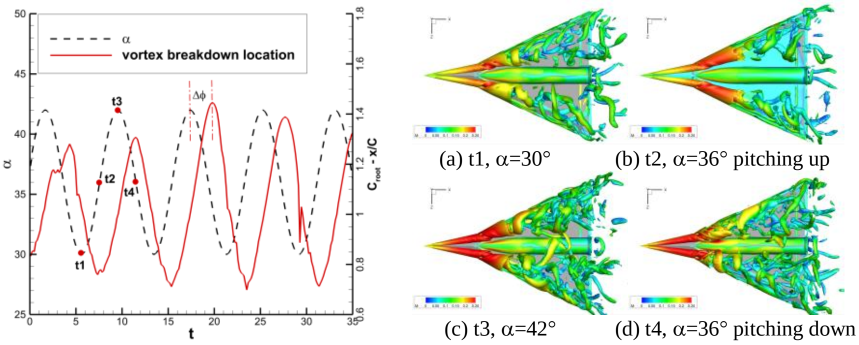

(a) t1, α=30° (b) t2, α=36° pitching up

(c) t3, α=42° (d) t4, α=36° pitching down

Fig. 2 The lag between burst point and incidence(k=0.4,α_m=6°)

Five samples are set on the upper surface in the post-breakdown regions to record the pressure fluctuation induced by both pitching and the spiral vortex structures, whose locations are shown in Fig.3. The typical PSD of C_p(x/C=1.5, z/C=0.2) is composed with three components. In the low frequency range, the dominated St is 0.127, which is in agreement with the reduced frequency(St=k/π). In the middle, a band of frequencies appears(0.87<St<1.80), which reflects multi-scale spiral vortex structures behind vortex breakdown. The equivalent centre frequency could be calculated by ECF=(0.87+1.80)/2=1.33. In the high, the PSD decays as St^{-3}, which corresponds to the unsteady turbulent boundary layer separation. The values of ECF of the five samples are also given and compared with the steady state. The linear law also maintains, but the slope is different.

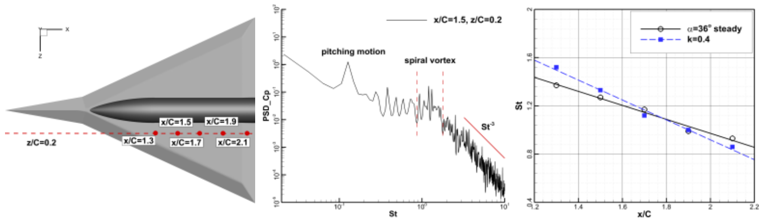

Fig. 3 Sketch of pressure samples and characters of PSD

References

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