Seventh HRLM Symposium, 19-21 September 2018, Berlin, Germany

Session:

Performance of a Modified DDES for the near stall flow past a NACA0015 Airfoil

Jian Liu[1,2], Wenqing Zhu[1], Zhixiang Xiao[1]

[1]School of Aerospace Engineering, Tsinghua University, Beijing, 100084 China
[2]China Aerodynamics Research and Development Center, Mianyang, 621000 China

Brief introduction of DDES-AC method

A modified delayed detached eddy simulation (DDES) with adaptive coefficient (DDES-AC) is proposed to alleviate the "Grey Area" problem and improve the performance in simulating the mild and moderate separation. The coefficient C_{DES} is designed to be adaptive with the flow patterns, quasi two-dimensional or three-dimensional (2-D or 3-D) vortex structures, as expressed in Equ. (1).

$$C_{DES} = (1 - f_{VTM})C_{DES,min} + f_{VTM}C_{DES,hit} \tag{1}$$

The hybrid function f_{VTM} is determined by a vortex tilting measure (VTM).

$$f_{VTM} = \max(0, \min(1.0, \frac{VTM - C_1}{C_2 - C_1})) \tag{2}$$

The VTM is originally proposed by Shur and Spalart [1], and modified as Equ. (3). It has been proved to be effective in the protection of DDES-AC from a premature switching to LES mode in the boundary layer. $C_{DES,min}$ is determined by a few numerical simulation using Smagorinsky type LES in computing strong shear flow. For the original DDES, C_{DES} is equal to $C_{DES,hit}$, and calibrated by the decay of homogeneous and isotropic turbulence (DHIT). This treatment leads to about 70% reduction of eddy viscosity in the quasi 2-D shear layer, which benefits the shear layer instability.

$$VTM_{eff} = \begin{cases} 1 & f_d < 0.99 \\ VTM & else \end{cases} \tag{3}$$

Computational set and initial results

The computations are based on our in-house code, *UNIT*s [2]. The fundamental turbulence model is the two-equation k-ω SST model. The

Session:

adaptive dissipation scheme is used to disperse the inviscid flux. The 2nd order *LU-SGS-τTs* is the time stepping method.

Separated flows over a NACA0015 airfoil at three AoAs (13°, 16° and 17°) are simulated. The Reynolds number based on the chord length is 1.98×10^6 and the Mach number is 0.28 [3]. Figure 1 presents the C_p and relative total pressure at x/C =1.5 when AoA is 13°. The DDES-AC agrees well with the experimental data on the suction peak and C_p in the separated region. In addition, the DDES-AC shows coincident relative total pressure profile with experiment, due to its excellent performance in the interaction between the vortex shedding on the upper surface (USV) and tailing edge vortex (TEV) as well as the vortex breakdown, as shown in Fig. 2. However, the DDES only presents alternatively shedding of USV and TEV, like a vortex street under low Reynolds number.

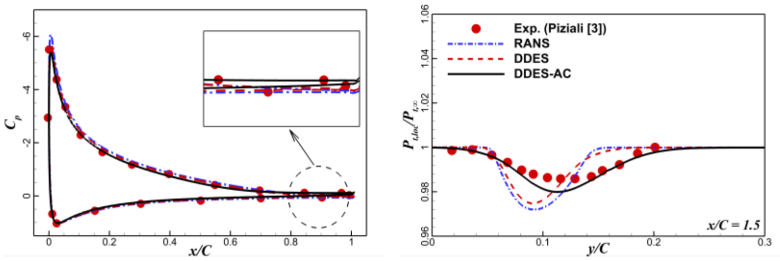

Fig. 1 C_p on the surface and relative total pressure in the wake at AoA = 13°

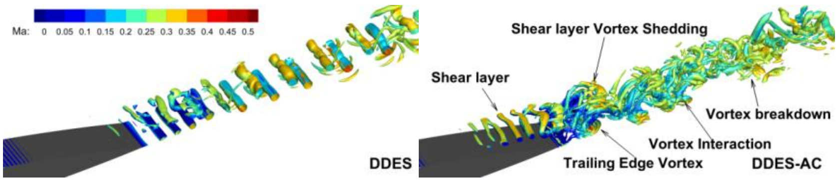

Fig. 2 Iso-surface of Q colored by Mach number at AoA = 13°

References

[1] Shur ML, Spalart PR, Strelets MK, Travin AK. An enhanced version of DES with rapid transition from RANS to LES in separated flows. Flow Turbulence and Combustion, 2015, 95: 709–737.

[2] Liu J, Luo KY, Sun HS, Huang Y, Liu ZT, Xiao ZX. Dynamic response of vortex breakdown flows to a pitching double-delta wing. Aerospace Science and Technology, 2018, 72: 564–577.

[3] Piziali RA. 2D and 3D oscillating wing aerodynamics for a range of angles of attack including stall. NASA TM 4632, 1994.