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HIGH-ORDER DETACHED EDDY SIMULATION BASED ON A REYNOLDS-STRESS BACKGROUND MODEL

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Referring the construction of SST-DES method, a variant of detached-eddy simulation (DES) method based on the SSG/LRR-ω Reynolds-stress model (RSM) as RANS background model is carried out. Through the combination of a fifth-order weighted compact nonlinear scheme (WCNS-E6E5), the SSG/LRR-DES method is applied to three aeronautic cases and compared with traditional methods: SST-URANS, SSG/LRR-URANS and SST-DES.

First, simulation of the NACA0012 airfoil stalled flows at four different angles of attack (AoA) is carried out to investigate the capability of the SSG/LRR-DES for predicting flows with different large turbulent structures, including: a flow with minor separation near the trailing edge (AoA=5°), stall flow with large wake separations (AoA=17°) and stall flows with massive flow separation (AoA=45°, 60°). At 5° angle of attack, all the SST-URANS, SSG/LRR-URANS, SST-DES and SSG/LRR-DES calculate lift and drag agree well with the experiment. At 17° angle of attack, SST-URANS, SSG/LRR-URANS and SST-DES predict a higher lift coefficient than the experimental data, while the SSG/LRR-DES method gives a better lift coefficient result and a higher fidelity vortical flow structure. It is indicated that the RSM can improve the RANS-mode's prediction of pressure-induced separations on airfoil surfaces in detached-eddy simulation. At 45° and 60° angles of attack, the SSG/LRR-DES method captures the massively separated flow with three-dimensional vortical structures and obtains a good result which is the same with the traditional method SST-DES.

The second case is NASA CRM wing-body configuration, which is a popular test case for the RSM. Because the traditional eddy viscosity model, like SST, would predict a separation in the side of body at AoA = 4°. However for the SSG/LRR-ω model, no separation is found. When combined with DES, SSG/LRR-ω model still predicted a smooth flow in the junction of the wing and body. It is indicated that the SSG/LRR-DES can maintain the advantage in accounting for normal stress differences.

Finally, for further verification of the SSG/LRR-DES method in simulating 3D separated flow, blunt-edge deltawing at AoA = 24.6° is carried out. At this angle of attack, the primary vortex will break, which is difficult to be predicted by using the SST-URANS method. For the SSG/LRR-URANS method, it predicts the vortex breakdown successfully, but the breakdown process does not show a significant unsteady characteristic. The SST-DES and the SSG/LRR-DES methods both predict a significant unsteady vortex breakdown. But in terms of the accuracy of surface pressure and the fidelity of unsteady flow, the result obtained by SSG/LRR-DES method is better than that of SST-DES method.