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Session:

Implementation and Assessment of the Synthetic-Eddy Method in an Unstructured Compressible Flow Solver

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Introduction

The application of hybrid RANS/LES methods to aeronautical flow problems is considered feasible for flows with large separations (e.g., behind deployed spoilers or landing gears), but flows with incipient separation, e.g., on a wing operating at maximum lift, still pose a challenge for these methods. One critical issue is the "grey area" at the RANS/LES interface, i.e., a delayed transition from modelled (RANS) to resolved (LES) turbulence. Although this problem can sometimes be remedied, e.g., by flow-adaptive LES filters or stochastic forcing, the high stability of weakly-separated boundary layers usually calls for more effective methods to enhance RANS-to-LES transition. One promising approach is the injection of unsteady synthetic fluctuations at the interface, which are derived from the statistics of the upstream modelled turbulence [1].

This paper presents the recent implementation and assessment of the Synthetic-Eddy Method (SEM, [1]) and its divergence-free variant, DF-SEM, in the compressible DLR-TAU solver. Unlike most other solvers with synthetic-turbulence capabilities, TAU uses an unstructured grid metric with different cell types, which imposes additional difficulties for the implementation. Nevertheless, it allows for a rather flexible placement of multiple interface planes (see Fig. 1, left) inside unstructured grids. The methods are assessed in different flow cases from the EU-project Go4Hybrid. To ensure sufficient numerical accuracy, a low-dissipation low-dispersion (LD2) scheme [2] is applied in all simulations.

Simulation Cases and Results

For a fundamental assessment of synthetic turbulence in TAU, the SEM and DF-SEM are applied as inflow condition for a wall-modelled LES (i.e., using IDDES) of the developing boundary layer on a flat-plate. An important accuracy measure for this flow is the streamwise evolution of the skin friction, which is compared to reference data in Fig. 1 (right). With both SEM and DF-SEM, c_f recovers quickly from the expected initial

drop, but only with DF-SEM the reference data further downstream is matched. Moreover, the large pressure fluctuations (c_p) observed with SEM are clearly reduced by the divergence-free formulation.
A more complex flow case is the pressure-induced separation behind a 2D wall-mounted hump. Here, synthetic turbulence from SEM is injected alternatively at two different streamwise locations inside the flow domain, and the SST-IDDES is applied with fixed RANS/LES interfaces. According to Fig. 2, with both interface locations a good agreement with the measured skin friction is obtained, whereas both RANS and basic IDDES (i.e., without SEM) fail to match the experimental separation size.

The final paper will include more detailed analyses of the flow predictions and sensitivities of (DF-)SEM in TAU, and will provide an application to the more relevant case of a multi-element airfoil near stall.

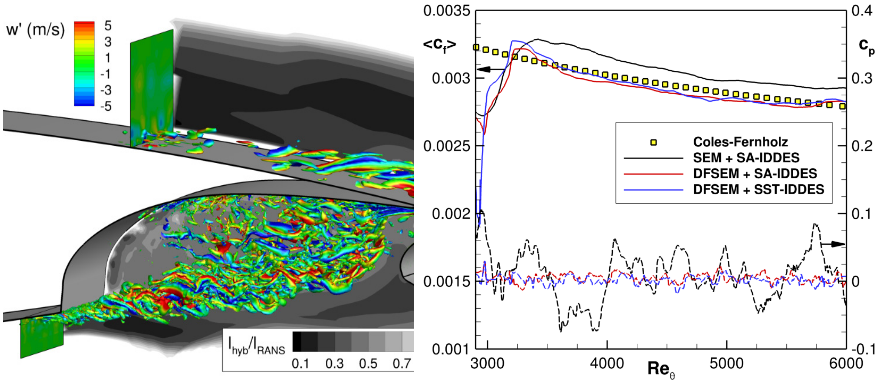

Fig. 1 *Left:* Injection of synthetic turbulence in two planes of a multi-element airfoil flow. *Right:* Mean skin friction and instantaneous pressure on a flat plate.

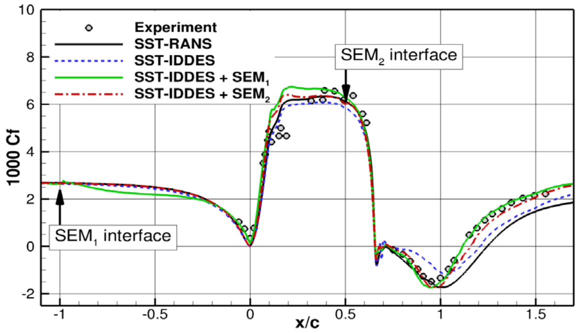

Fig. 2 Mean skin friction along a 2D wall-mounted hump.

[1] Jarrin, N. et al. (2006). A synthetic-eddy-method for generating inflow conditions for large-eddy simulations. IJHFF, 27(4), 585–593.
[2] Löwe, J., et al. (2015). A Low-Dissipation Low-Dispersion Second-Order Scheme for Unstructured Finite-Volume Flow Solvers. AIAA 2015-0815.