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Session:

Comparative Assessment of Synthetic Turbulence Methods in an Unstructured Compressible Flow Solver

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Introduction

The industrial use of scale-resolving methods in high-Reynolds-number applications (e.g., airplanes) requires efficient hybrid approaches, in which flow regions of interest are resolved by local LES embedded in a global RANS simulation. The transition from RANS to LES has to be augmented by synthetic turbulence to quickly transform the modelled turbulence into realistic velocity fluctuations. For compressible flow solvers such as the DLR-TAU code, the consistent treatment of density and temperature, and the generation of spurious noise need to be considered, as well [1].

Over the last years, different methods for synthetic turbulence generation have been implemented in the unstructured TAU code: the Synthetic-Eddy Method (SEM), the Divergence-Free SEM, and an extended variant of the Synthetic Turbulence Generator of Shur et al. [1], denoted by Random Velocity Field Generator (RVFG) [2]. Their implementations in TAU allow for flexible grid-independent turbulence injection in multiple planes or volumetric regions via forcing source terms in the flow equations [3].

While individual assessments for different flow cases have been conducted before [2,3], this paper presents the first systematic comparison of all these methods in TAU for the same test cases in a unified framework, ruling out uncertainties due to numerical and implementation details.

Simulation Cases and Results

Fundamental comparisons of the different methods, as well as sensitivity studies with regard to relevant modelling parameters (e.g., the size of the synthetic forcing region or the effect of additional compressible source terms) are conducted for the developing boundary layer on a flat plate starting at $Re_{\Theta} = 3000$. Exemplarily, Fig. 1 (left) qualitatively compares the lateral synthetic fluctuations from the standard SEM and the RVFG based on the same statistical input. The assessment of the different methods in combination with wall-modelled LES (using IDDES) will be based on high-quality reference data from measurements and DNS computations.

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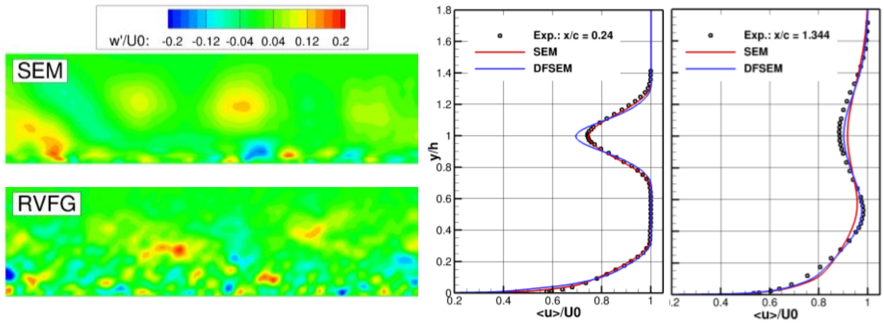

Fig. 1 *Left:* Lateral synthetic fluctuations in the flat-plate boundary layer at Re_Θ = 3000. *Right:* Mean velocity profiles in the mixing co-flow.

A more complex test case is the mixing co-flow of Pot (1979), which can be considered a simplified model flow for a high-lift airfoil, where the wake of the main-wing element interacts with the boundary layer on the deployed flap. The simulations employ a carefully-adapted hybrid grid with $14{\cdot}10^6$ grid points and three hybrid interface planes with injected synthetic turbulence, as illustrated in Fig. 2. Preliminary results for the development of velocity profiles using SEM and DFSEM are shown in Fig. 1 (right). The final assessment will include results from the RVFG as well as more detailed comparisons with measurements and reference RANS computations.

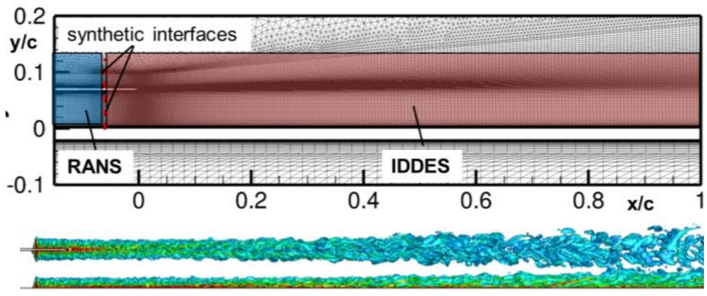

Fig. 2 Mixing co-flow: Simulation setup and Q-criterion from DFSEM.

[1] Shur, M.L., Spalart, P.R., Strelets, M.K., Travin, A.K. (2014). Synthetic Turbulence Generators for RANS-LES Interfaces in Zonal Simulations of Aerodynamic and Aeroacoustic Problems. Flow Turbul. Combust., 93, 63–92.
[2] Francois, D. G., Radespiel, R., Probst, A. (2015). Forced synthetic turbulence approach to stimulate resolved turbulence generation in embedded LES. Progress in Hybrid RANS-LES Modelling. NNFMMD, Vol. 130, Springer.
[3] Probst, A. (2018). Implementation and Assessment of the Synthetic-Eddy Method in an Unstructured Compressible Flow Solver. Progress in Hybrid RANS-LES Modelling. NNFMMD, Vol. 130, Springer, 91-101.