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APPLICATION OF A SYNTHETIC TURBULENCE GENERATOR TO SOLUTION OF AERODYNAMIC AND AEROACOUSTIC PROBLEMS WITH THE USE OF EMBEDDED LES

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Contemporary Computational Aerodynamics (CFD) and Computational Aeroacoustics (CAA) are characterized by a rapid moving from semi-empirical methods to the methods based on “first principles”. As far as aerodynamics is concerned, this implies scale-resolving methods ranging from DNS and LES to different hybrid RANS-LES approaches. Their fundamental advantage over the conventional RANS-based semi-empirical methods which for a long time have been and still remain a valuable practical framework in applied CFD/CAA, is that they do not rely or, at least, are much less dependent on empirical information, thus allowing a deeper understanding of flow and noise physics and making possible reliable prediction apart from calibration conditions. This has stimulated intensive studies employing scale-resolving approaches. However, as of today, the accuracy ensured by such approaches for many problems of practical interests is still insufficient, and a lot of challenging physical and numerical problems should be yet resolved to make them high-fidelity numerical tools. One of the key issues in this area is imposing of physically adequate unsteady inflow boundary conditions, which are of crucial importance for an overall success of any scale-resolving simulation. As applied to zonal RANS-LES methods, which level of technology readiness is currently considerably higher than that of the pure LES, these conditions must ensure a rapid transition from fully modeled Reynolds stresses in the RANS zone to resolved stresses in the LES zone or, in other words, mitigate so called “grey area” which inevitably exists at the interface of the two zones and causes a significant degradation of solution accuracy, especially in the aeroacoustic applications.

In the present work a progress reached in this direction by the authors is presented, based on applications of a recently developed Synthetic Turbulence Generator (STG) [1] aimed at imposing of turbulent content at RANS-LES interface in zonal simulations. The STG employs ideas of Kraichnan [2] and has many common features with the STGs of Bechara *et al.* [3], Batten *et al.* [4], and Billson *et al.* [5]. Particularly, it creates velocity fluctuations as a superposition of weighted spatio-temporal Fourier modes satisfying a prescribed (von Karman) spatial spectrum. Its peculiar feature is a plausible representation of the anisotropy of the vortical structures of the near-wall turbulence, even when a linear eddy-viscosity (i. e., isotropic) RANS model is used in the RANS zone. This is achieved by a specific definition of the turbulent length scale and by using a global time-scale for setting time-dependence of synthetic velocity fluctuations and ensures creation of the energy-containing “synthetic eddies” which are small and elongated in streamwise direction near solid walls and relatively large and nearly isotropic away from them. Other than that, the STG uses a fixed set of the wave numbers for the entire RANS-LES interface, and random quantities entering the STG are computed only once, which prevents generation of high-frequency “noise” leading to “re-laminarization” (damping of created turbulence) downstream of RANS-LES interface typical of many other STG’s available in the literature.

A wide set of examples will be presented illustrating a high potential of the STG within zonal RANS-LES approaches. One of such examples, Wing+Flap test case studied in the course of the EC Project VALIANT, is shown in Fig.1.

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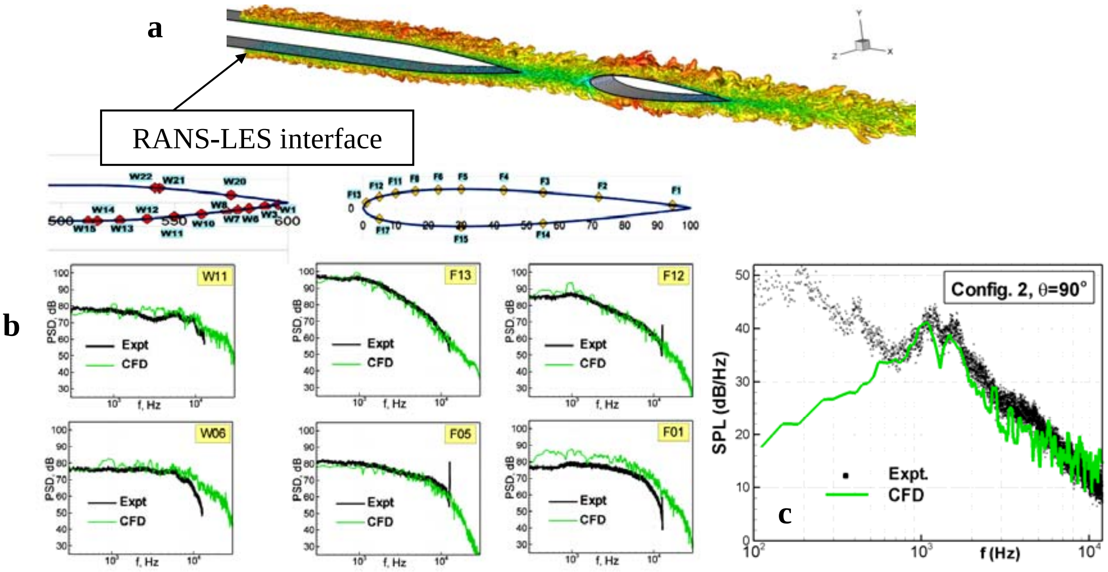

Fig.1. Results of zonal RANS-IDDES of flow past Wing + Flap configuration with the use of STG. **a**: flow visualization (instantaneous swirl isosurface colored by streamwise velocity); **b**: wall pressure spectra at different points; **c**: SPL spectra of the far-field noise at observer angle 90 degrees. Experiment of ECL [6].

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