11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

IMPLEMENTATION OF A PHYSICALLY BASED SYNTHETIC TURBULENCE GENERATOR FOR EMBEDDED LES APPROACHES

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Key Words: *Synthetic Turbulence, Turbulence Convection, Embedded LES, RANS-LES interface.*

Performing reliable computations of massively separated flows is a great challenge of today being DNS (Direct Numerical Simulation) and LES (Large Eddy Simulation) the only alternatives which allow computing accurately such cases. But regrettably, both methods are excessively expensive in terms of computational resources. Therefore, DES (Detached Eddy Simulation) or Embedded LES approaches have emerged as potential alternatives to the above mentioned techniques which consist in applying RANS models where they are known for providing accurate solutions and locally LES where detached flow or detailed information of the turbulent structures need to be computed. But unfortunately, due to the discrepancy of both methods in solving the turbulence, all the turbulent content of the flow is missed when it moves from RANS to LES domain. Therefore, they exhibit a large transition area downstream of the RANS/LES interface until LES mode is able to re-construct the missed turbulence.

For the purpose of restricting this drawback of the embedded LES approaches, a synthetic turbulence generator was applied in the present work. The applied synthetic turbulence generator is a modified version of the algorithm presented by Ref.[1] (Eq. 1), which defined a velocity field of fluctuations as a superposition of Fourier modes where the amplitude of each mode is defined following a spectral approach.

$$v'(r,t) = \sqrt{6} \cdot \sum_{n=1}^{N} \sqrt{q^n} \cdot \left[\sigma^n \cdot \cos\left(k^n \cdot d^n \cdot r + \varphi^n + S^n \frac{t}{\tau}\right)\right] \qquad 1$$

This generated fluctuating velocity field accurately reproduces the Reynolds stress tensor provided by the RANS solution just before the RANS/LES interface. In addition, it contains information of time and space correlation which is expected to be transferred to the resolved flow of the LES domain.

Among the modifications performed to the original approach are corrections to improve its flow divergence property and to allow for convection of synthetic turbulence. Being the latter vital for getting a realistic behavior of the flow field when the synthetic turbulence is added to the resolved flow as a volume source, as it is in the present work.

In order to assess the implementation, first several tests were performed in a stand-alone code of the synthetic turbulence generator to check the statistic features of the generated velocity field. Then, computations of a flat plate boundary layer were carried out as to appraise the effectiveness of the method in speeding up the production of realistic turbulence in the LES domain. The obtained results were compared with global RANS solutions. Supplementary, certain parameters of the synthetic turbulence generator, such as the design length scale of the turbulence and size of the spatial application range of the synthetic turbulence, were modified in the interest of determining their influence on the obtained resolved turbulence.

Finally, in order to validate the implementation against experimental data, computations were performed over the HGR-01 airfoil at angle of attack α=12°. This configuration was selected based on the substantial experimental data, obtained with PIV measurements and oilflow visualization, available for this test case.

In order to carry out these computations, the synthetic turbulence generator was added to the DLR TAU-Code. JHh-RSM was selected as background RANS model because it was already proved to supply accurate solution of the boundary layer development and precise detection of the separation [3]. ADDES (Algebraic Detached DES) was selected as DES version since it produces accurate shielding of the attached boundary layer avoiding Modeled-Stress Depletion and exact switch between RANS and LES modes due to the implemented algebraic sensors [2].

The results showed that the implementation effectively speeds up the generation of resolved turbulence in the LES domain providing resolved turbulence in the area where, without this approach, virtually no turbulence content is obtained (Fig. 1). In addition, it was observed that the continuity and smoothness of the transition from the modeled to the resolved turbulence depend mainly on the settings of the synthetic turbulence generator whilst the realism of the resolved turbulent structures further downstream of the RANS-LES interface depends on the inherent capacities of the LES approach and the proper grid design.

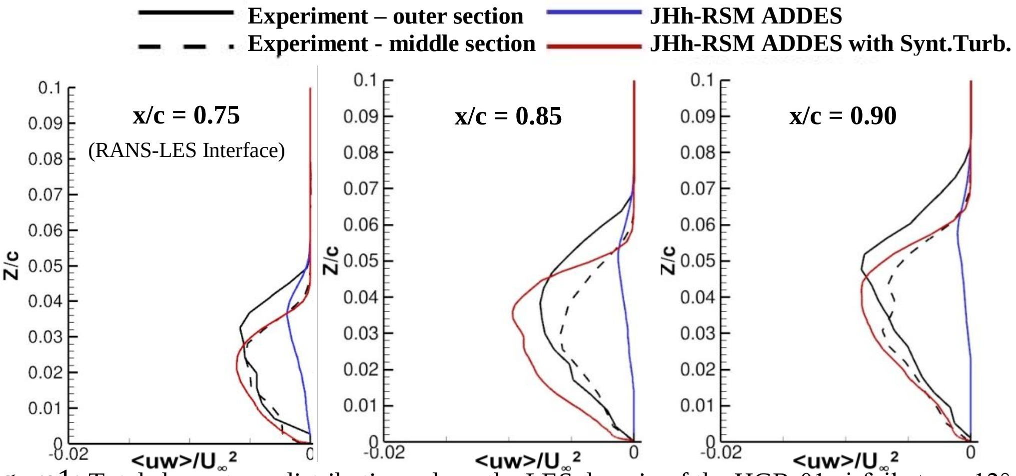

Figure1: Total shear stress distributions along the LES domain of the HGR-01 airfoil at α = 12°.

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