Assessment of LES techniques for mitigating the Grey Area in DDES models

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February 11, 2019

Accurate numerical simulations are essential for understanding the complex flow physics present in many aeronautical applications. RANS models are commonly used in the industry, as they are cost-effective, but their limitations for predicting complex flow behaviours and providing unsteady data are also well-known. Moreover, the routine use of accurate numerical methodologies such as Large Eddy Simulation (LES) require heavy computational cost, so their applications are not yet feasible. In this regard, Delayed-Detached Eddy Simulation (DDES) [1] is intended to circumvent the massive costs of pure LES simulations, modelling the boundary layer using RANS and simulating the unsteady flow behaviour with LES at the core. This hybrid turbulence model is widely used due to its user-friendly non-zonal approach and its proved success in several applications (in comparison to RANS). Apart from that, these turbulence models (in contrast to RANS) can provide high quality transient data, which is completely necessary for simulating other kind of physics, such as Fluid-Structure Interaction and Computational Aeroacoustics. It is therefore not surprising that during the last decade, these methods have been gaining importance in the aeronautical industry. However, some of their well-known weaknesses are still present. In this paper we are focused on addressing the slow transition from RANS to LES, which can lead to unphysical results, delaying the flow instabilities in complex zones such as free shear layers. This numerical phenomenon is known as the Gray Area phenomenon (*GA*). In the literature, there are two main strategies for leading this issue [2]. One of them consists on using artificial oscillations in specific areas (zonal approach), whereas the other is based on reducing the subgrid-scale viscosity when LES is activated in 2D flow regions. The second approach is preferable as it is aligned with the initial non-zonal DES philosophy. Our approach is based on attributing kinematic sensitivity to the subgrid-length scale (Δ) coefficient, as well as some other authors such as Mockett et al. [2] ($\tilde{\Delta}_{\omega}$) and Shur et al. [3] (Δ_{SLA}). The main difference is that our approach is completely inherited from the LES literature [4] (Δ_{lsq}), instead of being specifically designed for leading the *GA* issue in DDES simulations. Satisfactory results were observed in a previous work [5], exhibiting a similar performance to the most advanced and widely used mitigation strategies (Δ_{SLA}). In this work, we will present a comparison of the existing techniques for mitigating the *GA* in an unheated compressible jet at $Re = 10^6$ and $M = 0.9$, which is an interesting configuration for the aeronautical industry.

References

[1] P.R. Spalart, S. Deck, M.L. Shur, K.D. Squires, M.K. Strelets, A. Travin, Theoretical and Computational Fluid Dynamics **20**(3), 181 (2006)

[2] C. Mockett, M. Fuchs, A. Garbaruk, M. Shur, P. Spalart, M. Strelets, F. Thiele, A. Travin, in *Progress in Hybrid RANS-LES Modelling* (Springer International Publishing, Cham, 2015), pp. 187–201

[3] M.L. Shur, P.R. Spalart, M.K. Strelets, A.K. Travin, Flow, Turbulence and Combustion **95**(4) (2015)

[4] F.X. Trias, A. Gorobets, A. Oliva, Physics of Fluids **115109** (2017)

[5] A. Pont-Vílchez, F.X. Trias, A. Revell, A. Oliva, in *Proc. of Hybrid RANS-LES Methods 7* (17-19 September, Berlin, Germany, 2018)