A novel DES-based approach to improve transition from RANS to LES in free shear layers

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Over the past 15 years, the new family of hybrid RANS-LES Methods (HRLM) has emerged as the most promising candidate for the next generation of CFD methods for increased fidelity at industrially-feasible numerical expense. These methods combine the conventional RANS model approach in attached boundary layers with the scale-resolving technique of LES in detached flow regions. While a considerable improvement of predictive accuracy for HRLM over conventional RANS approaches could be established for flows featuring massive separation with strong instabilities in the separated shear layer, less trust is placed in HRLM for cases featuring thin separation regions where shear layer instabilities are weaker. This is in part due to a problem framed as “grey area”, which refers to a region of undefined modelling existing between the RANS mode and fully-developed LES zones. The problem frequently arises for more streamlined geometries, in which shallow separation and possible reattachment pose enormous difficulties to HRLM. As these geometries are representative for many CFD applications and therefore of high importance (e.g. prediction of aircraft loads), the acceptance of HRLM strongly depends on the ability to mitigate the extent of the grey area.

In the talk, a brief summary about current state-of-the-art hybrid RANS-LES methods such as detached-eddy simulation (DES) [1] will be given first as well as an overview about their potential application range and limits. Subsequently, an enhancement to the standard DES formulation is presented which targets to accelerate RANS to LES transition especially in early separated shear layer regions [2]. The core idea of the approach is to re-formulate the behaviour of the model in LES mode, thereby applying an enhanced subgrid-scale (SGS) model instead of a Smagorinsky-like form as it is the case for standard DES. Results for the new method are presented for a range of test cases, from academic studies such as a shear layer separating from a splitter plate to more complex applications such as a jet flow at M = 0.9. For all investigated cases, the new method proved to be more accurate and reliable than standard DES [3] without sacrificing its beneficial properties, such as the non-zonal nature of DES.

[1] P. Spalart, W. Jou, M. Strelets, S. Allmaras. *“Comments on the feasibility of LES for wings, and on a hybrid RANS-LES approach”*. Advances in DNS / LES, vol. 1, 1997.

[2] C. Mockett, M. Fuchs, A. Garbaruk, M. Shur, P. Spalart, M. Strelets, F. Thiele, A. Travin. *“Two non-zonal approaches to accelerate RANS to LES transition of free shear layers in DES”*. Progress in hybrid RANS/LES Modelling, Notes on Numerical Fluid Mechanics and Multidisciplinary Design, vol. 130, pp. 187-201, Berlin / Heidelberg, Springer, 2015.

[3] M. Fuchs, C. Mockett, M. Steger, F. Thiele. *“A novel DES-based approach to improve transition from RANS to LES in free shear layers”*. In Proceedings of the 10th International ERCOFTAC Symposium on Engineering Turbulence Modelling and Measurements, Marbella / Spain, 2014.