A dynamic model adaptation strategy for the high-order discontinuous Galerkin VMS approach to LES

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ABSTRACT

The use of high-order discontinuous Galerkin (DG) methods in the context of scale-resolving simulations has seen a rapid increase in recent years, particularly due to their excellent parallel scalability and ability to achieve high-order accuracy on general meshes. The variational framework on which these methods rely also allows for the local separation of scales using the polynomial basis functions, which leads to the straightforward implementation of variational multiscale (VMS) approaches to LES [1].

The VMS technique is based on the assumption that the effect of the unresolved scales on the largest resolved scales is negligible and thus the effect of the subgrid-scale (SGS) model is confined to a range of small resolved scales. In most works found in the literature on VMS the scale separation is defined either heuristically or a-posteriori by performing simulations of a given configuration based on different definitions of the large-scale space. These approaches present serious limitations, especially when dealing with inhomogeneous or (statistically) unsteady turbulence simulations that require the adaptation of the scale-partition parameter in space and/or time.

In this work, the spectral properties of the DG-VMS approach to LES are analysed by performing a-priori tests of the inter-scale energy transfer in Fourier space [3]. In particular, a consistent methodology to evaluate the ideal SGS stresses from DNS data including the effect of the DG filter is proposed. The DG filter introduces discontinuities in the filtered field that need to be taken into account to properly evaluate the ideal SGS stresses. In this research, the ideal energy transfer has therefore been evaluated from DNS data of the Taylor-Green vortex (TGV) configuration at Re = 5000 and Re = 20000 [2] for various hp-discretizations and compared to the energy transfer provided by the DG-VMS approach based on the Smagorinsky model. Based on these results, a locally adaptive DG-VMS strategy allowing us to adjust the VMS partition in space and time has been developed. It relies on the estimation of the decay rate of the modal energy spectrum as an indicator of the local smoothness of the solution. For the considered TGV configuration, the adaptive algorithm yields improved accuracy and robustness as compared to its standard counterpart.

REFERENCES

[1] J.B. Chapelier, M. de la Llave Plata, and E. Lamballais, Development of a multiscale LES model in the context of a modal DG method, *Comput Method Appl Mech Eng*, Vol. **307**, pp. 275–299, (2016).

[2] T. Dairay, E. Lamballais, S. Laizet, and J.C. Vassilicos, Numerical dissipation vs. subgrid-scale modelling for large eddy simulation, *J Comput Phys*, Vol. **337**, 252–274, (2017).

[3] F. Naddei, M. de la Llave Plata, E. Lamballais et al., Large-scale space definition for the DG-VMS method based on energy transfer analyses, Proc. of the *Summer Program, Center for Turbulence Research, Stanford University*, 2018.