Large eddy simulation – overview

LES is now more and more considered as a mature technique, even though improvements/validations are still required before it can be accepted as the gold standard. This is for example the case for aerothermal applications where wall heat fluxes are sought for, and more generally for flows with industrial complexity. In such cases, numerical and modeling issues are real and many questions remain open: Which class of algorithms should be used for solving the flow equations over complex, time-evolving domains while keeping the necessary low level of artificial dissipation and high level of parallel efficiency? Which class of sub-grid scale models should be used in order to ensure that the right amount of dissipation is introduced while no direction of homogeneity is present? How do we quantify the uncertainties related to the sub-grid scale model when modeling and numerical errors are so intimately connected? The objective of the four projects and more than fifteen people (at least partly) involved in the LES group was to deal with these different issues. Of course, definite answers were not provided during the Summer Program, but new promising ideas were put forward for future progress in the field.

One route to the efficient representation of complex, turbine-related flow configurations is to use sliding, non-conformal meshes. Domino proposed a new algorithm which can handle such features for low Mach number flows. The basic idea is to combine the finite element method at interior domains with a discontinuous Galerkin approach at the non-conformal mesh interface. The second order of accuracy of the method was established theoretically and verified using manufactured solutions. The results obtained for multiple rotating domains demonstrate the potential of the method for wind-turbines applications.

Since the very first days of LES almost fifty years ago, many LES formulations have been proposed. Yet, nowadays, the gold standard is still based on the very first sub-grid scale model proposed by Smagorinsky in 1963, very much improved by the dynamic procedure proposed during a former Summer Program. Because a robust and accurate implementation of this procedure is undoubtedly challenging when dealing with complex geometries, there is a renewed interest in defining SGS models with better properties than the strain rate. A relevant question is then the one addressed by Verstappen *et al.*: what is the minimal amount of eddy-viscosity that should be introduced to perform a LES with a given size of the spatial filter? A detailed theoretical analysis led to the conclusion that a model based on the absolute value of the determinant of the strain rate tensor should be optimal in a certain sense. Another route was followed by Baya Toda *et al.* who proposed a static model build from the three singular values of the same tensor. Both models have the desirable property to produce zero eddy-viscosity for any 2D flow; the latter also has the proper cubic asymptotic behavior near solid boundaries.

A last project investigated the possibility to separate modeling and numerical errors in LES. More precisely, You *et al.* extended previous results and proposed a proper framework to perform explicit filtering when dealing with compressible flows. They were able to demonstrate the possibility to reach mesh convergence by considering the academic yet complex case of a channel flow with periodic hills. As for the three other contributions, it is expected that the results obtained during the Summer Program will initiate further studies promoting the routine use of LES in industrial-like situations.

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