IMPLICIT LARGE EDDY SIMULATION OF COMPLEX FLOWS

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ABSTRACT

Further development of large-eddy simulation (LES) towards a standard tool in industrial development faces two major obstacles: First, the mutual interference between turbulence modeling and the numerical discretization can have large and generally unpredictable effects on the accuracy of the solution. Second, the change of turbulence structure near flow boundaries such as solid, flexible or permeable walls or fluid interfaces has to be taken into account properly.

The subgrid-scale model of a large-eddy simulation generally operates on flow scales that are marginally resolved by the underlying discretization scheme. The truncation error of common approximations for the convective terms can outweigh the effect of a physically sound subgrid-scale model. On the other hand, one can exploit this link - approaches where SGS models and numerical discretizations are fully merged are called implicit LES. The subject of the first part of this talk is the analysis and the control of local truncation errors in large-eddy simulations. We show that physical reasoning can be incorporated into the design of discretization schemes. The ALDM (Adaptive Local Deconvolution Method) approach is introduced and discussed with respect to its numerical and turbulence-theoretical background. Using systematic procedures, numerical and turbulence-theoretical modeling are fully merged. The truncation error itself functions as an implicit turbulence model accurately representing the effects of unresolved scales. Various applications demonstrate the efficiency and reliability of ALDM as well as the superiority of an holistic approach.

The extension of this implicit LES framework to flows in complex geometries is addressed by an adaptive Cartesian-grid method with zonal embedding. Adaptive local refinement by dyadic sub-partitioning can be easily accounted for in implicit SGS modeling, which is an advantage over fully unstructured grids. Geometric boundaries and fluidic interfaces do not necessarily coincide with grid lines so that boundary conditions have to be applied at the subcell level, i.e., by a so-called immersed-boundary methods. Non-conforming boundaries are represented by a novel cut-cell approach, which is consistent with the underlying finite volume scheme and therefore fully conservative. The cut-cell method is combined with a wall model based on the Thin Boundary Layer Equations (TBLE), which allows for representing high Reynolds number wall-bounded flows without resolving the wall layer.