Large-Eddy Simulation with Finite-Elements: Some Fundamental Issues

Mark A. Christon*
Computational Physics Research & Development

Thomas M. Smith, Rodney C. Schmidt
Parallel Computational Sciences

Thomas E. Voth
Thermal Sciences

Sandia National Laboratories, MS 0819
Albuquerque, NM 87185-0819
*Corresponding author, email: machris@sandia.gov

Large-eddy simulation (LES) is a promising alternative to traditional turbulence modeling approaches that rely upon Reynolds averaging and closure models based upon ad-hoc transport equations for the rate of dissipation. Unlike conventional Reynolds averaged models, LES provides a high degree of accuracy with a minimum of empiricism, i.e., there is no need to fit model constants to each new flow configuration. In addition, LES relies on resolving a large fraction of the energetic dynamics of the flow directly resulting in a reduced burden on the turbulence model. Despite its advantages, large-eddy simulation is relatively computationally expensive and has typically been applied to problems where the geometry is relatively simple and the physics is constrained for the purpose of performing controlled numerical experiments to study specific turbulent phenomena.

Although LES has been demonstrated for simple geometries, typically using structured grids and finite-difference or finite-volume methods, the issues associated with complex geometries and unstructured grids are just beginning to be addressed. These issues include, but are not limited to the effects of dispersive and diffusive errors, commutative errors, and grid anisotropy on the resolved scales and subgrid-scale (SGS) models. These issues are compounded by the emerging use of large-eddy simulations for high Reynolds number engineering applications, where the errors introduced by ''spectrally'' under-resolved LES computations are not well understood.

Recently, an LES research effort at Sandia National Laboratory has been launched in order to advance finite-element algorithms and methods for large-eddy simulation on unstructured grids with irregular geometries. The emphasis for this effort is upon understanding and quantifying the numerical errors, reducing uncertainty, and improving reliability of large-eddy simulation by quantifying the effects of filters and filter width, under-resolved flow fields, diffusive and dispersive errors, and subgrid-scale models on unstructured grid turbulence simulations. Of special interest is understanding the effects of applying explicit filters on non-uniform grids. In this talk, a brief survey of the issues surrounding LES for unstructured grids will be presented with a summary of progress on the use of explicit filters along with filter commutativity and multi-scale analysis for dynamic models. The role of derived turbulence statistics in LES computations will be discussed with an emphasis on the sensitivity to numerical errors.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.