

Abstract

In the Large-Eddy Simulation (LES) method, the small flow scales near the so-called cut-off frequency are dampened either by explicit or implicit filtering induced by applied discretization. Recovering these scales is possible using an approximate deconvolution method (ADM), but this 'healing' process is largely dependent on the assumed parameters of the deconvolution procedure. It is based on an iterative van Cittert method in which unfiltered (recovered) flow and/or scalar fields are approximated by the truncated series expansion of the inverse filter operator. Generally, in the LES method, the filter operator applied to the governing equations is unknown. Together with the filter induced by spatial discretization, it constitutes an effective filter in LES. However, to perform the van Cittert deconvolution, the form of the effective filter must be assumed. This work focuses on the accuracy and dependence of ADM on the type of filter, its order, the number of iterations during the deconvolution procedure, and the order of the derivatives discretization. The accuracy of ADM is investigated based on simulation results of non-reactive homogeneous isotropic turbulence and Taylor-Green flow, as well as unsteady combustion phenomena (auto-ignition and flame propagation) in a forced homogeneous isotropic turbulent flow field and temporally evolving turbulent jet. The LES-ADM results are compared with those obtained using the well-known sub-grid LES models (eddy-viscosity and similarity models) or sophisticated combustion model (Eulerian stochastic fields), and with direct numerical simulation (DNS) data.

This work demonstrates that ADM is a promising tool for simulating turbulent flows and combustion processes characterized by mixed-mode combustion. A comprehensive analysis of ADM demonstrates the importance of the combined effect of the numerical methods used to discretize the governing equations describing the flow field and species/energy transport equations as well as the parameters of the discrete filters used in the deconvolution procedure. The obtained results show that in some cases their unfortunate combination may lead to instability of the solution procedure or inaccurate results. Conversely, particularly in reactive flows, if ADM is appropriately tuned, the results are at least as accurate as those obtained using a complex combustion model, but can be achieved at a significantly lower computational cost.