A priori testing of alpha regularization models as subgrid-scale closures for large-eddy simulations

Denis F. Hinz* Tae-Yeon Kim* Eliot Fried* James J. Riley†

April 9, 2013

Abstract

Alpha-type regularization models provide theoretically attractive subgrid-scale closure approximations for large-eddy simulations of turbulent flow. We adopt the *a priori* testing strategy to study three different alpha regularization models, namely the Navier–Stokes-α model, the Leray-α model, and the Clark-α model. Specifically, we use high-resolution direct numerical simulation data of homogeneous isotropic turbulence to compute the mean subgrid-scale dissipation, the spatial distribution of the subgrid-scale dissipation, and the spatial distribution of elements of the subgrid-scale stress tensor. This is done for different filter parameters and different large-eddy simulation grid resolutions. Predictions of the three regularization models are compared to the exact values of the subgrid-scale stress tensor, as defined in the filtered Navier–Stokes equations. The potential of the three regularization models to provide good approximations is quantified using spatial correlation coefficients. Whereas the Clark-α model exhibits the highest spatial correlation coefficients for the subgrid-scale dissipation and the subgrid-scale stress tensor elements, the Leray-α model provides lower correlation coefficients, and the Navier–Stokes-α model exhibits the lowest correlation coefficients of the three models. Our results indicate the presence of an optimal choice of the filter parameter α depending on the large-eddy simulation grid resolution.

*Department of Mechanical Engineering, McGill University, Montréal, Québec, Canada H3A 2K6
†Department of Mechanical Engineering, University of Washington, Seattle, WA 98195, USA