Approximate Deconvolution vs. Unresolved Scale Estimation Model - Burgers turbulence analysis

A. Boguslawski*, K. Wawrzak*

Large Eddy Simulation (LES) has been proven to be a promising method to predict complex turbulent flows. To solve the closure problem that arises due to low-pass filtration of the non-linear terms in the Navie-Stokes equations subfilter scales must be related to the resolved scales. The majority of subgrid models utilize the eddy viscosity concept. Alternatively, a method based on an approximate deconvolution (ADM) of the resolved scales was proposed [1]. In this approach, the subgrid stresses are calculated by the filtration of non-linear terms applying the deconvolved field. The ADM model introduces small scales based on the resolved scales but these deconvolved scales are larger than the cut-off length scale determined by the LES filter. Consequently, the ADM model evaluates the subfilter stresses without any contribution from the subgrid scales. By contrast, the subgrid scales are explicitly involved by the unresolved scales estimation model proposed by Domaradzki and Saiki [2]. According to this model, the velocity field is estimated on a refined mesh. The idea for the subgrid velocity field estimation is to impose the following constraints on the unresolved field: (i) the estimated velocity coincides with the resolved field when filtered with the top-hat filter of size Δ (Δ − LES- mesh size) (ii), both estimated and resolved fields coincide when they are filtered with the top-hat filter of 2Δ-size. These constraints define the system of equations for the estimated velocity field. The ADM model can be applied not only to momentum equation but also to turbulence-combustion interaction as shown recently by Domingo and Vervish [3] and Wang and Ihme[4]. Unresolved scales estimation model can also be applied to combustion modeling. Hence, it is important to understand better the characteristics, similarities, and differences between both models. For simplicity reasons, this study focuses on one-dimensional Burgers turbulence problem. The results of both models will be evaluated based on Direct Numerical Simulation (DNS) in terms of energy spectra and non-linear energy transfer predicted by both models. The Burgers turbulence analyzed in the current work follows studies of San [5]. To avoid an influence of the filtration imposed by the numerical scheme interacting with the LES-filter the calculations were performed by the Fourier pseudospectral method [6]. The unresolved scales estimation model will be compared with the ADM approach taking into account various LES filters applied for deconvolution. Moreover, the ADM will be applied using van Cittert [1] iterative inversion procedure as well as Wiener-type [7] exact deconvolution.

---

*Dep. Mechanical Engineering and Computer Science, Czestochowa University of Technology, ul. Dabrowskiego 69,42-201 Czestochowa,Poland

[1]Stolz and Adams, *Physics of Fluids* **11**, (1999).

[2]Domaradzki and Saiki, *Physics of Fluids* **9**, (1997).

[3]Domingo and Vervish, *Combustion and Flames* **177**, (2017).

[4]Wang and Ihme, *Combustion and Flames* **176**, (2017).

[5]San, *International Journal of Computational Fluid Dynamics* **30**,(2016).

[6]Canuto et al., *Spectral Methods in Fluid Dynamics*, Springer (1988).

[7]Wiener, *Extrapolation, interpolation, and smoothing of stationary time series*, The MIT press (1949).