Map-based stochastic methods for accurate modeling of turbulent transport: towards poly-dispersed engineering flows

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We present an overview of the application of the One-Dimensional Turbulence (ODT) model at several types of single-phase and gaseous multi-species statistically 1-D inhomogeneous flows. The current outlook for future research foresees simulations of particle-laden gaseous electrohydrodynamic (EHD) flows with feedback of the flow properties on the electrostatic fields. Complex engineering processes, such as the deinking of waste paper for recycling might also be studied in the future.

Stochastic turbulence modeling in multiphase flows

The stochastic modeling (SM) finds a niche in multiphase particle-laden flows for the description of particle collisions. Generally, the task at hand is the modeling or reconstruction of the particle number density functions via population balances. In this work, we are interested in the SM of turbulent flows. In a general sense, the latter relies on the faithful reproduction of the probability density functions (PDFs) associated to the flow quantities, see [1].

As a stochastic turbulence model, ODT emulates the Kolmogorov picture of turbulence implying a kinetic energy cascade from small to large wavenumbers. This is represented by the effects of a turbulent eddy in a scalar profile [2]. Viewing eddies as local wave packets, the local change in the scalar velocity gradient corresponding to an increased strain is the model representation of the kinetic energy cascade. This is operationally defined by the transformation of scalar profiles by *triplet maps* [2]. The location and time of implementation of the maps conforms with a stochastic sampling process, such that the reconstruction of a joint PDF of *eddy events* can be assumed to take place [2]. Ensemble averages performed on this stochastic process demonstrate that ODT is able to reproduce ensemble statistics for dominantly 1-D statistically inhomogeneous flows. As an example, we mention the assessment of the turbulent mixing at various Schmidt numbers, as well as the effects of mixed scalars on the actual flow statistics in the context of reactive flows [3, 4].

Learning outcomes from previous ODT investigations and future work

ODT investigations in the field of convective flows have been addressed at the achievement of asymptotic turbulence states, e.g., asymptotic wall-bounded turbulence at large Reynolds (Re) numbers [5], or asymptotic turbulent thermal convection at large Rayleigh numbers (Ra = Gr*Pr, where Gr is the Grashof number, and Pr is the Prandtl number) [6]. This is visualized in Figure 1, which shows the previously commented ODT investigations, as well as [7], in the context of a forced, mixed, and natural convection regime diagram. Recent research has focused on the extension of the ODT model for EHD flows [5]. One research question discussed in [5], is whether a regime map such as that of Figure 1 exists for EHD flows, with the equivalent of Gr being N_{EHD}, the EHD number. Investigations done in [5] are aimed at ultimately evaluating realistic particle-laden gaseous flows in electrostatic precipitators (ESPs). The role of the mobility ratio, as an integral scale, will be discussed in that context. Implementation of a charged particle collision modeling in ODT, such as the one used in [8], is required. This may also be beneficial for evaluating other types of engineering flows of interest, e.g., deinking processes for the recycling of waste paper.

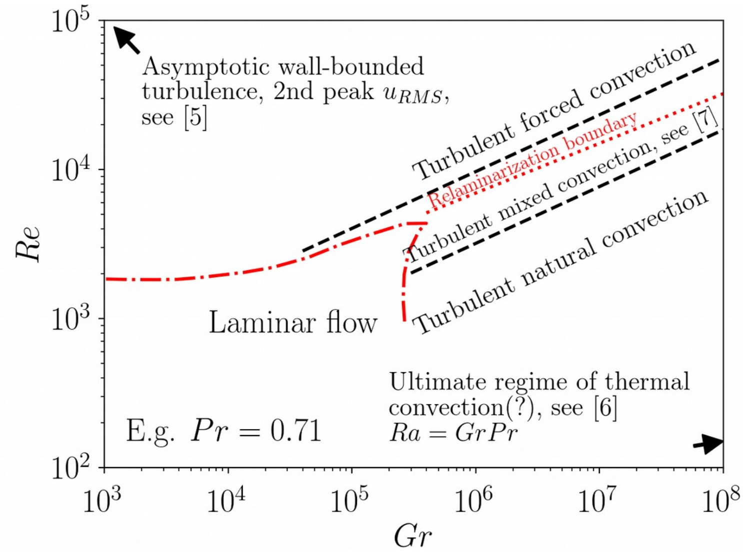

Figure 1: Regime diagram in turbulent forced, mixed and natural convective flows. The diagram is adapted from that presented in [9], to include relevant ODT investigations. [5] asks the research question concerning whether such a diagram also exists for $Re(N_{EHD})$.

References

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