Coherence and randomness of Rayleigh-Taylor turbulent mixing

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Turbulent mixing induced by Rayleigh-Taylor instability plays an important role in a variety of phenomena spanning astrophysical to atomistic scales and low to high energy density regimes. Examples include inertial confinement fusion, dynamics of accretion disks and explosions, stellar and planetary convection, premixed and non-premixed combustion, and realistic aero-dynamic flows (wall-bounded and free---subsonic, supersonic as well as hypersonic) as well as the atmospheric and the oceanic phenomena. Theoretical description of non-equilibrium transports is a challenging problem due to singular aspects of the governing (Euler or Navier-Stokes) equations. Furthermore these processes are statistically unsteady and their fluctuating quantities are essentially time-dependent and non-Gaussian. A striking similarity of behavior of Rayleigh-Taylor mixing in the vastly different regimes indicates that this turbulent process has some features of universality and is eligible to first principles consideration (Abarzhi 2008, Abarzhi 2010).

To capture the anisotropic and non-local character of the turbulent mixing dynamics we applied new theoretical concept of the rate of momentum loss and put forward the ideas on how to quantify coherence and randomness in the statistically unsteady turbulent flows. We have considered the effect of momentum transport on some scaling, invariant and statistical properties of Rayleigh-Taylor mixing flow. It is shown that the rate of momentum loss is a better indicator of the unsteady turbulent dynamics than the rate of energy dissipation. Our consideration does not presume a single-scale character of the mixing dynamics and distinguishes between the evolution of horizontal and vertical scales. The obtained results indicate two possible mechanisms for the mixing development. The first is the traditional “merge” associated with the growth of horizontal scales. The second is associated with the production of small-scale structures and with the growth of the vertical scale, which plays the role of the integral scale for energy dissipation (Abarzhi et al. 2005). Based on invariance of the rate of momentum loss, we have shown that the fundamental invariant and scaling properties of Rayleigh-Taylor turbulent mixing depart substantially from classical Kolmogorov scenario. Particularly, turbulent mixing flow appears more order compared to isotropic turbulence, and its viscous scale is finite and set by the flow acceleration. Invariance of helicity may serve for obtaining an integrated description of highly anisotropic and isotropic turbulent flows and for further extension of the range of applicability of the canonical approaches. The stochastic modeling results (Abarzhi et al 2007) indicate that the growth-rate of the mixing zone is a parameter sensitive to statistical properties of dissipation. The momentum-based consideration of Rayleigh-Taylor mixing resonate with the properties rigorously derived from the conservation principles by the linear and nonlinear theories (Abarzhi 2008), including existence of characteristic length-scale and multi-scale nonlinear dynamics, and indicate a principal opportunity of regularization of the mixing process.

Abarzhi S I 2008 Review on nonlinear coherent dynamics of unstable fluid interface: conservation laws and group theory *Physica Scripta* **T132** 297681 1-18.

Abarzhi S I, Cadjun M, Fedotov S 2007 Stochastic model of Rayleigh–Taylor turbulent mixing Phys. Lett. A **371** 457–461.

Abarzhi, S. I., Gorobets, A., Sreenivasan, K. R., 2005, “Turbulent mixing in immiscible, miscible and stratified media,” *Phys. Fluids* **17**, 081705.

S.I. Abarzhi 2010, Review of theoretical modeling approaches of Rayleigh–Taylor instabilities and turbulent mixing, Phil. Trans. Roy. Soc. A (2010) 368, 1809-1828