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Mattner, Pullin & Dimotakis

Large eddy simulations of miscible Rayleigh-Taylor instability

T.W. Mattner¹, D.I. Pullin² & P.E. Dimotakis²

1. Department of Applied Mathematics,
The University of Adelaide, Australia
tmattner@maths.adelaide.edu.au

2. Graduate Aeronautical Laboratories,
California Institute of Technology, USA
dale@galci.caltech.edu, dimotakis@caltech.edu

This paper describes some results from large eddy simulations (LES) of miscible Rayleigh-Taylor (RT) instability at density ratios up to 7. We consider a high-density fluid located above a low-density fluid subject to a constant downward acceleration field. The fluids are assumed to be incompressible and miscible. Fluid motion is governed by the Favre-filtered continuity, species-transport, and Navier-Stokes equations. The subgrid-scale (SGS) scalar flux and stress are estimated using the stretched-vortex mixing (Pullin 2000) and stress (Misra & Pullin 1997) models. A compact filter and a circular spectral filter are applied in the inhomogeneous direction and homogeneous directions, respectively. These filters damp wavenumbers larger than the model cut-off wavenumber.

Performance of the model is assessed by comparison of coarse-resolution ($64 \times 64 \times 256$) LES against fully resolved ($256 \times 256 \times 1024$) direct numerical simulations (DNS) at three density-ratios: 5/3, 3, and 7. The initial conditions for the LES are obtained by filtering the DNS data at a time when the mixing-zone has grown sufficiently thick to be represented on the coarse LES grid. LES mixing-zone widths, as well as scalar and kinetic energy spectra, are in satisfactory agreement with the DNS results. DNS resolution limitations limit the comparison to Reynolds numbers (based on mixing-zone width and growth-rate) of less than 4000. As a result, SGS scalar and model dissipation is less than 10% of the total dissipation.

We use the stretched-vortex model to obtain predictions of RT unstable flow at Reynolds numbers as large as $0.5\text{--}2 \times 10^6$, on $128 \times 128 \times 256$ grids, at three density ratios: 5/3, 3, and 7. Mixing-zone growth is approximately quadratic in time and mean mole-fraction profiles are approximately self-similar. Resolved-scale kinetic-energy spectra exhibit an approximate $k^{-5/3}$ dependence, whereas the scalar-energy spectra decay more sharply than this approaching the cut-off wavenumber. The mole-fraction field exhibits unphysical excursions (over/undershoots of the initial scalar maximum/minimum) of up to 6%.

References

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- Pullin, D. I. 2000 A vortex-based model for the subgrid flux of a passive scalar. *Phys. Fluids* **12**, 2311–2319.