Turbulence Energetics in an Inclined Interface Richtmyer-Meshkov Instability

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The interaction of a Mach 1.55 shockwave with a nominally inclined interface between N$_2$ and CO$_2$ is considered. Unlike the classical Richtmyer-Meshkov problem, the interface evolution is non-linear from early time and large highly correlated vortical structures are observed even after reshock. Simulations target the experiment of McFarland et al. (2014). Simulations are performed using high-order spectral-like numerics (Lele, 1992). Results from multiple grid resolutions up to 4 billion grid points establish grid convergence. Comparisons to the experiments show that the simulations adequately capture the physics of the problem.

The turbulence energetics in the problem is investigated using a TKE balance equation based on Favre-averaging and a scale decomposition analysis. Due to the competing time scales of relaxation after compression of the turbulence by the shock and the circulation time scale, a non-monotonic return to isotropy is seen post reshock. TKE budgets are presented and the effect of the dealiasing-filter is quantified and shown to be small ($\sim 10\%$). The budget shows that pressure-dilatation correlation is important even when the turbulent Mach number is $\sim 0.1$ (RMS). Scale decomposition shows that the compressibility is due to a complex pattern of shocks and rarefactions created due to the inhomogeneity in the transverse direction and not due to compressible effects in the turbulent mixing region itself. Energetics are investigated at different scales and show that the net flux of energy to smaller scales is scale invariant in the inertial range. Energy injected into the flow due to shocks and rarefactions is seen to be broadband. Finally, the kinetic energy was decomposed into bins in wavenumber space and a $k^{-2}$ scaling of the energy spectrum was inferred although a larger range of scales could potentially reveal a different scaling at larger wavenumbers.

REFERENCES


(a) Kinetic energy binned in scale intervals depicted by the horizontal bars at a time instant after reshock. The $k^{-1}$ scaling seen here in the logarithmically binned kinetic energy indicates a $k^{-2}$ scaling of the energy spectrum as opposed to the standard $k^{-5/3}$ scaling.

(b) Large scale density, production, baropycnal work and pressure-dilatation correlation after reshock from top to bottom.