Tue2.3 Inogamov & Oparin

Exact expansion law for Richtmyer–Meshkov turbulent mixing zone

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Definition of mixing fronts and turbulent mixing zone

Development of the Richtmyer–Meshkov instability leads to mixing of two substances separated by contact boundary. Let the axis z is perpendicular to a plane of boundary and $z = 0$ corresponds to an unperturbed plane. The turbulent mixing zone is limited by front $z = h_+(t) > 0$ from heavy fluid side and by front $z = h_-(t) < 0$ from light fluid. Mixture of two fluids is confined between these two fronts (layer $h_- < z < h_+$).

Initial conditions

Before pass of a shock wave both liquids were motionless and $z = \eta_0(x,y)$ was perturbed contact boundary. We consider linear (small amplitude) perturbation: $|\nabla \eta_0| \ll 1$. Then the shock wave passes perturbations quickly: $\Delta t << \lambda \dot{\eta}_0$, where Δt is shock wave passage time, λ is typical wavelength (or space scale) of perturbations, and $\dot{\eta}_0$ is typical velocity after shock wave passage, $\dot{\eta}_0(x, y, t = \Delta t)$.

Transition and asymptotic stages

Universal asymptotics follows transition stage at $t >> \left|\lambda \dot{\eta}_0\right|$. Functions $h_\pm(t)$ asymptoticaly transform to power law dependences. Mixing is accompanied by cascade of enlarging of dominant scale of a turbulent mixing zone. Under condition $\mu = 0$ exact scaling laws are: $h_+^{2D} \propto t^{2/5}$ and $h_+^{3D} \propto t^{1/3}$, where μ is density ratio, 2D and 3D mark dimension of space. These scalings are calculated in our work. The scaling exponents 2/5 and 1/3 are determined by the mechanism of redistribution of z–component of momentum from small in the large scales. For $\mu \neq 0$ the exponents 2/5 and 1/3 define the bottom limit of a range of possible values for both functions $h_+(t)$ and $h_-(t)$. Our 2D direct numerical simulations at different values $\mu \approx 1$ show that $\dfrac{d \ln h_\pm}{dt} \approx \dfrac{2}{5}$.

This work has been supported by RBRF (grants 02–02–17499, 03–01–00700) and scientific schools (NSh–2045.2003.2, NSh–70.2003.1).