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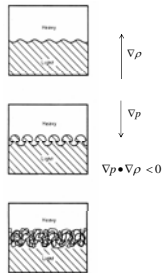
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9th International Workshop on the Physics of Compressible Turbulent Mixing

1. Rayleigh-Taylor Instability: Background

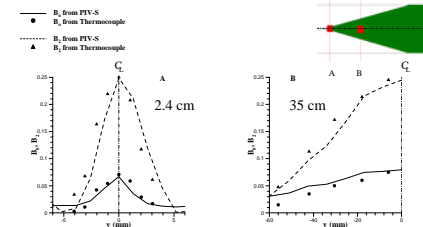
- Rayleigh-Taylor instability (R-T) occurs when a density gradient is accelerated by a pressure gradient such that $\nabla \rho \cdot \nabla p < 0$.
- Rayleigh-Taylor mix experiments are difficult!
- Modern turbulent mix models involve statistical quantities and demand extensive experimental data sets for validation.
- Transient Rayleigh-Taylor experiments do not lend themselves to statistical data collection.
- Over the past 8 years we have developed a statistically steady R-T experiment that facilitates statistical data collection.
- Our Rayleigh-Taylor mix data is used to validate models for the description and understanding of hydrodynamic instabilities that develop during the implosion phase of ICF capsules.



8. PIV-S

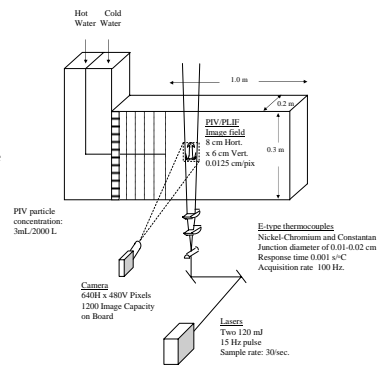
- PIV-Scalar (PIV-S), a variant of conventional PIV, was developed to simultaneously measure density and velocity fields in an R-T mix.
- Different concentrations of seed particles used in light and heavy fluid streams to mark density differences.
- Density measurements show good agreement in the mean and RMS with thermocouple data.

9. Density Fluctuations

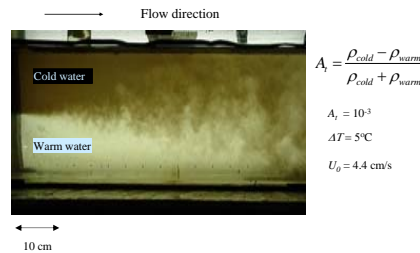


2. Schematic of the Texas A&M R-T experiment

Cold and warm water enter through separate inlet plenums. As they pass through flow straighteners and wire meshes, they are kept separated by a splitter plate. As the different-density streams leave the edge of the splitter plate, they form an unstable interface resulting in a statistically-steady R-T mix.



3. Photograph from experiment: Visualization using dye



$$A_t = \frac{\rho_{cold} - \rho_{warm}}{\rho_{cold} + \rho_{warm}}$$

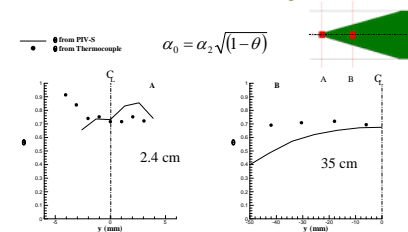
$$A_t = 10^{-3}$$

$$\Delta T = 5^\circ C$$

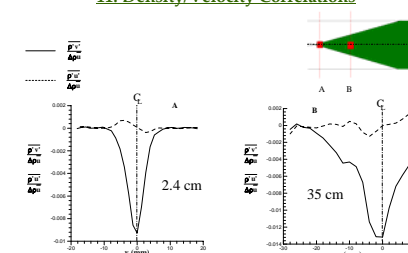
$$U_0 = 4.4 \text{ cm/s}$$

The figure shows a snapshot of the experiment, with Nigrosine dye added to the cold water stream. The flow is from left to right. The evolution of the mix is quadratic in x (downstream coordinate), with the mix width depending on the Atwood number (A_t), and the acceleration due to gravity. In this experiment, the distance downstream can be related to time through the Taylor hypothesis.

10. Molecular Mixing



11. Density/Velocity Correlations



4. Measurement of α

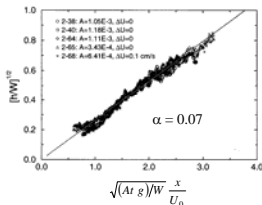
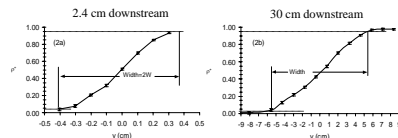


Figure on the left shows the time evolution of the mix-width h . The mix-width was deduced from the 5% and 95% contours of the volume fraction obtained from the above dye images. When normalized by self-similar coordinates, a value of 0.07 for the growth constant α may be inferred.

5. Mean Density Profiles (thermocouple measurements)



Mean density profiles across the mix, measured using thermocouples.

7. Parameter Definitions

$$B_0 = \lim_{T \rightarrow 0} \frac{1}{T} \int_0^T (\rho - \bar{\rho})^2 dt / \Delta \rho^2 = \lim_{T \rightarrow 0} \frac{1}{T} \int_0^T (\rho^*)^2 dt / \Delta \rho^2$$

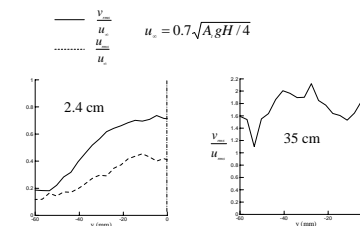
$$B_2 = \overline{\rho^* (1 - \rho^*)} = f_1 (1 - f_1) \quad \theta \equiv 1 - B_0 / B_2$$

$$\rho^* = \frac{(\rho - \rho_{min})}{(\rho_{max} - \rho_{min})} \quad \rho^* = \frac{\sum \rho_i^*}{n}$$

$$B_0 = \frac{n \sum \rho_i^2 - (\sum \rho_i)^2}{n(n-1)}$$

$$B_0(\omega_n) = \frac{2\Delta}{N} \left| \sum_{i=0}^{N-1} (\rho_i^*) e^{-2\pi i \omega_n} \right|$$

12. Velocity Fluctuations ($x = 35 \text{ cm}$)



13. Energy Dissipation

$$PE_i = \int_0^W \rho_{avg} z dz \Rightarrow \int_0^W \rho_i g z dz + \int_0^W \rho_2 g z dz$$

$$PE_f = \int_0^W \rho_{measured} z dz \Rightarrow \sum_{i=0}^n \rho_i g z_i \Delta z$$

$$PE_{released} = PE_i - PE_f$$

where, $\rho_{measured}$ is the measured density, and ρ_{avg} is the step-profile of density at the interface corresponding to the initial condition

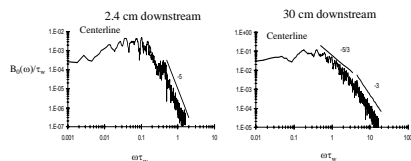
$$KE_i = 0 \quad KE_{generated} = \frac{1}{2} \int_0^W \rho v^2 dz$$

where, W = mix width, v = rms velocity

$$\text{Dissipation, } D = PE_{released} \cdot KE_{generated}$$

$$\left| \frac{D}{PE_{released}} \right| = 0.49$$

6. Density Fluctuation Power Spectra (thermocouple measurements)



14. Acknowledgements

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