- IFSA2025 –

Transition to Turbulence in a Shock-Driven High-Energy-Density Experiment

Sam Pellone [(1)], Alex Rasmus [(1)], Carlos Di Stefano [(1)], Elizabeth Merritt[(1)], Forrest Doss [(1)]
[(1)] *Los Alamos National Laboratory (USA)*

In the context of Inertial Confinement Fusion (ICF), material mixing between the outer ablator and the inner Deuterium-Tritium (DT) fuel is an observed phenomenon related to the burn efficiency of the DT fuel [1]. Mixing may be initiated when perturbations (e.g., from manufacturing defects) grow under acceleration (e.g., shock waves), and is often driven by turbulence, necessitating the use of mix models to simulate systems like ICF. Mix models, such as LANL's Besnard-Harlow-Rauenzahn (BHR), present significant challenges in practice due to their problem-specific nature, nontrivial initialization of free parameters (e.g., turbulent kinetic energy), and the common assumption that mean-flow quantities are taken over an ensemble of realizations. In this work, we examine the performance of BHR in capturing the evolution of a single-mode perturbation with imposed surface roughness in a laser-driven Richtmyer-Meshkov environment. We conduct high-resolution 2D simulations using our in-house code xRAGE [2], which includes a laser model to capture late-time Rayleigh-Taylor deceleration after laser shutoff. Our baseline case is based on the OMEGA-EP ModCons experiments [3], where three laser beams irradiate a high-density plastic (1.45 g/cm^3) adjacent to a low-density foam (0.1 g/cm^3), launching a shock that interacts with the perturbed plastic-foam interface (single mode 100 μm wavelength, 10 μm amplitude). The effect of surface roughness is investigated by superimposing a 2D profile, extracted from 3D scans of experimental targets, onto the main carrier mode. The turbulent character of the flow is assessed via a resolution convergence study that includes plasma viscosity, providing insight into the range of resolved wavenumbers. These high-resolution simulations provide a baseline for evaluating BHR parameters and assessing the choice of averaging method. This work lays down the foundation for on-going 3D modelling efforts of full experimental target with surface roughness and laser model.

References

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Acknowledgment

This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory (Triad National Security, LLC. Contract No. 89233218CNA000001).