

Driver-Independent Freeze Out of Converging Richtmyer-Meshkov Instability

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The Richtmyer-Meshkov instability (RMI) characterizes mixing of 2 fluids of differing density under shock loading. Quantifying its behavior and exploring methods to mitigate its growth is vital for applications such as Inertial Confinement Fusion (ICF), but most explorations to date have been 1D planar in nature. We present experimental results from a campaign to demonstrate suppression of cylindrically convergent RMI using a novel engineered void technique [1]. A compact pulsed-power generator (120 kA in 600 ns) vaporizes a cylindrical wire array of 35mm diameter, driving a cylindrically converging shock wave traveling at 1.9 km s^{-1} through a surrounding gelatine dielectric. The shock wave interacts with an azimuthally symmetric pattern of 12 air-filled voids in the gelatin that collapse under compression to split the initial shock into distinct, temporally-separated concentric shocks. These in turn interact with a cylindrical, sinusoidally perturbed interface between gelatin and air; characterized by Atwood number $A = -1$, wavelength $\lambda = 1.2 \text{ mm}$, and amplitude $a_0 = 0.12 \text{ mm}$.

Through differences in the vorticity deposited on the perturbed interface, the deconstructed shock wave inhibits or ‘freezes out’ the growth rate of RMI amplitude [2], as compared to control experiments utilizing no voids and a single cylindrical shock. Initial analysis shows that the engineered void technique suppresses RMI growth rate by $> 90\%$, vastly reducing fluid mixing at convergence ratio $r(t)/r_0 = 0.44$. Hydrodynamics were captured by multi-MHz X-ray radiography of $24 \text{ }\mu\text{m}$ spatial resolution and 176 ns interframe time, provided by the ID19 beamline of the European Synchrotron Radiation Facility.

Radiographs are being used to validate hydrodynamic simulations using the blastFoam package for OpenFOAM [3], enabling more complex geometries to be explored. Extension of the presented work will utilize machine learning to optimize void shaping [4] and explore mitigation of single defects for possible application in ICF revolver schemes [5].

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