3D Simulations of NIF Wetted Foam Experiments to Understand the Transition from 2D to 3D Flow Behavior

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Recent work has demonstrated the importance of 3D flows in ICF capsule implosions [1,2]. These are particularly important for layered capsules due to the low adiabat and high convergence ratio (CR) of the implosions, both of which contribute to high performance in 1D simulations yet make the implosion more susceptible to hydrodynamic instabilities. The wetted foam platform [3,4] is an alternative approach to hot spot ignition that has been used to achieve low-to-moderate convergence in layered capsule implosions (12<CR<25) on the NIF [5]. Convergence ratios in this range are unobtainable using capsules containing an ice layer. Detailed high-resolution modeling of wetted foam experiments in 2D and 3D, including all known experimental asymmetries (fill tube, support tent, drive asymmetries, and capsule asymmetries and defects), demonstrates that 2D hydrodynamics are sufficient to explain capsule performance at CR~12 but become less suitable as the CR increases. As the CR increases, the jet caused by the fill tube is enhanced, the aerial density modulation caused by the tent is increased, and the impacts of drive asymmetry are amplified. Details of the mechanisms responsible for this behavior will be presented as well as an analysis of how these contribute to the development of 3D flows. Detailed comparisons of simulation results to the three completed wetted foam experiments on the NIF will also be presented. Additionally, we will also discuss the impact of implosion adiabat, which impacts the stability of the implosion with regard to the support tent and surface defects, but does not help to mitigate the impact of the fill tube or drive asymmetry.

In order to evaluate the tradeoff between increased instability and improved 1D capsule performance, we present a full-scale wetted foam capsule design that can achieve a CR ranging from 17<CR<42 and evaluate its sensitivities to known experimental asymmetries. Despite exhibiting robustness to the fill tube, simulations predict that, given currently achievable levels of asymmetry, the effects of the support tent negate all advantages of increasing the CR, and the highest performance is achieved at the lowest CR.

References

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