FUEL ENERGY BALANCE IN LAYERED IMPLOSIONS ON THE NIF

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ICF implosions rely on the efficient conversion of shell kinetic energy to fuel internal energy at stagnation. In an ideal 1-D implosion the conversion efficiency is near 100%, with little residual kinetic energy remaining in the fuel. Several mechanisms, such as low-mode drive asymmetry or hydrodynamic instability seeded by the capsule surface roughness or the tent perturbation, can reduce this efficiency, implying that less energy is coupled to the fuel as internal energy, resulting in a reduction in stagnation pressure and yield [1,2]. A number of experimental observations, including larger than anticipated neutron-time-of-flight peak width measurements, anisotropy in the primary neutron yield, and hot-spot motion in time-resolved x-ray images, suggest some degree of incomplete energy conversion, though as yet no direct quantitative measurement exists.

We present a model that attempts to infer the energy in the fuel at peak compression through an isobaric description of the hot spot and cold fuel constrained by the experimentally measured yield, ion temperature, hot-spot size, burnwidth, and neutron down-scatter-ratio. Further, by estimating the energy delivered to the fuel by compressive work, and accounting for alpha-particle energy deposition and radiation loss, we can infer the coupling efficiency of kinetic to internal energy in the fuel, and the residual kinetic energy. We find that for the original low-foot design implosions only half of the energy available in the shell at peak velocity is converted to internal fuel energy at stagnation. The high-foot design implosions show a higher coupling efficiency, in the range of 70-80%, consistent with their improved performance in hot-spot pressure and yield. However, the inferred residual kinetic energy is still at a level that would be predicted to significantly impact yield, indicating that there is margin for improvement.

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[1] A.L. Kritcher et al., Phys. Plasmas 21, 042708 (2014)
[2] C.R. Weber et al., Phys. Plasmas 22, 032702 (2015)