Preprint
UCRL-JC-136640

Turbulent Mix Study of a Double Shell Capsule

H.C. Vantine and R.E. Tipton

This article was submitted to
7th International Workshop on the Physics of Compressible Turbulent Mixing
St. Petersburg, Russia
July 5-9, 1999

November 16, 1999

U.S. Department of Energy

Lawrence Livermore National Laboratory

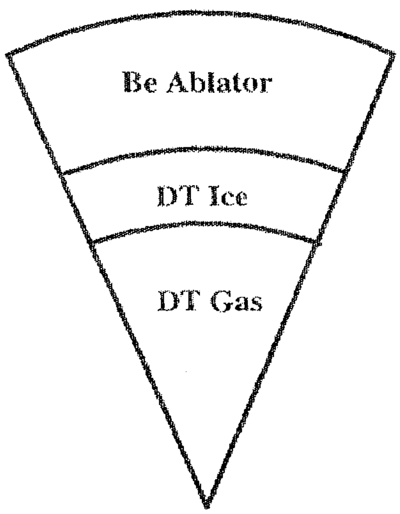
Turbulent Mix Study of a Double Shell Capsule

Harry C. Vantine, Robert E. Tipton
Lawrence Livermore National Laboratory, Livermore, California, 94551; USA
Telephone: 925 423-8186, Fax: 925 422-0779
E_mail: vantine1@llnl.gov

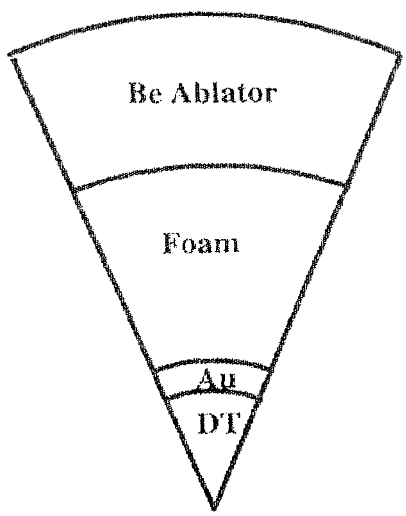
Abstract: Double shell capsules present an alternative, non-cryogenic design for NIF ignition targets. Such capsules have received little interest because it was assumed that hydrodynamic instabilities would forestall ignition. We used a K-L turbulent mix model, integrated into a hydro code, to evaluate a series of double shell implosions. The double shell implosions were laser-driven experiments performed at the OMEGA laser. We briefly review the turbulent mix model. The model has adjustable parameters for the growth and dissipation terms. These are initially set by comparison to classical experiments. The model also requires an initial length scale and an initial wavelength scale. Next we briefly describe the experiment. The target assembly consists of an inner shell of glass and an outer shell of brominated plastic. We present the analysis of the hydrodynamic implosion, using the turbulent mix model. The agreement between experiment and calculation suggests that the model could be successfully applied to ignition targets.

Introduction: Recent calculations[1] suggest that double shell targets may provide an alternative, non-cryogenic path to ignition on NIF. The double shell targets have additional advantages: they do not require pulse shaping, and have low ignition temperatures (2 KeV). They do have disadvantages; they are difficult to fabricate; further, their non-linear mix needs to be characterized.

We developed a phenomenological turbulent mix model and applied it to double shell ICF targets. Unlike standard single shell targets, the inner shell is not stabilized by radiation-ablation.[2] Rather, the inner shell experiences nonlinear mix.

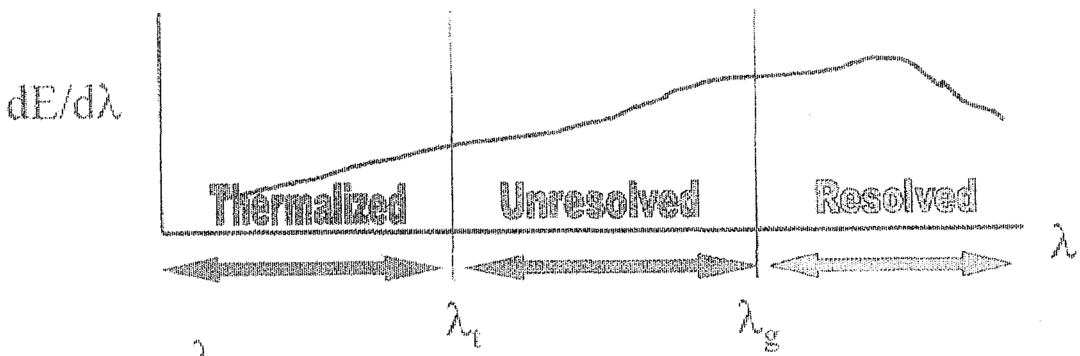


Standard Single Shell NIF Target



Double Shell NIF Target

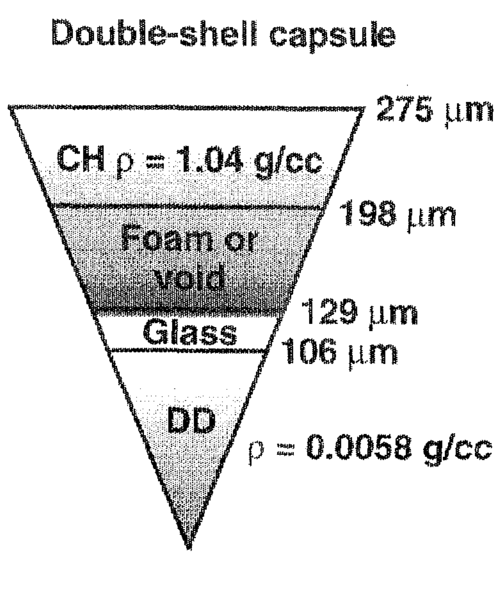
Mix Model: The model evolves two variables, K and L, in space and time. The variable K represents the kinetic energy of the unthermalized and unresolved turbulence. L represents the longest characteristic wavelength of the turbulence. The adjustable parameters of the model are set by matching classical Rayleigh-Taylor and Richmeyer-Meshkov experiments.

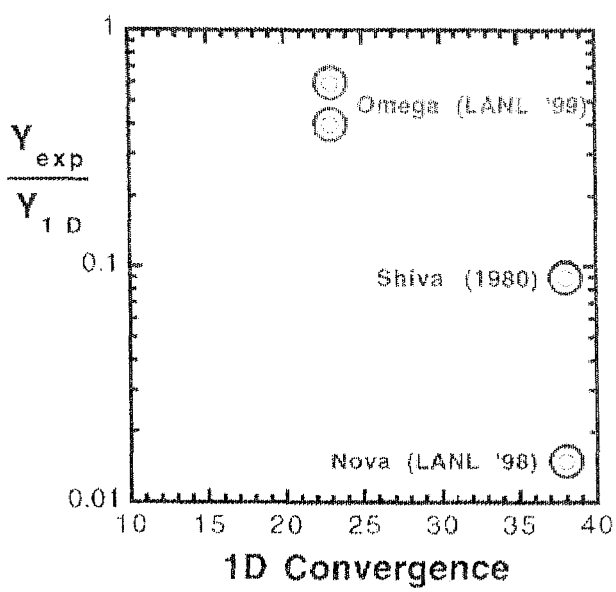


- $K = \int_{\lambda_t}^{\lambda_g} dE/d\lambda \, d\lambda$

The model simulates the nonlinear R-T and R-M instabilities and the associated mixing of species, momentum and energy. The governing equations of the model and comparisons to data were the subject of a companion presentation.[3]

Comparison with Experiment: Double shell experiments performed by Watt[4] at the NOVA and OMEGA lasers were simulated in order to evaluate the adequacy of the mix model. We assume that the capsule fabrication has been carefully controlled. In this case the perturbations on the inner shell, not being ablatively stabilized, determine capsule performance. Performance is measured by neutron production and is shown in the figure.





At the mid convergence range (~23) the capsules show a 60% yield degradation. The higher convergence (~38) capsules show a larger degradation. It may be significant that the higher convergence capsules were fielded at the NOVA laser in a hohlraum with lower symmetry (cylindrical vs. tetragonal).

To model the performance we considered several sources of unresolved turbulent mix. The foam support layer had an internal cell structure with a characteristic size of 3000nm. As the accompanying table shows, this length scale had only a small effect on performance. Next we considered the effect of a 40 nm surface waviness on the glass capsule. This perturbation did grow significantly and degraded the performance. Finally we considered what effect an internal waviness within the glass might have on performance. Such an internal structure might be the result of silicate ridges in the glass, although we hasten to point out that no such structure has actually been observed. Nonetheless, we evaluated the effect of a 10nm waviness within the glass capsule itself. As seen in the table, this had a significant effect on performance.

Description	$\mathbf{Y_{exp} / Y_{1D}}$
Clean	1.0
3000 nm volume waviness (foam)	0.91
40 nm surface waviness (glass)	0.31
10 nm volume waviness (glass)	0.15

Conclusions: We applied a turbulent mix model to the investigation of laser-driven double shell implosions. The performance of the double shell implosion is consistent with the development of turbulent mix at the fuel/glass interface. This study supports the use of turbulent mix models in further evaluations of double shell ignition targets for NIF. Such capsules would be a scaled by a factor of roughly four from the present design and use alternate materials to provide better confinement.

References:

1. J.D.Lindl, Inertial Confinement Fusion, Springer-Verlag, p. 32 (1998)
2. S.W.Haan, Physics of Fluids B3(8), p. 2349 (1991)
3. R.G.Watt et al., Bull.Am.Phys.Soc.**43**, p.1782 (1998)
4. R.E.Tipton, Abstract 114, 7th IWPCM, p. 17 (1999)

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.