The KL Mix Model Applied to Directly Driven Capsules on the Omega Laser

R. E. Tipton, K. O. Mikaelian, H.-S. Park, G. Dimonte, J. R. Rygg, C. K. Li

October 12, 2005

47th Annual Meeting of the APS-DPP
Denver, CO, United States
October 24, 2005 through October 28, 2005
The KL Mix Model Applied to Directly Driven Capsules on the Omega Laser*

Robert Tipton, Karnig Mikaelian, Hye-Sook Park
Lawrence Livermore National Laboratory

Guy Dimonte Los Alamos National Laboratory

J. R. Rygg, C. K. Li
Plasma Science and Fusion Center M.I.T.

Prepared for the 47th Annual Meeting of the Division of Plasma Physics of the American Physical Society
FO2.00003

October 25, 2003

*This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.
Main Points

• The coefficients of the KL mix model were set by Dimonte to match RT and RM instabilities as measured on the Linear Electric Motor (LEM).

• The KL mix model has been applied to directly-driven capsule implosions with a variety of laser energies, ablator materials, ablator thicknesses and convergence ratios.

• The KL calculations nearly match the observed $Y_{DD}$, $Y_{DT}$, $Y_P$, $T_{ion}$ and implosion times for many (but not all) capsules.
The KL model characterizes sub-grid hydrodynamics with 2 variables

$$dE \over dK \int_{kg}^{kt} dE dk$$

$L$ is the characteristic eddy size

Please see Guy Dimonte’s talk on the KL equations – LO1.00009 3:36 Wed Oct 26, 2005
All coefficients of the KL model can be derived from four numbers

- $\alpha_B = 0.07$ – Young’s RT bubble coefficient
- $\theta = 0.25$ – RM exponent
- $f_{PE} = 0.50$ – Ratio of turbulent to potential energy
- $C_c = 0.$ – the compression coefficient in the L eq.

$\alpha_B$ inferred from LEM data is 0.06 rather than 0.07
The ideal value of $C_c$ is 1/3 rather than 0
1D Calculations with CALEICF

- Sn radiation transport
- Electron thermal flux limiter of 0.05
- LTE opacities from SHM
- Lee-More thermal conductivities
- Thermonuclear reactions
- MC charged particle transport
- $T+D \rightarrow N + \text{He}4$ reactions in flight
- $\text{He}3+D \rightarrow P + \text{He}4$ reactions in flight
- Initialize L field to 50nm on inner surface
- Initialize L field to 50-150nm on outer surface
Three different types of capsules were tested

Three types of direct drive laser capsules were fired with different fuel pressures, ablator thickness and laser energies. Measured quantities include:

1 Primary DD neutrons and secondary DT neutrons
2 Primary DHe\(^3\) protons (for D\(_2\) fuels secondary DHe\(^3\) protons were measured)
3 Ion temperatures (inferred from TOF spreading of the DD neutrons)
4 Implosion Time
Carbon mass fraction front nearly follows the free-fall line
Streak plot of $d \log(\rho)/dL$ shows shocks, rarefactions and ablation fronts.

1st Shock
2nd Shock
Rarefaction fan

Critical Surface
Electron Thermal Ablation Front

Time (ns)
L - Lagrange Coordinate
Min Volume

APS DPP 2005
Streak plot shows turbulent energy feeds through from thermal-ablation front to fuel surface.
KL model predicts instabilities near laser absorption will degrade performance. Outer surface roughness can be adjusted to match data.

$L_0 = 57\text{nm}$ on the outside surface will match data for this capsule.
A surface roughness of 50-70nm gives good results for most capsules however, some require 150nm.

L₀ Study for Shot 32316

L₀ Outer Surface Roughness in nm

Calculated Yield/Measured Yield

YDD
YP
YDT
Poly. (YDD)

L₀ = 135nm on the outside surface will match data for this capsule.
Thin capsules need $L_0 = 50 \text{ nm}$
Thick capsules need $L_0 = 150 \text{ nm}$
$Y_{DD}$ from $D_2$/CH Capsules gave $YOC(Clean) \sim 0.3-0.6$
$Y_{DD}$ from $D_2/CH$ Capsules gives $YOC(KL) \sim 0.8-1.05$
$Y_{DD}$ from DHe$^3$/CH Capsules gave $YOC(Clean) \sim 0.1-0.4$

DHe3/CH Capsules YOC Measured/Calculated (clean)

$Y_{DD}$ Trend line
$Y_{DD}$ from DHe$^3$/CH Capsules gives $YOC(KL) \sim 0.7-1.3$
$Y_{DD}$ from DHe$^3$/SiO$_2$ Capsules gave $YOC$(Clean) $\sim 0.2$-$1.0$

DHe3/SiO2 Capsules YOC Measured/Calculate(clean)

YOC Measured/Calculate(clean)

- YOC/DD
- YOC/P

YOC Trend line

$Y_{DD}$

YOC 0.2-1.0
$Y_{DD}$ from DHe3/SiO$_2$ Capsules gave $YOC(KL) \sim 0.6-1.3$
Summary

• The coefficients of the KL mix model were set by Dimonte to match RT and RM instabilities as measured on the Linear Electric Motor (LEM).

• The KL mix model has been applied to directly-driven capsule implosions with a variety of laser energies, ablator materials, ablator thicknesses and convergence ratios.

• The KL calculations nearly match the observed $Y_{DD}$, $Y_{DT}$, $Y_p$, $T_{ion}$ and implosion times for many (but not all) capsules.