A One-Dimensional Planar Model of Shock Ignition

Planar stagnation profiles

Pressure (Gbar)

Shock
No shock

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Summary

A planar hydrodynamic model is used to understand the basic physics behind shock ignition

• The peak hot-spot pressure is the optimization metric (model does not include any burn physics)

• An optimum shell thickness ($\Delta_{crt}$) exists that maximizes the conversion of shell kinetic energy into hot-spot internal energy (i.e., hot-spot pressure)

• Implosions augmented with their optimal ignitor shock are shown to have an increase in the $\Delta_{crt}$ resulting in $\sim 3 \times$ higher-peak hot-spot pressures over conventional hot-spot ignition
Collaborators

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Motivation

With the same kinetic energy, SI increases the peak hot-spot pressures versus conventional hot-spot ignition.

A planar slab hydrodynamic model has been developed to understand the basic physics of the increase in shock-ignition pressure.
In conventional ICF, the hot-spot internal energy results from the conversion of shell kinetic energy:

\[ E_{L}^{\text{ign}} \sim P_{hs}^{-3^*} \]

KE may be increased by

- Raising the implosion velocity
  - increases the hot-spot pressure
  - drives higher levels of hydrodynamic instabilities

- Thickening the shell
  - more fuel available to burn once ignition is reached
  - thicker shell provides better hydrodynamic stability
  - more often than not, this does not increase the peak hot-spot pressure

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Increasing the shell mass above a critical value in conventional hot-spot ignition does not increase the peak hot-spot pressure.

For $\Delta > \Delta_{\text{crt}}$, the shell kinetic energy poorly couples to the hot spot.
Applying a late shock increases the shell velocity just before stagnation, enhancing the coupling of shell kinetic energy to hot-spot internal energy.

Initial configuration

\[ u \text{_{imp}} \]

\[ \rho_0 \]

Final configuration

\[ \rho = 4 \rho_0 \]

\[ u > u \text{_{imp}} \]

Return shock collides with ignitor shock at the shell’s inner surface. The shock effectively increases the \( \Delta_{\text{crt}} \) of the initial configuration.
The ignitor shock increases $\Delta_{crt}$, utilizing “unused” kinetic energy to boost the maximum hot-spot pressure.
Summary/Conclusions

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- An optimum shell thickness ($\Delta_{crt}$) exists that maximizes the conversion of shell kinetic energy into hot-spot internal energy (i.e., hot-spot pressure)

- Implosions augmented with their optimal ignitor shock are shown to have an increase in the $\Delta_{crt}$ resulting in $\sim 3 \times$ higher-peak hot-spot pressures over conventional hot-spot ignition
A simple planar 1-D model is used to optimize the peak hot-spot pressure in ICF implosions

**Optimal shock strength**

**Optimal launch time**