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Photos placed in horizontal position with even amount of white space between photos and header

Tamped RMI for Non-Shock Loading

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U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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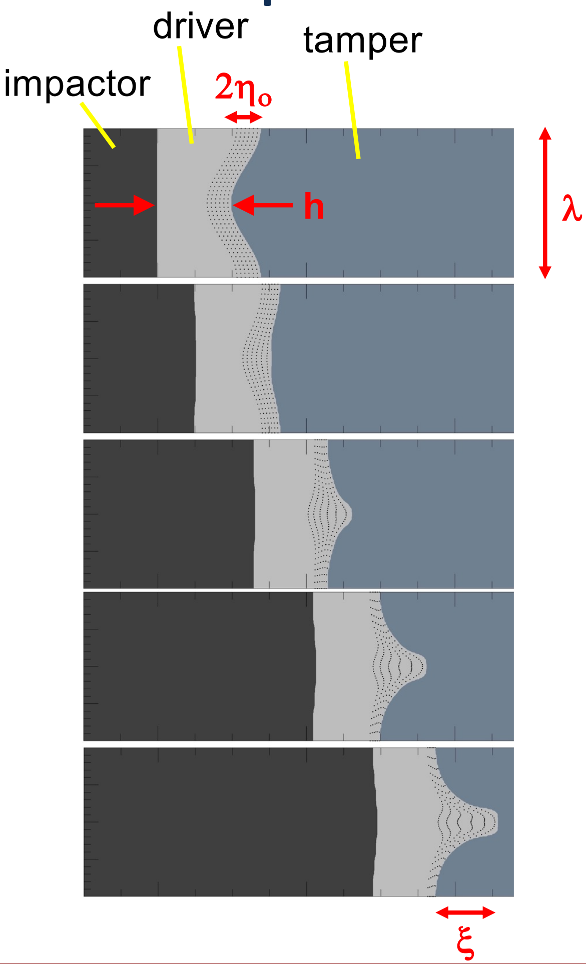
Tamped Richtmyer-Meshkov Instability

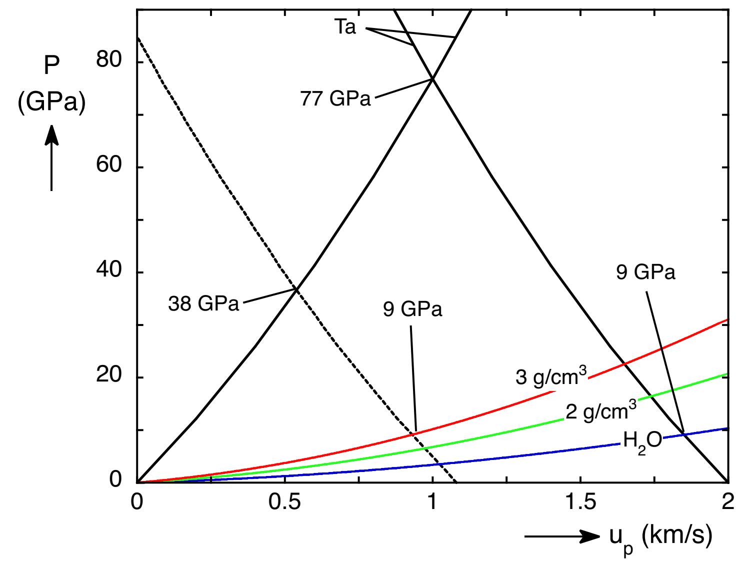


- Adding tamper keeps P above zero, reducing role of damage
- Initial shock leads to significant heating of driver
- Can adjust history by choosing different tampers

$$A = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}$$

$$k\eta = \frac{2\pi\eta}{\lambda}$$

Hudspeth et al., *JAP* 2020
Olles, et al, *JDBM* 2020
Vogler & Hudspeth, JDBM 2020

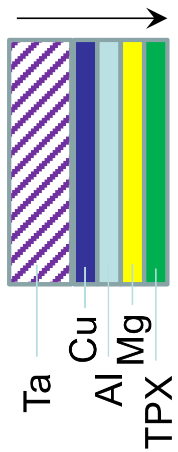


for arresting jets (Vogler & Hudspeth):

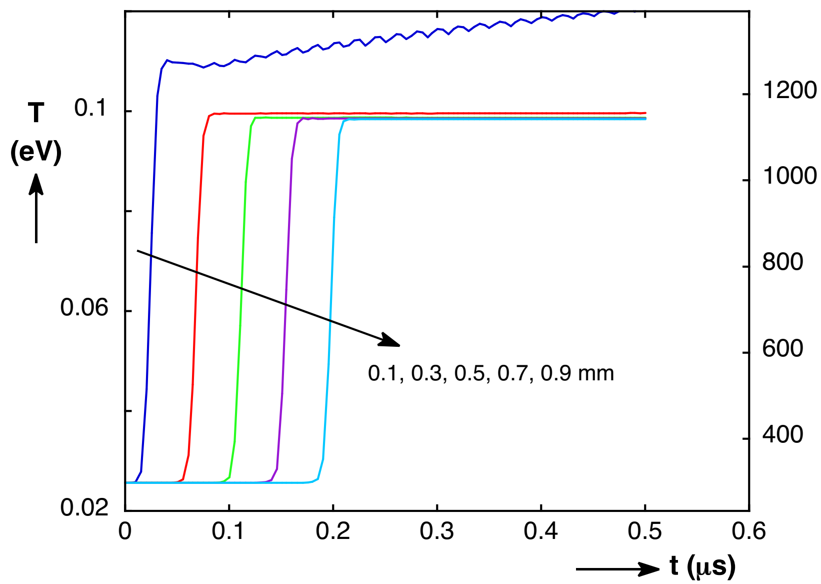
$$\frac{\pi(\xi_\infty + 2\eta_o)}{\lambda} \approx 0.2\, A^2\, (k\eta_o)^2\, \frac{\bar{\rho} u_2^2}{\bar{Y}}$$

RMI – It's not just for shocks anymore!

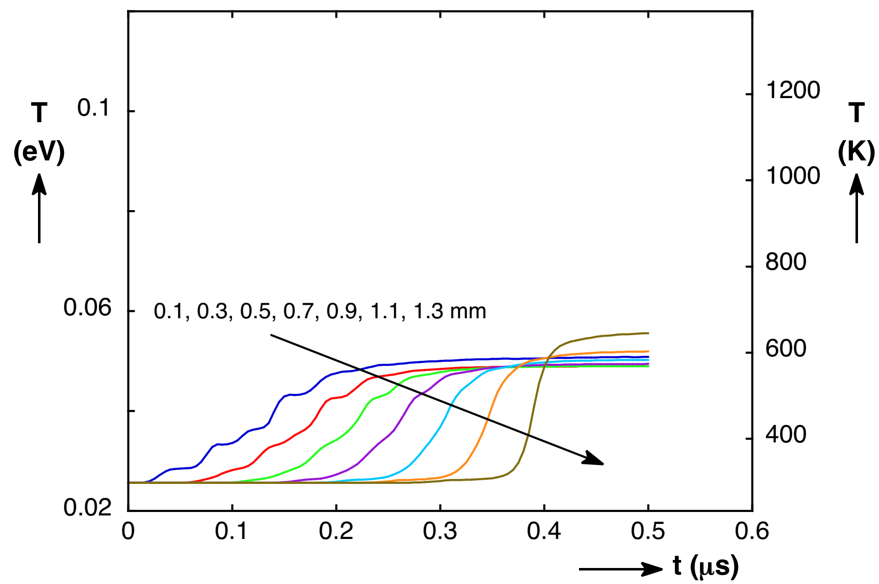
Using a GDI reduces temperature in driver for planar case



planar, shock loading

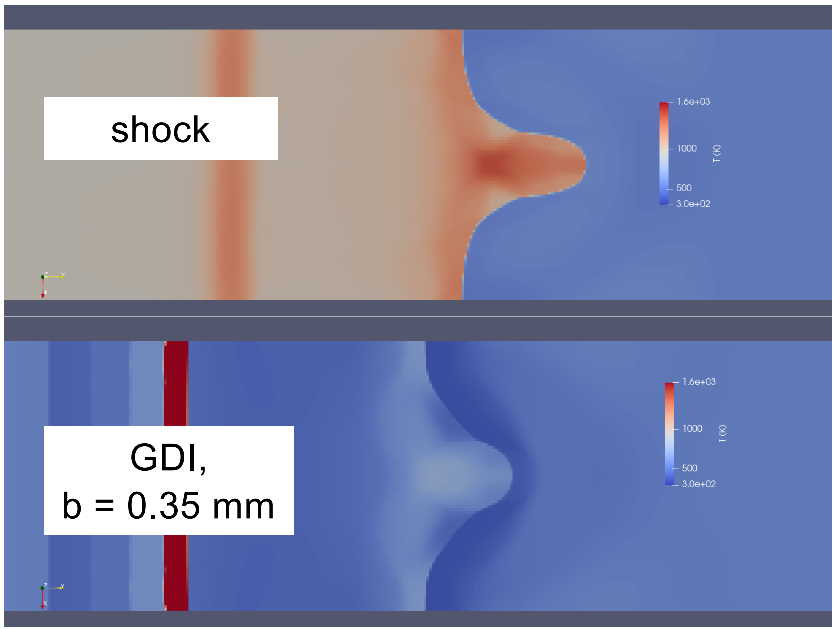


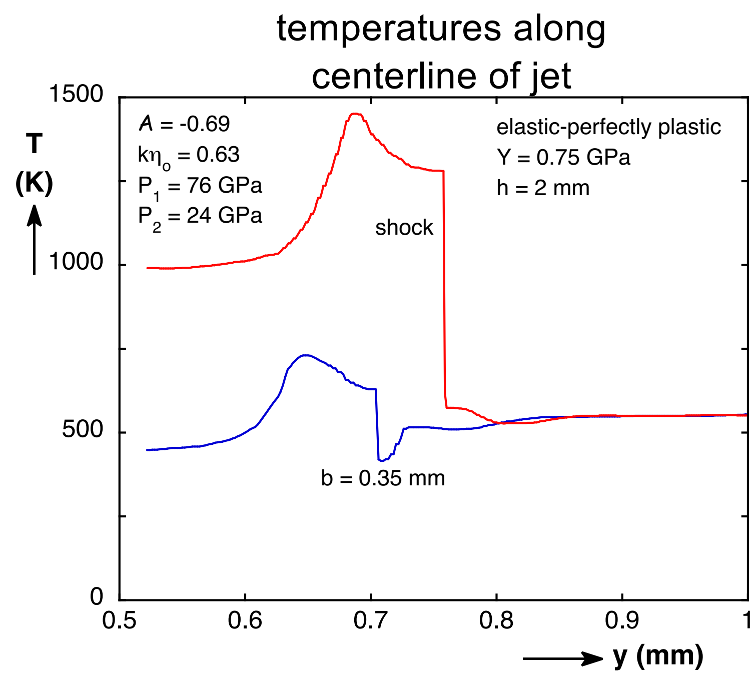
GDI, b=0.15 mm thick



- shock heating in the driver is significantly less when a GDI is used, ~300 C vs. 900 C
- GDI not optimized but reasonable – shock starting to form at 1.3 mm

Temperature Map for Driver





- temperatures are significantly higher for the shock case, mainly because of reduced shock dissipation
- also somewhat greater plastic work for shock case
- somewhat different behavior in liquid tamper ahead of shock

GDI, h=2 mm, vary b

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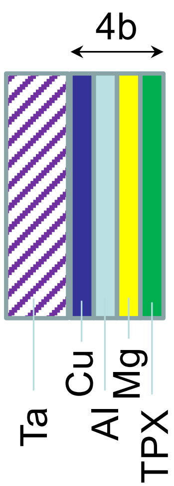
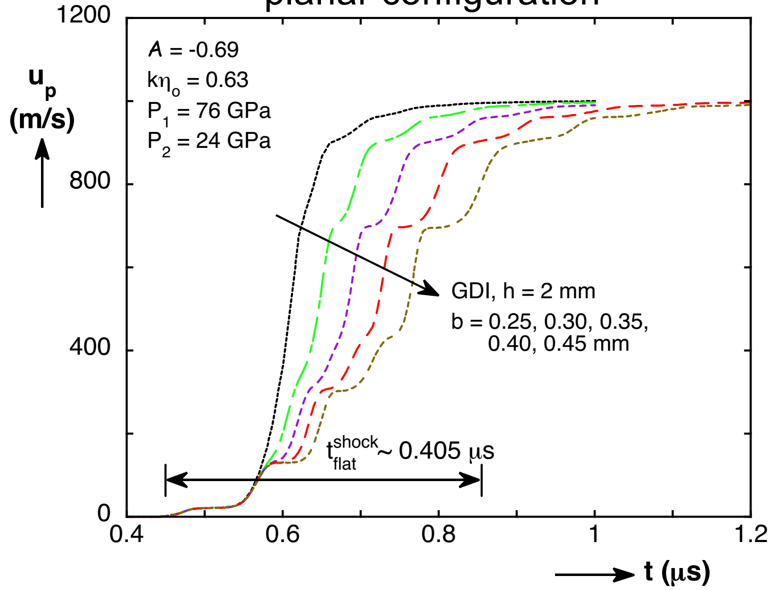
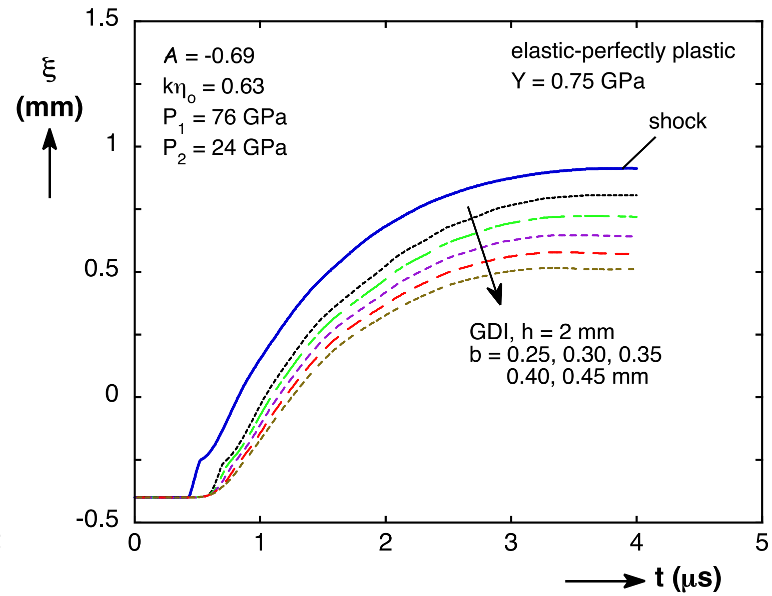


rise times for h=2 mm,
planar configuration

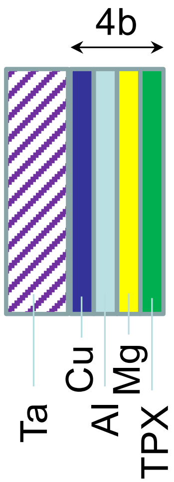


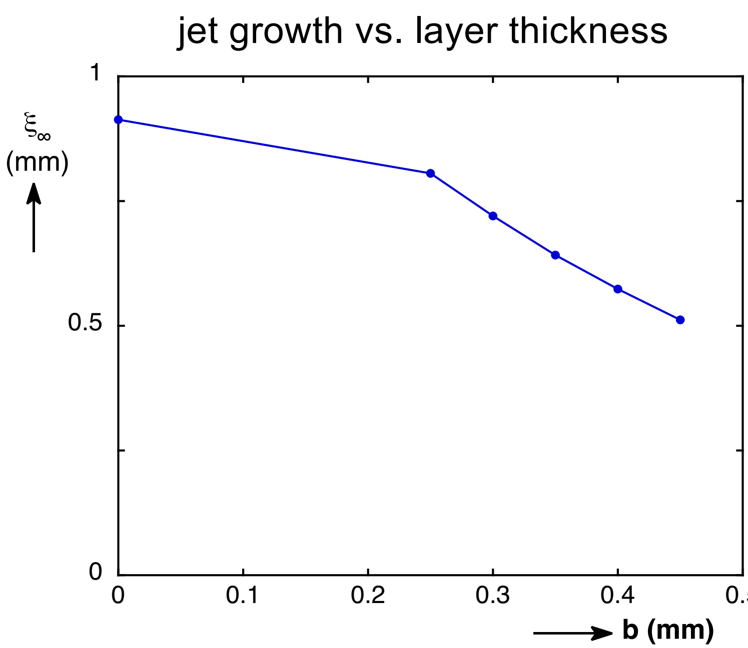
jet growth

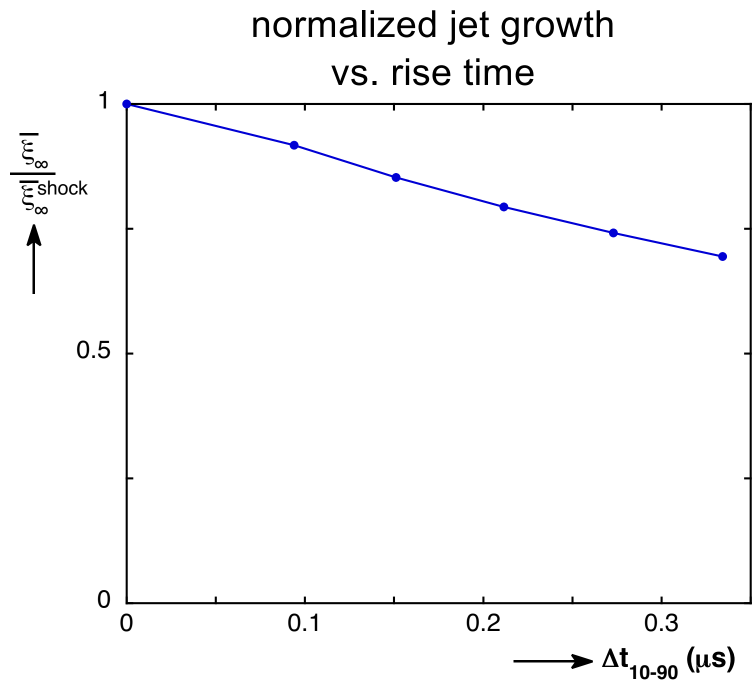


- for b=0.20 mm, wave has shocked up at h=2 mm
- rise time increases as b increases
- jet growth decreases as b increases

Efficiency of GDI

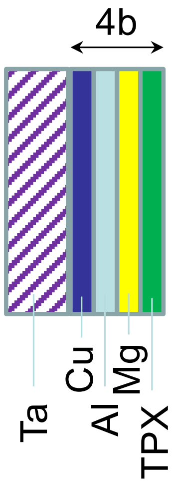




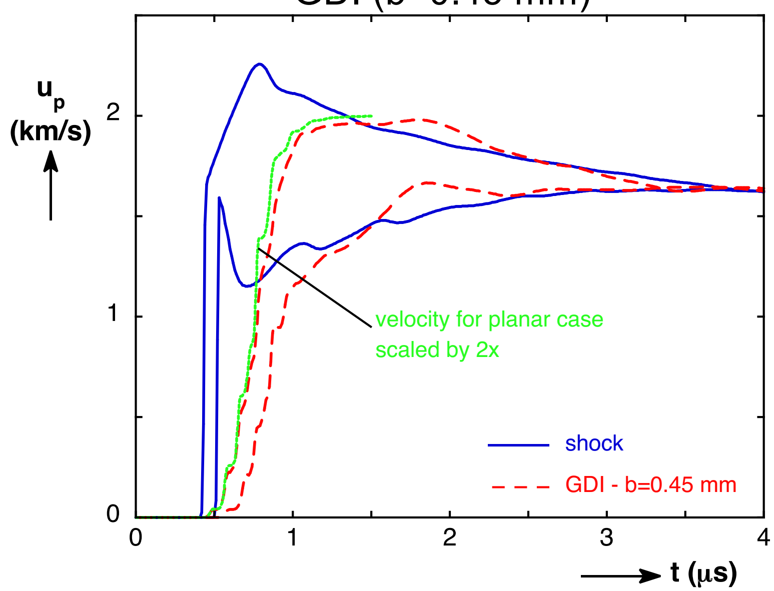


- jet growth shows dependence on layer thickness and rise time ($\Delta t_{10\text{-}90}$ – time from 10% to 90% of wave amplitude)
- when plotted versus rise time (0 for shock), a consistent linear trend emerges

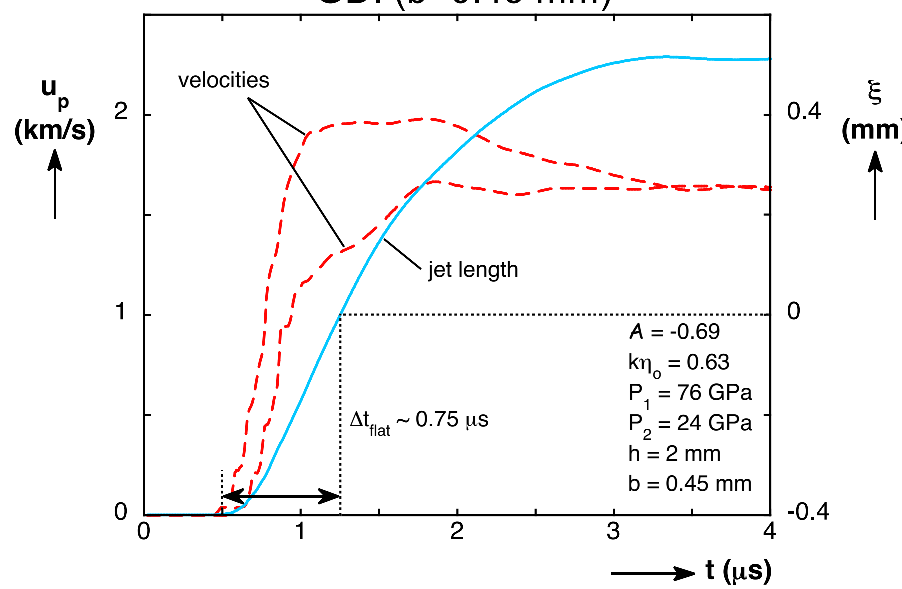
Spike and Bubble Velocities for GDI



velocities for shock and
GDI (b=0.45 mm)

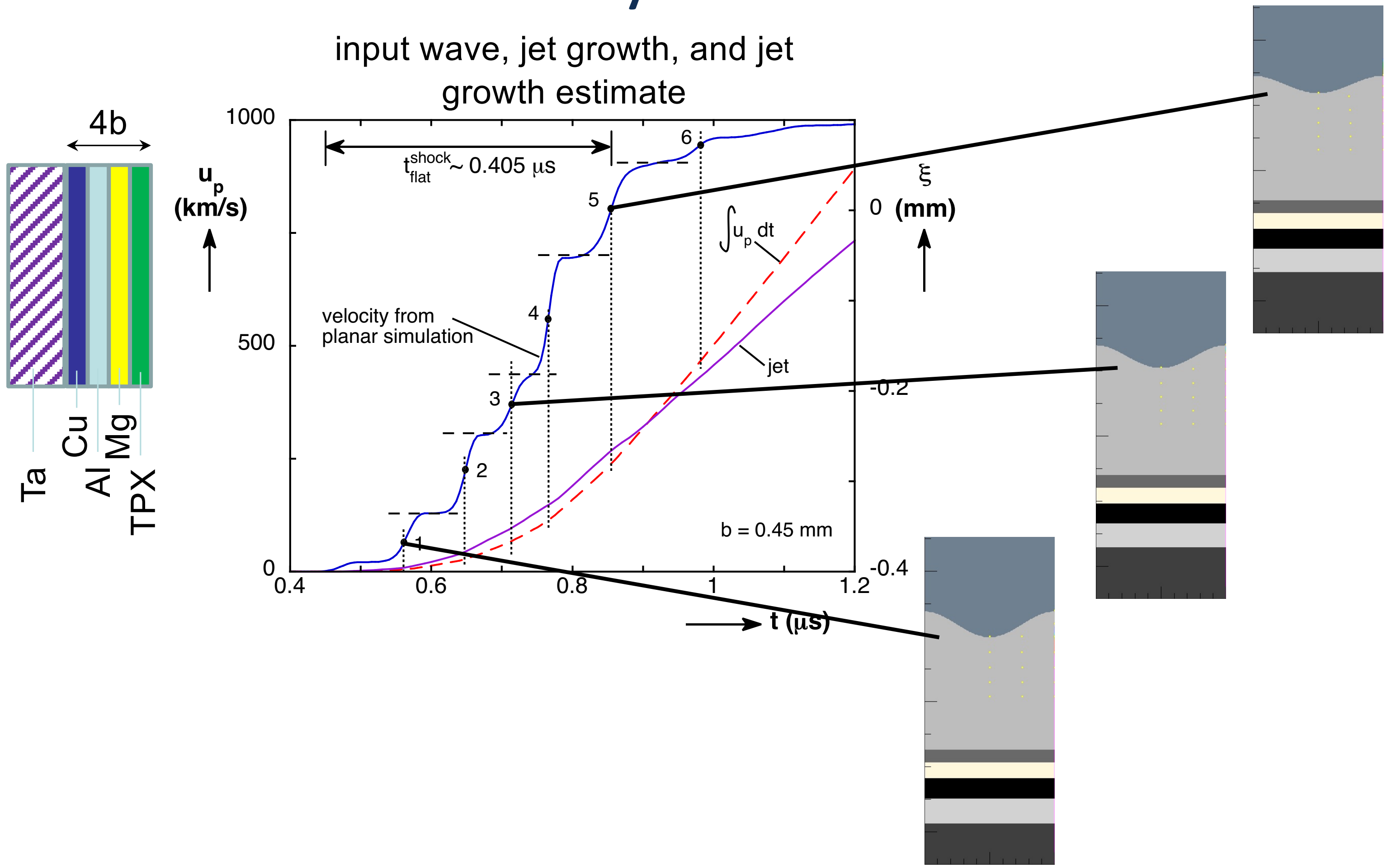


velocities and jet length
GDI (b=0.45 mm)



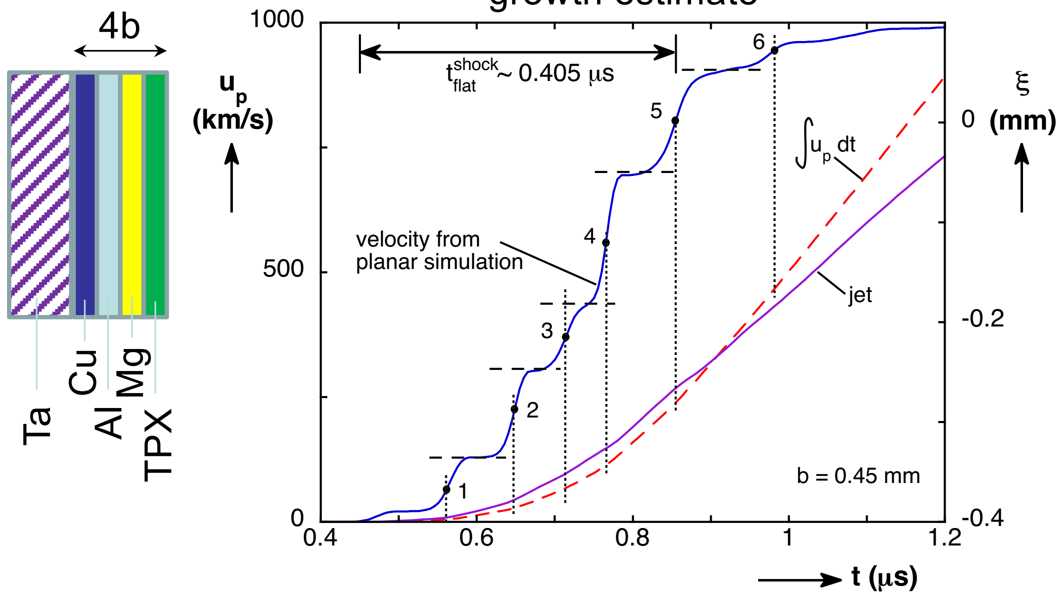
- velocity histories quite different for shock and GDI cases
- *in situ* planar velocity history (x2) very close to spike velocity for GDI
- rise time for spike (~0.55 µs) comparable to Δt_{flat} (~0.75 µs)

Incremental Analysis of non-shock GDI



Incremental Analysis of GDI

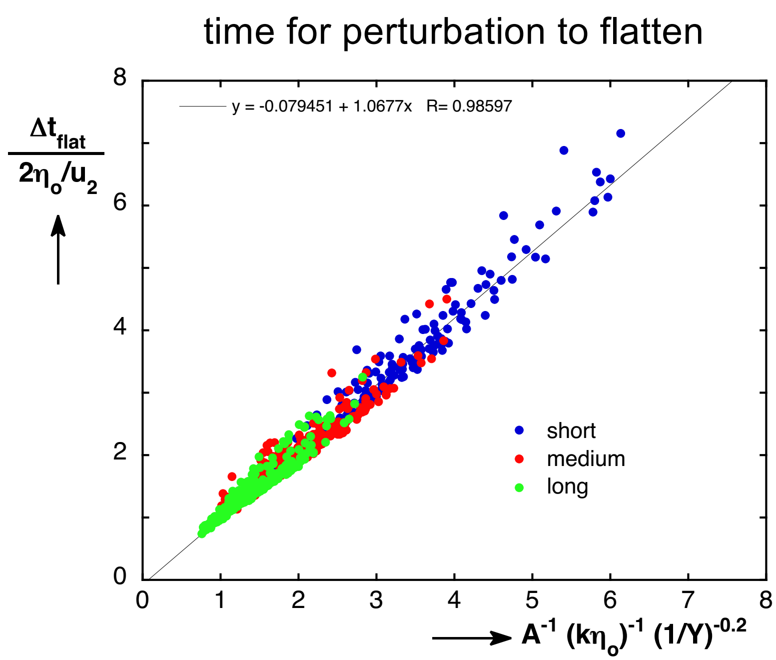
input wave, jet growth, and jet growth estimate



- For shock loading, $\bar{\xi}_\infty$ scales as $A^2(k\eta_o)^2\frac{\bar{\rho}u_2^2}{\bar{Y}}$ [Vogler & Hudspeth, 2021]
- Interpreting the last term as a normalized jump in stress $\Delta\bar{\sigma}$, the jet growth for multiple shocks can be written as $\bar{\xi}_\infty \propto \sum A^2(k\eta_i)^2\Delta\bar{\sigma}_i$ where η_i is the amplitude of the interface perturbation when the i^{th} shock arrives and $\Delta\bar{\sigma}_i$ is the amplitude of the i^{th} shock.
- For simplicity, we assume that $\Delta\bar{\sigma}_i \propto \Delta\bar{u}_i$, where $\Delta\bar{u}_i$ is the jump in particle velocity for the i^{th} shock
- To obtain an estimate for η_i, we integrate the input wave velocity (dashed red curve). It is a good approximation to the actual jet length (purple).

- For the case of b=0.45 mm, approximate the wave using the six jumps shown.
- Using the integral for velocity to estimate η_i, a value $\bar{\xi}_\infty / \bar{\xi}_\infty^{shock}$=0.71. The actual value is 0.69.
- More testing is needed to ensure that the approach is generally applicable.

Scaling for Δt_{flat}

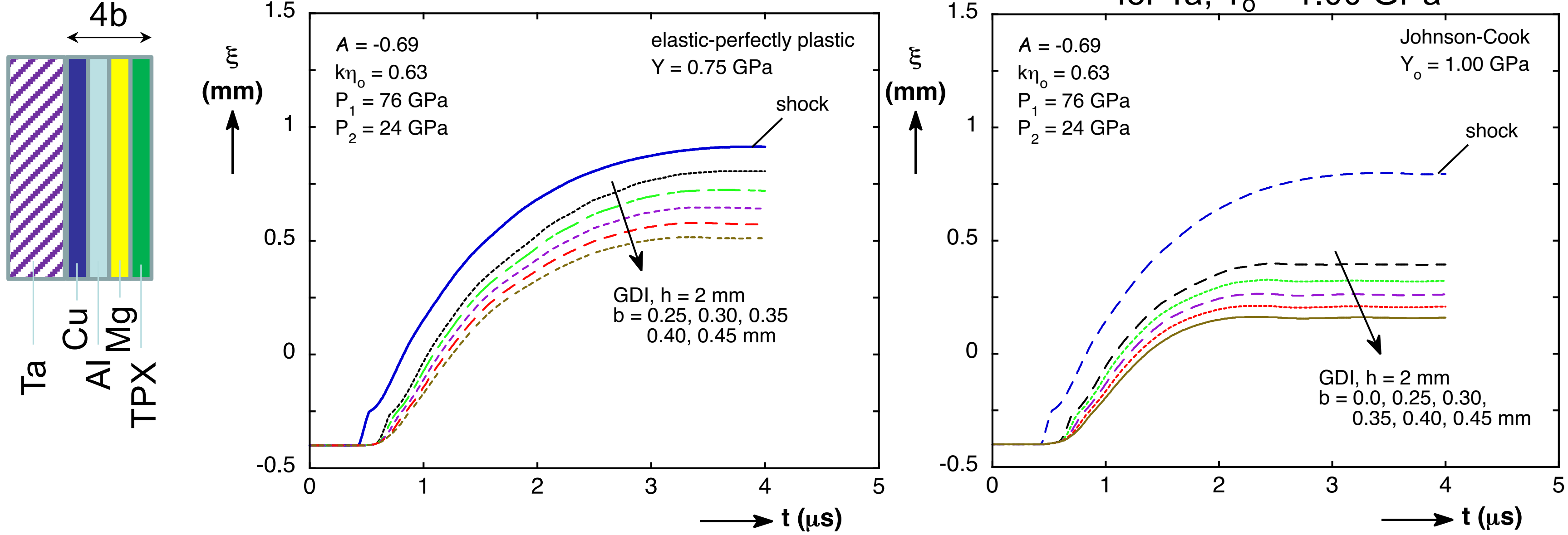


- For relatively long jets that arrest, Δt_{flat} linear against non-dimensional groups, only weakly dependent on Y (exponent -0.2-0.0)

Probing Thermal Aspects of Strength Models

elastic-perfectly plastic

Johnson-Cook strength model
for Ta, Y_o = 1.00 GPa



- Johnson-Cook strength model used with Y_o adjusted to give results similar to EPP model (Y_o =0.75 GPa) for shock case
- There is a dramatic difference between the shock and GDI results with Johnson-Cook because of the temperature dependence of that strength model

Conclusions

- Although RMI is termed the shock instability, it can also occur under non-shock (ramp) loading for loading times less than or comparable to the time for the surface to flatten
- Non-shock loading leads to less heating of the driver material, allowing thermal aspects of the strength model to be probed
- Non-shock loading is less efficient for jet growth
- Efficiency can quantified by considering evolution of the interface during the arrival of the ramp wave
- Behavior of liquid tamper (e.g. solidification) might complicate interpretation

Related Talks:

TBD – Voorhees et al., tamped RMI expts. on Mo

TBD – Padgiotis et al., RMI on ALOX

TBD – Guo et al., shock and optical characterization of PFO