SAND2018-2259C

Perturbation Decay Experiments on Granular Materials

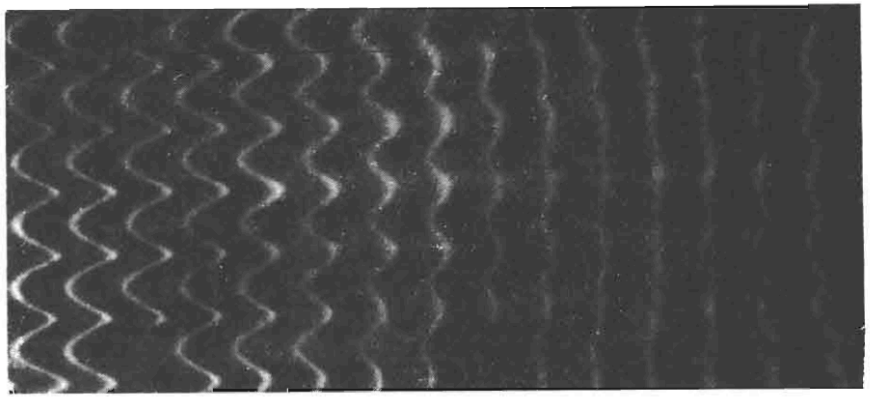
Tracy J. Vogler & Marcia Cooper
Sandia National Laboratories

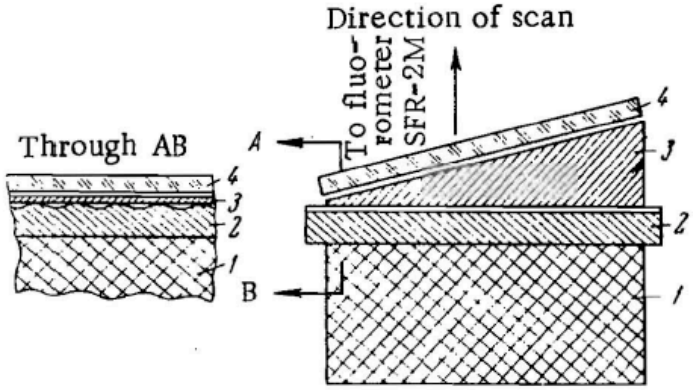
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Sakharov et al. Perturbation Decay Experiment

Sandia National Laboratories

Sakharov, A. D., R. M. Zaidel, V. N. Mineev and A. G. Oleinik (1965). "Experimental investigation of the stability of shock waves and the mechanical properties of substances at high pressures and temperatures." *Soviet Physics JETP* **9**: 1091-1094.





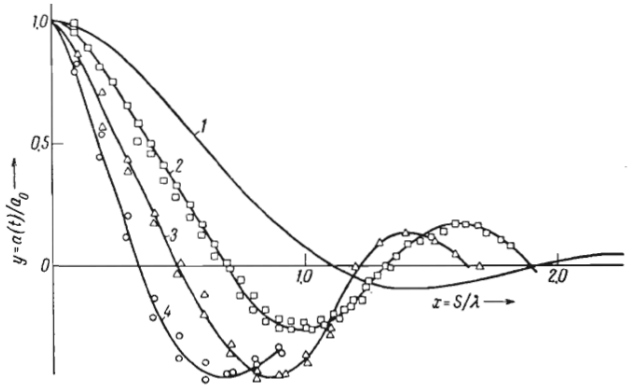
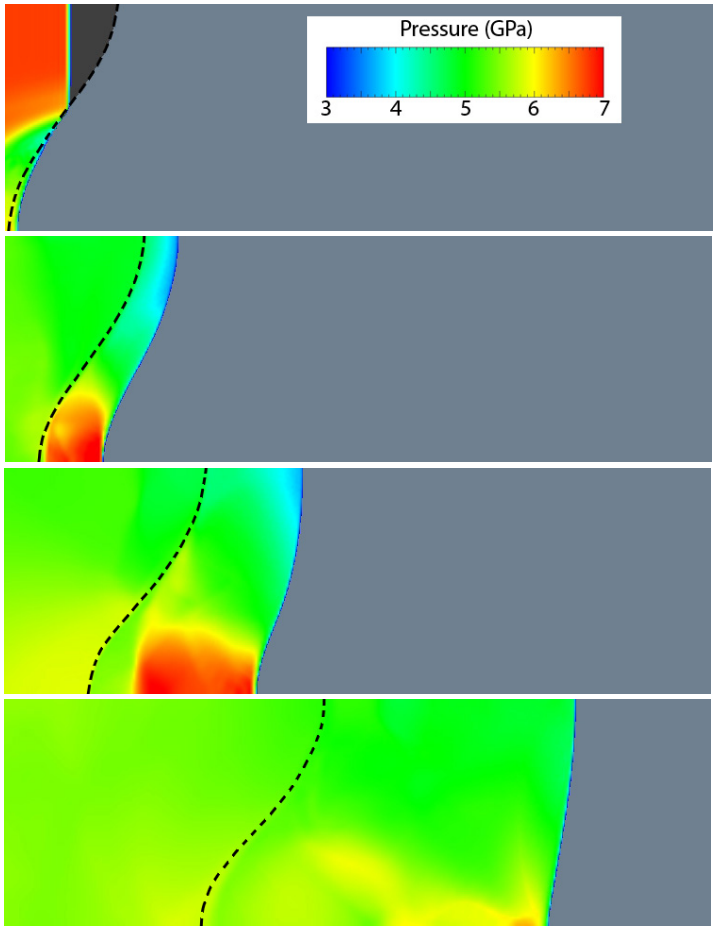
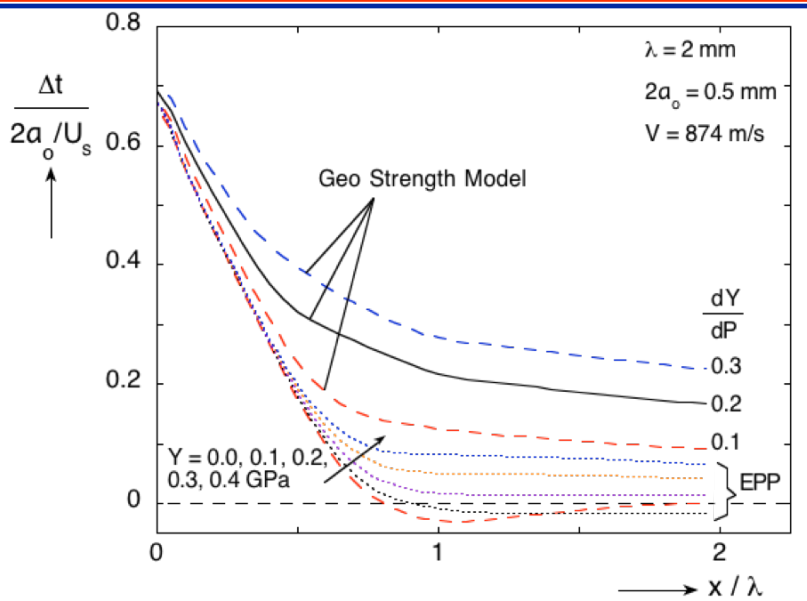


Fig. 3. Some experimental curves of the development of perturbations at a shock-wave front. 1) Calculated curve; 2) $\lambda = 2$ cm; $ka_0 = 0.872$; 3) $\lambda = 1$ cm, $ka_0 = 0.872$; 4) $\lambda = 1$ cm, $ka_0 = 1.74$.

- Chinese work using gas gun drive
- Vogler, JDBM 2015 on granular WC
- laser-driven work at LANL (Opie et al., PRL 2017)

Continuum Simulations



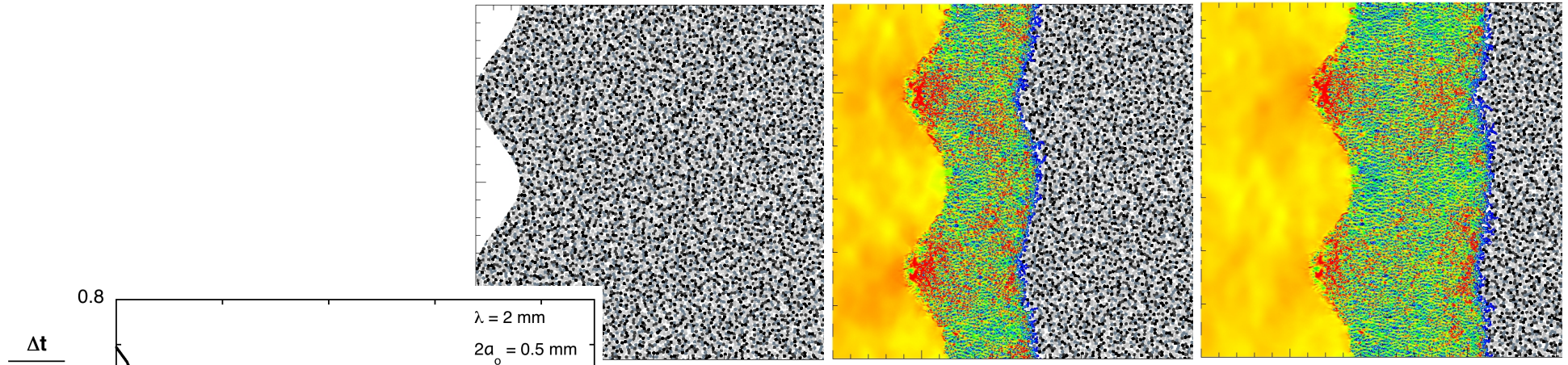


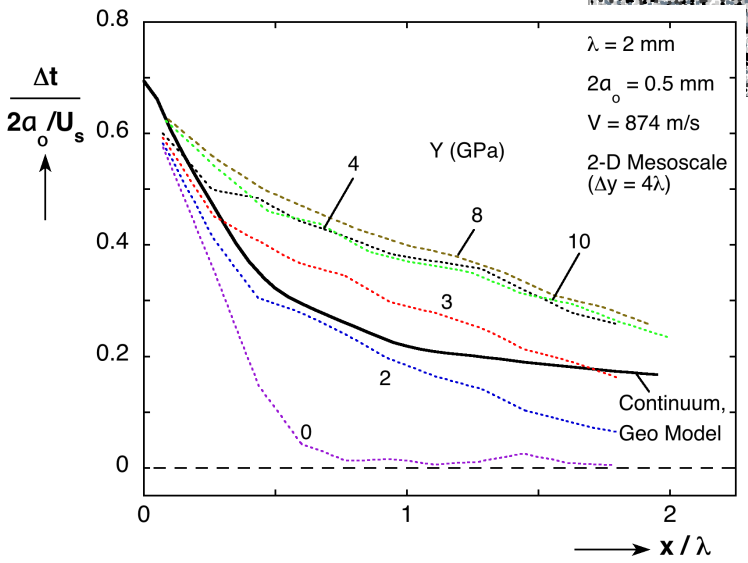
- P-λ compaction model in CTH
- constant or pressure-dependent strength

$$Y = Y_\infty + (Y_o - Y_\infty) exp\left[-\frac{dY}{dP}\frac{P}{Y_\infty - Y_o}\right]$$

- dependent on strength, not compaction

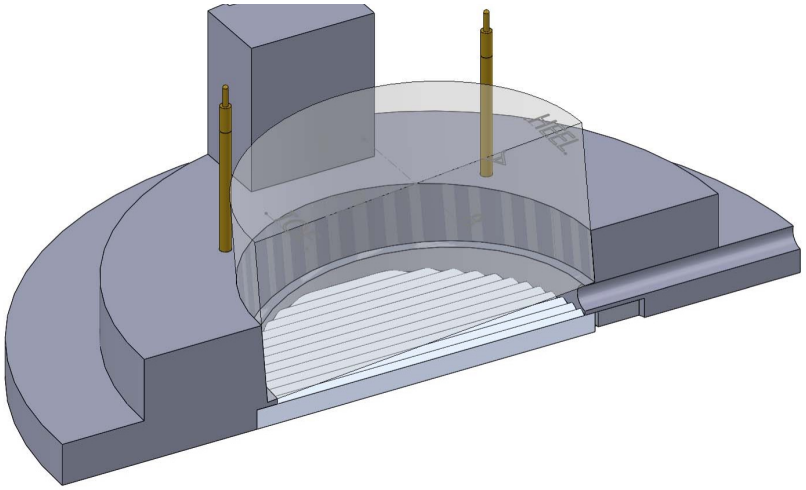
CTH Mesoscale Simulations





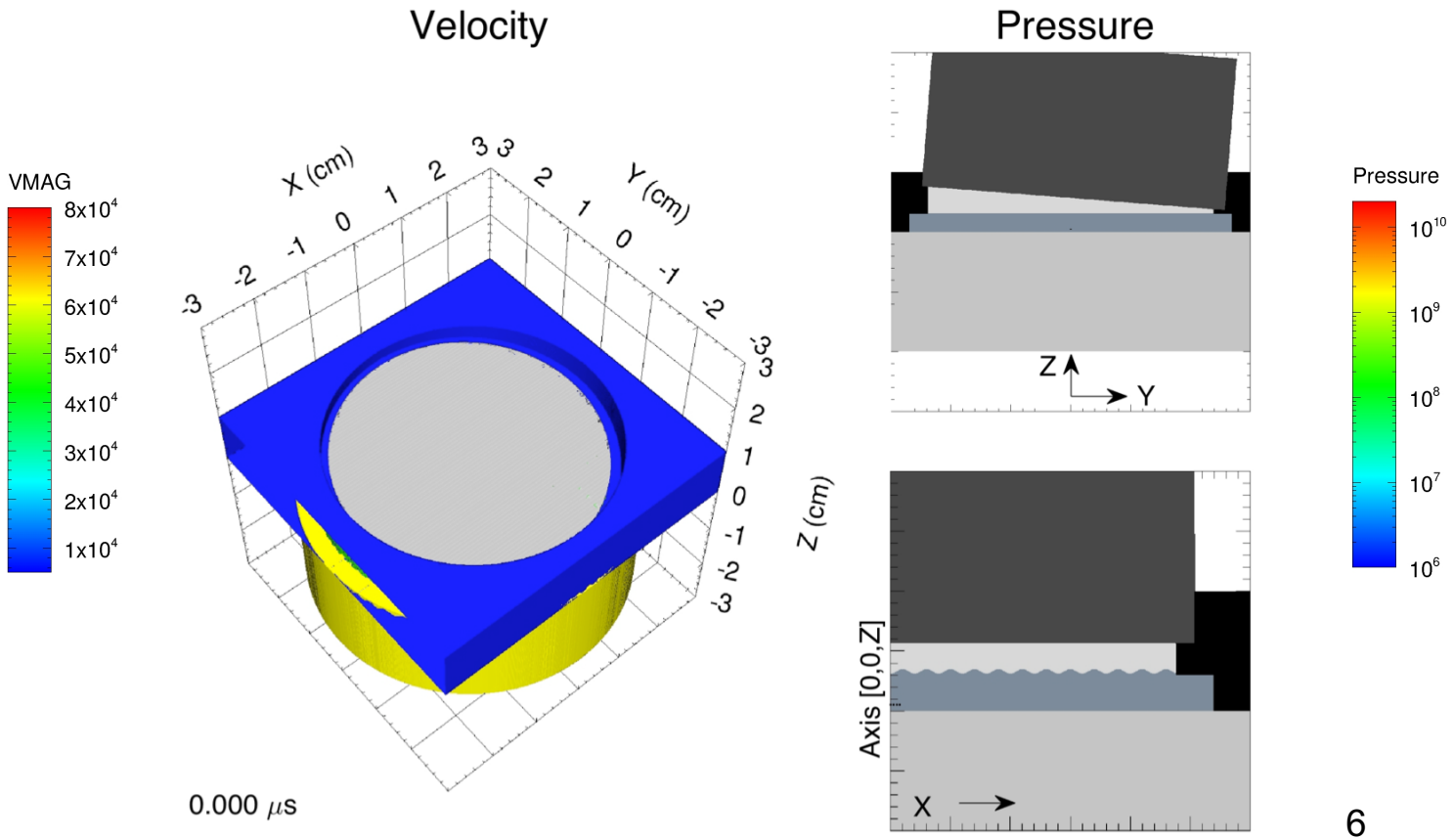
- 2-D mesoscale calculations similar to Borg & Vogler
- individual WC particles idealized as circles
- WC modeled with Mie-Gruneisen EOS and elastic-perfectly plastic strength
- decay is dependent on strength of WC

Wedge Target Design



- wedge shaped sample probes multiple sample thicknesses in single experiment (similar to Russian and Chinese configurations)
- reflective Al coating destroyed by shock arrival; high speed framing camera used to monitor loss of reflectivity at powder/window interface

Simulations of Experiment



6

WC Powder, λ=2 mm, 2a=0.5 mm

Sandia National Laboratories

Target Wavy B-3

Tungsten Carbide

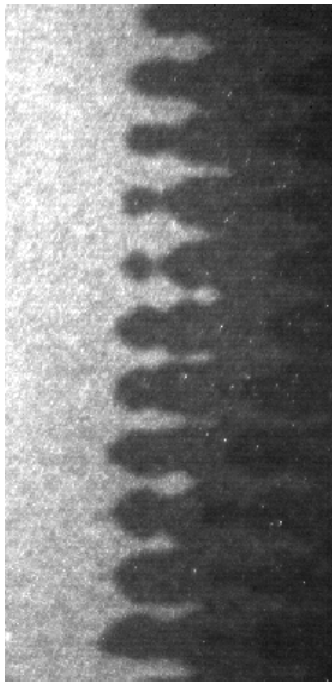
Impact Velocity: 0.88 km/s

EXPLOSIVE TECHNOLOGIES 2550 GROUP

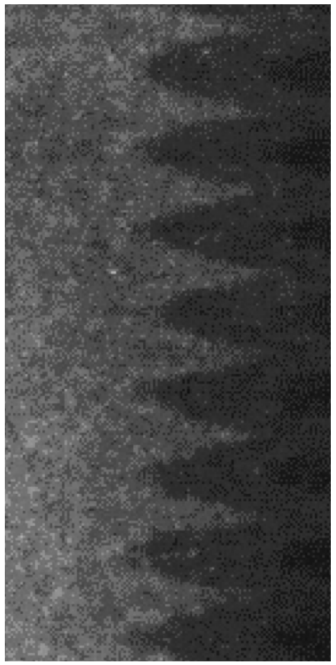
Sandia National Laboratories

return

Irregular Shapes at Late Times



“late” time



“early” time

- no indication of this in simulations
- reminiscent of bubbles in R-T, but physics is different
- could be due to a low-level elastic precursor?
- using thicker (22 μm) Al coating largely removes these artifacts

return

Cu Powder, λ=2 mm, 2a=0.5 mm

Target Wavy B-6

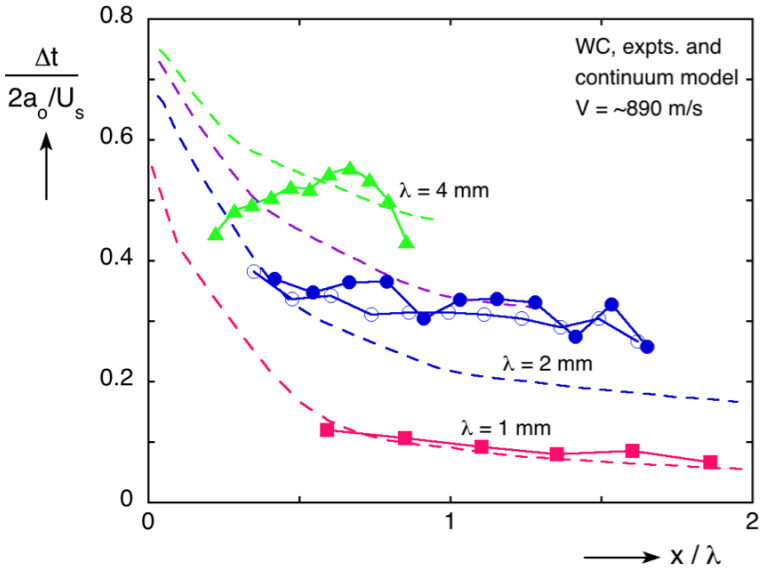
Copper

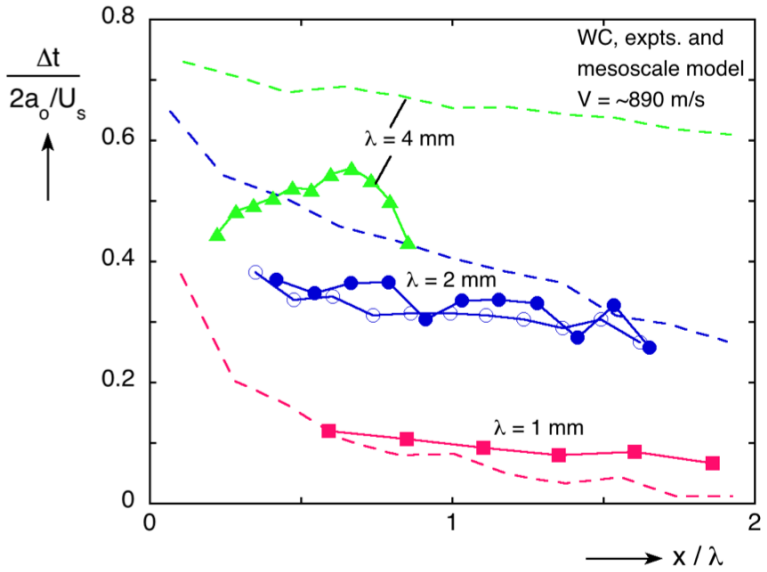
Impact Velocity: 0.89 km/s

Sandia National Laboratories

Comparison with Simulation Results

- trend consistent for both models
- results more sensitive to strength for larger λ
- neither model agrees for all λ





$$Y = Y_\infty + (Y_o - Y_\infty) exp\left[-\frac{dY}{dP}\frac{P}{Y_\infty - Y_o}\right]$$

Conclusions

Sandia National Laboratories

- design with wedge sample exploiting loss of reflectivity largely successful
- decay is rapid in Cu powder (low strength), slow in WC (high strength) → consistent with mesoscale simulations
- experiments mostly in slow-decay regime – difficulties with thinner samples
- artifacts seen at later times
- loss of reflectivity process not well understood
- additional work:
  - planar drive
  - intermediate thickness Al coating
  - multiple λ on same shot?
  - WC/Ta mixture to promote decay