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Peridynamic Investigation of Shock Wave Decay

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Abstract

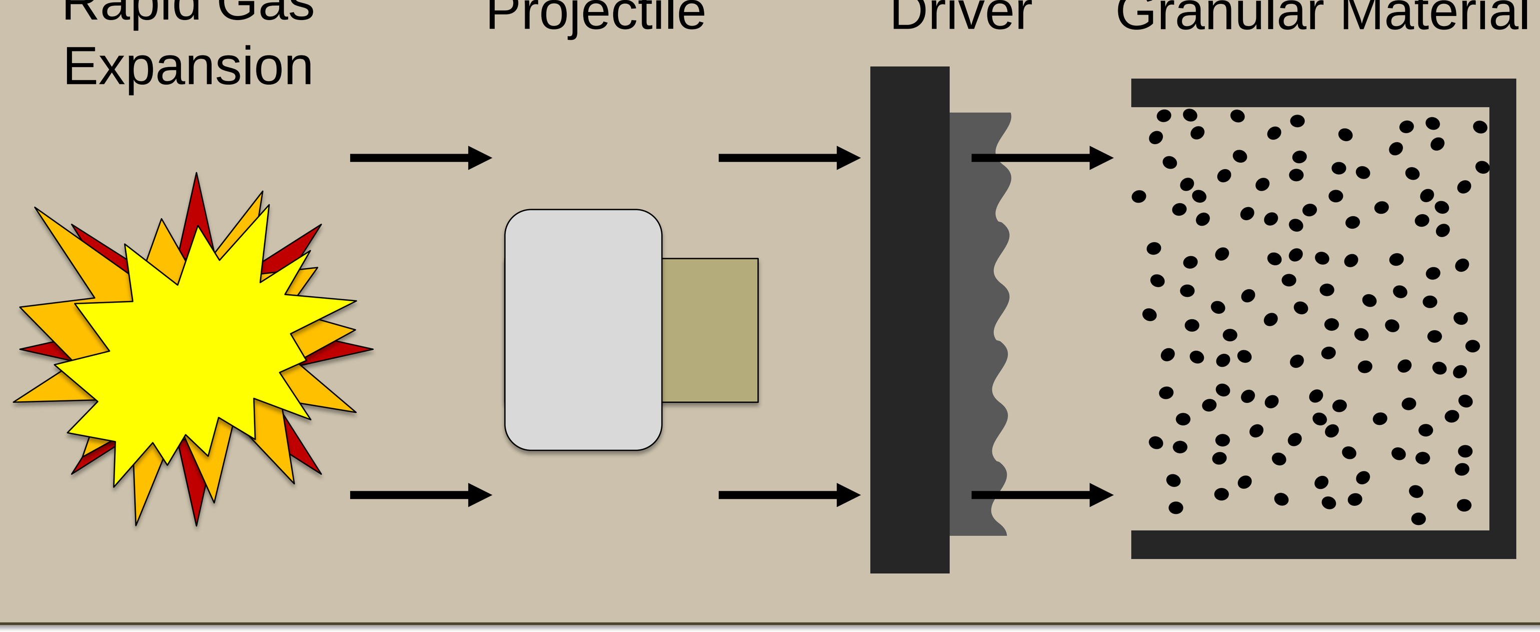
The behavior of a transverse shock waves through granular media is not well understood. It is apparent that transverse wave attenuation is proportional to some equivalent dissipative force which may include viscoplasticity, material strength, and frictional contact. It is desirable to understand the impact of grain fracture on the decay rate of perturbed shock waves. This will be achieved using a Peridynamic approach.

Background

- A sinusoidal shock front decays to a planar shape as it travels through the material
- Decay speed is a function of material strength and dissipative forces
- The impact of fracture on decay rate is not well quantified for granular materials
- Peridynamics is a natural tool to study granular material fracture
- The Sandia code Peridigm is an open source software implementing peridynamics

Shock Generation

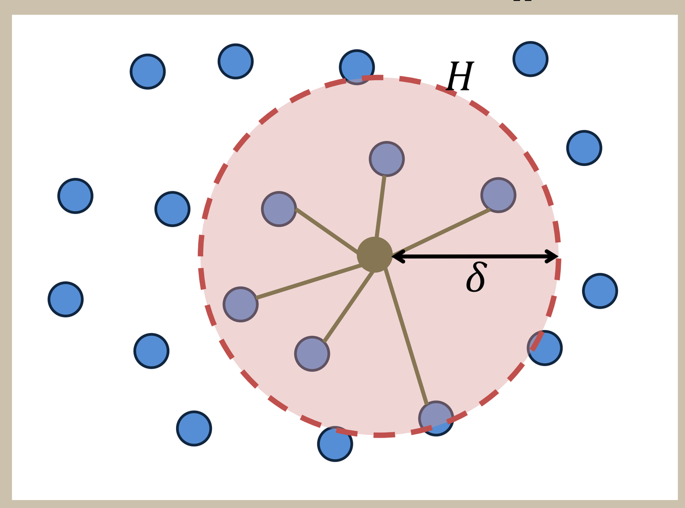
- A high pressure gas is released from a pressurized gun or controlled explosion
- The rapid gas expansion accelerates the projectile which impacts the driver
- The driver has a sinusoidal grooved surface which impacts the granular material



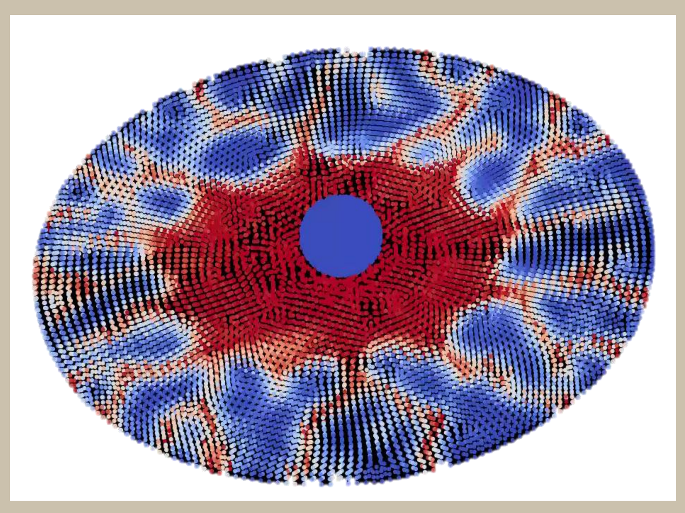
Peridynamic Modelling

- Peridynamics is an integral formulation of continuity using a set of Lagrangian nodes
- Bonds are created within the neighborhood, *H*, described by the horizon, δ
- Bonds break between two nodes when a critical stretch threshold is reached

$$\rho\ddot{u}(x,t) = \int_H f(u(x',t) - u(x,t), x' - x)dV' - b(x,t)$$



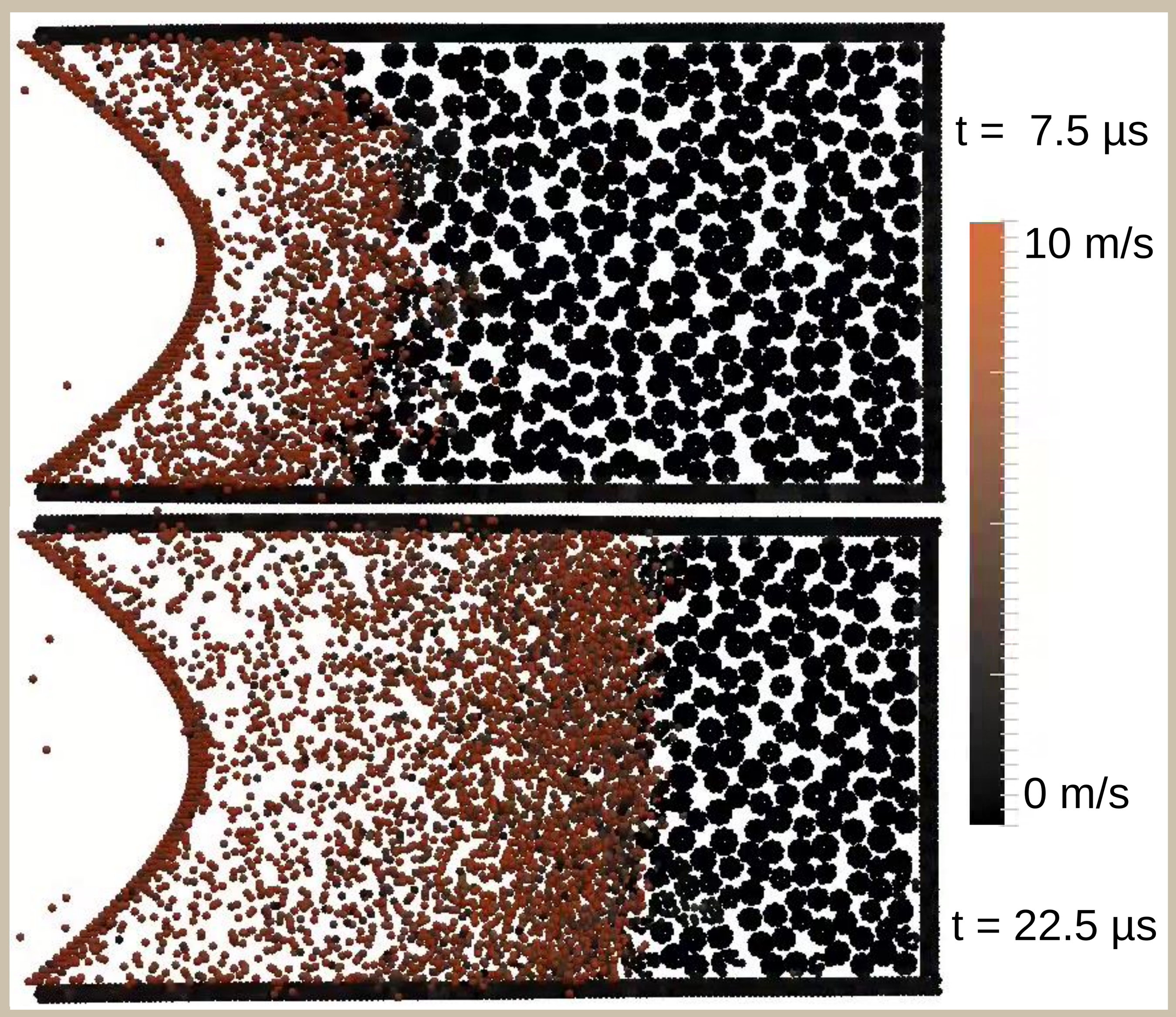
Basic peridynamic node relationship. The highlighted node is bonded to all nodes within its neighborhood.



Damage propagation after a projectile impact. Redder areas have more bonds broken.

Current Simulation Status

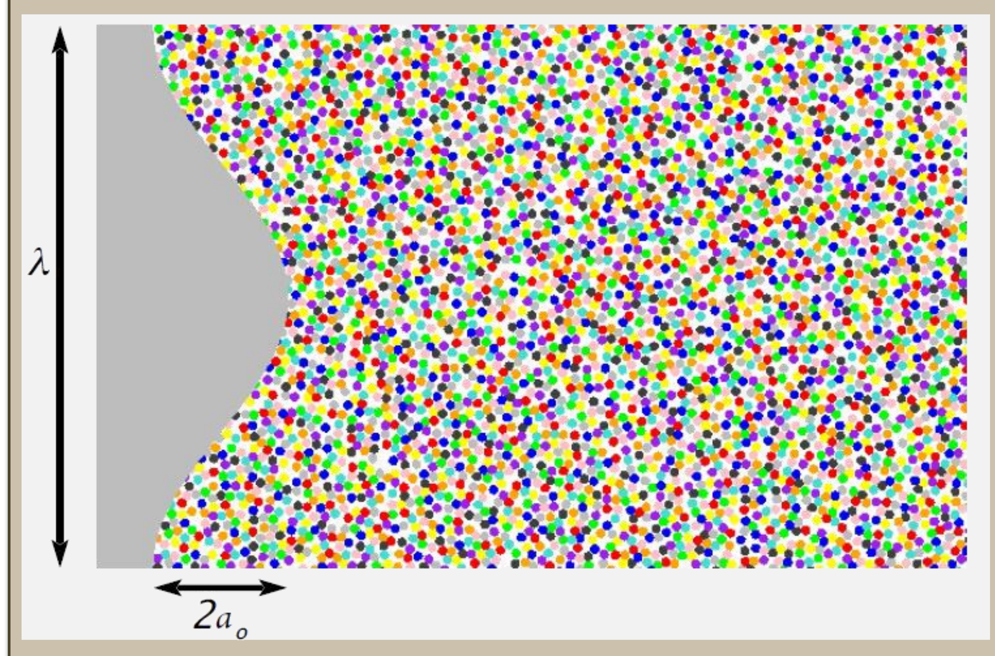
- Grains are randomly positioned in the simulation space and allowed to settle
- An arbitrary function can be used to determine the shape of the driver
- A framework was developed to quickly iterate Peridigm input decks
- A 2D simulation without fracture was developed and run on a representative area



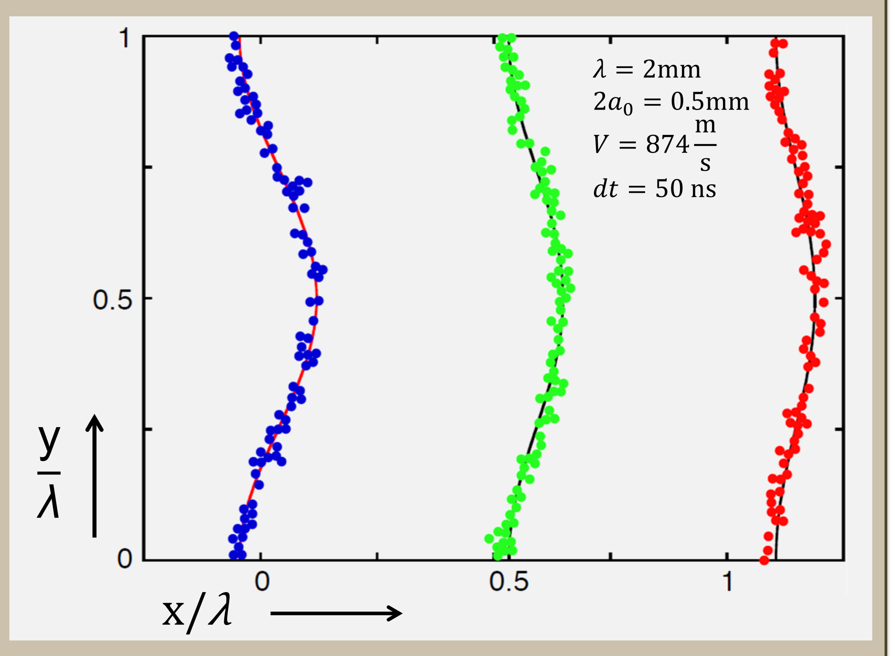
Peridigm simulation visualized using Paraview. Each image shows the same simulation at a different point in time. The shock wave can be seen travelling rightward from the initial impact and decaying into a planar shape.

Comparison to Existing Data

- Mesoscale and continuum scale simulations performed by Tracy Vogler
- Both simulations were verified for many granular materials with experimental data



Mesoscale simulation setup. This 2D simulation uses a single sinusoidal region from the driver with a periodic boundary condition. λ and a_0 are geometric constants.



Shock front position at various times in the simulation. The shock waves decay toward a planar shape as the shock front progresses through the material.

References

- T. J. Vogler, "Shock Wave Perturbation Decay in Granular Materials," *J. dynamic behavior mater. Journal of Dynamic Behavior of Materials*, vol. 1, no. 4, pp. 370–387, May 2015.
- M.L. Parks, D.J. Littlewood, J.A. Mitchell, and S.A. Silling, Peridigm Users' Guide, Tech. Report SAND2012-7800, Sandia National Laboratories, 2012.

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