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ALEGRA: finite element modeling for shock hydrodynamics and multiphysics

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Introduction

ALEGRA is a finite element code for explicit solid dynamics based on arbitrary Lagrangian-Eulerian (ALE) technology. It provides predictive modeling of large-deformation dynamics in 2D and 3D on Lagrangian, Eulerian, or ALE meshes.

This core is coupled to multiphysics capabilities for these areas:
- Magnetohydrodynamics (MHD)
- Quasi-static electromechanics/ferroelectricity (FE)
- Radiation hydrodynamics, high energy-density physics (HEDP)

Solid dynamics

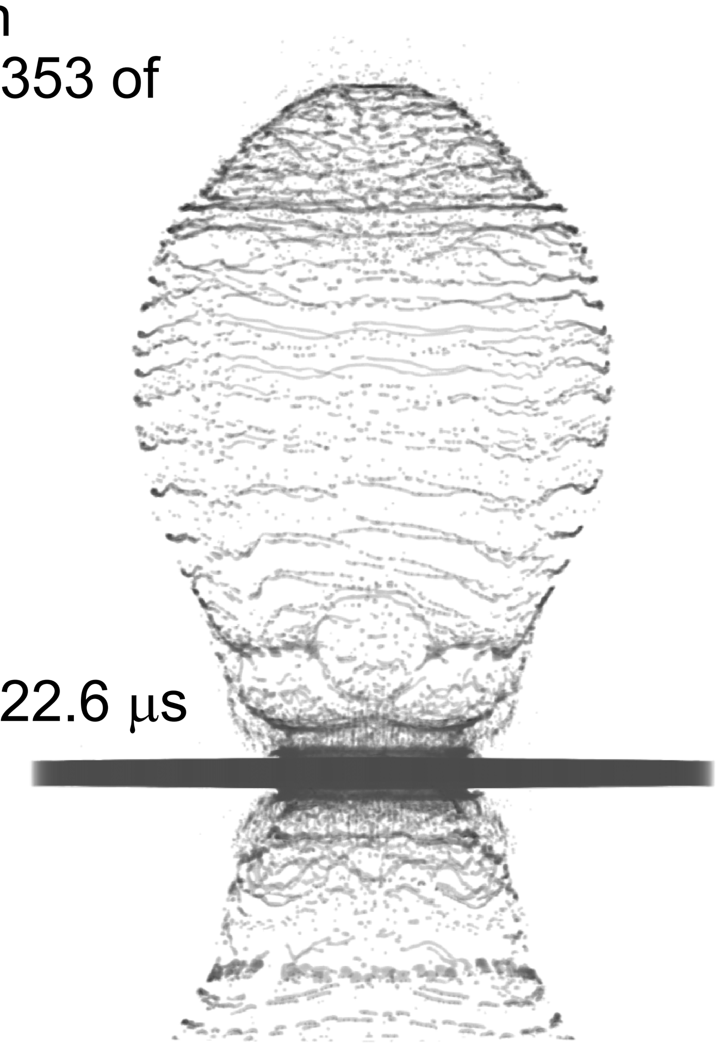
- Linear finite element discretization
- Up to second order time integration
- Unstructured meshes
- Multi-material elements with shock capturing
- ALE remeshing
- Up to third order remap, interface reconstruction, multimaterial aware limiting
- Strong V&V testing
- Demonstrated scaling up to 65,000 cores, 2 billion elements
- Multiphysics via operator splitting

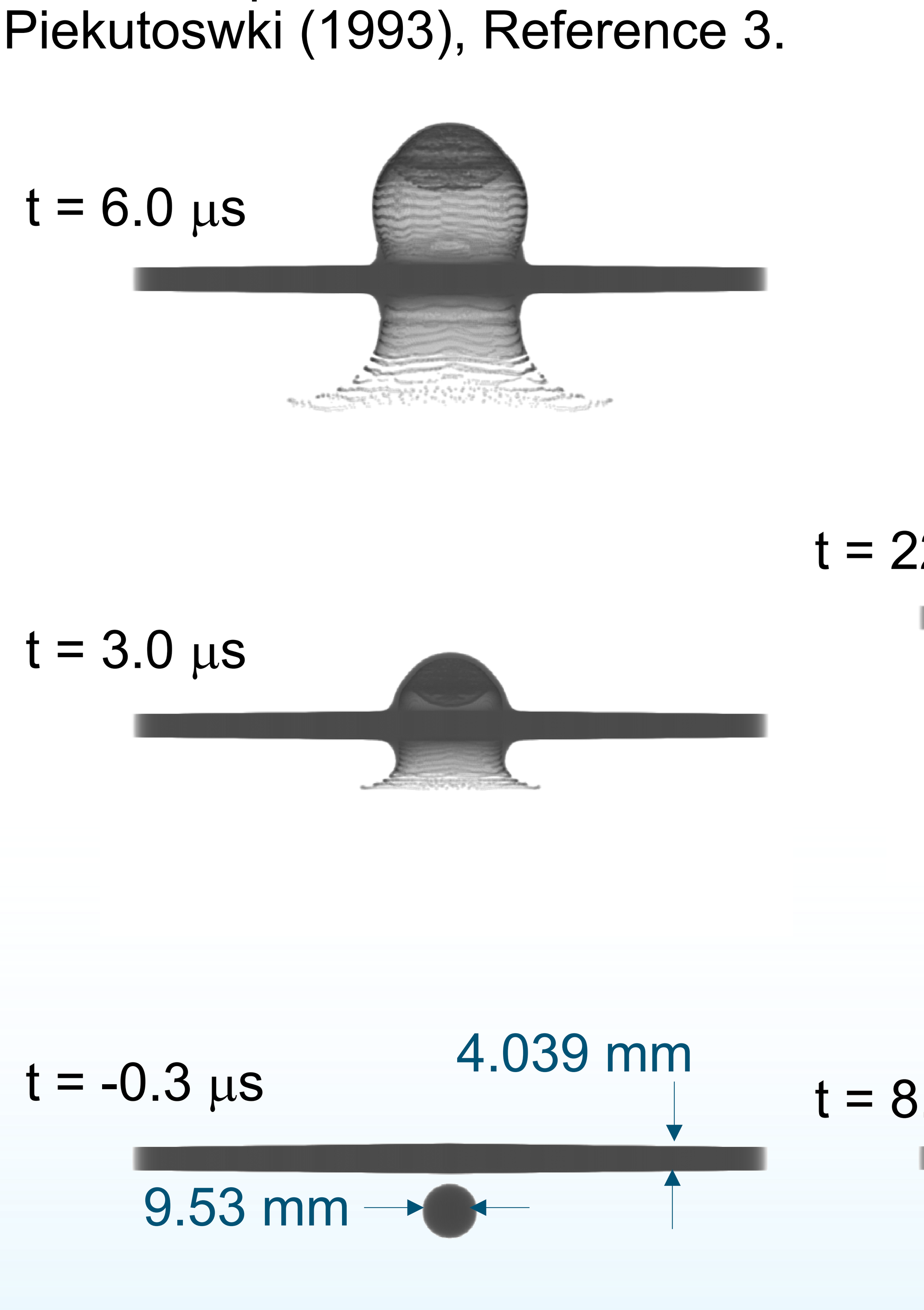
Material models

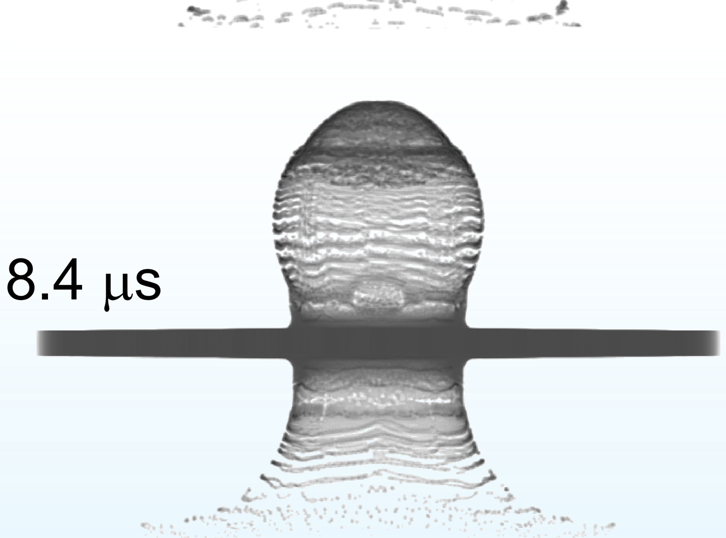
- Equation of state
  - Tabular (SESAME)
  - Analytic
- Classical yield models
- Sandia reactive burn models
- Brittle failure models
- Ductile damage & fracture
- Spatially variable material properties using statistical distributions
- User defined models (UMAT)
- Electrical and thermal conductivity
- Polarization and magnetization
- Opacity

Example 1: hypervelocity impact (3D)

Normal impact of aluminum sphere on aluminum plate at 6.68 km/s: shot 4-1353 of Piekutoswki (1993), Reference 3.





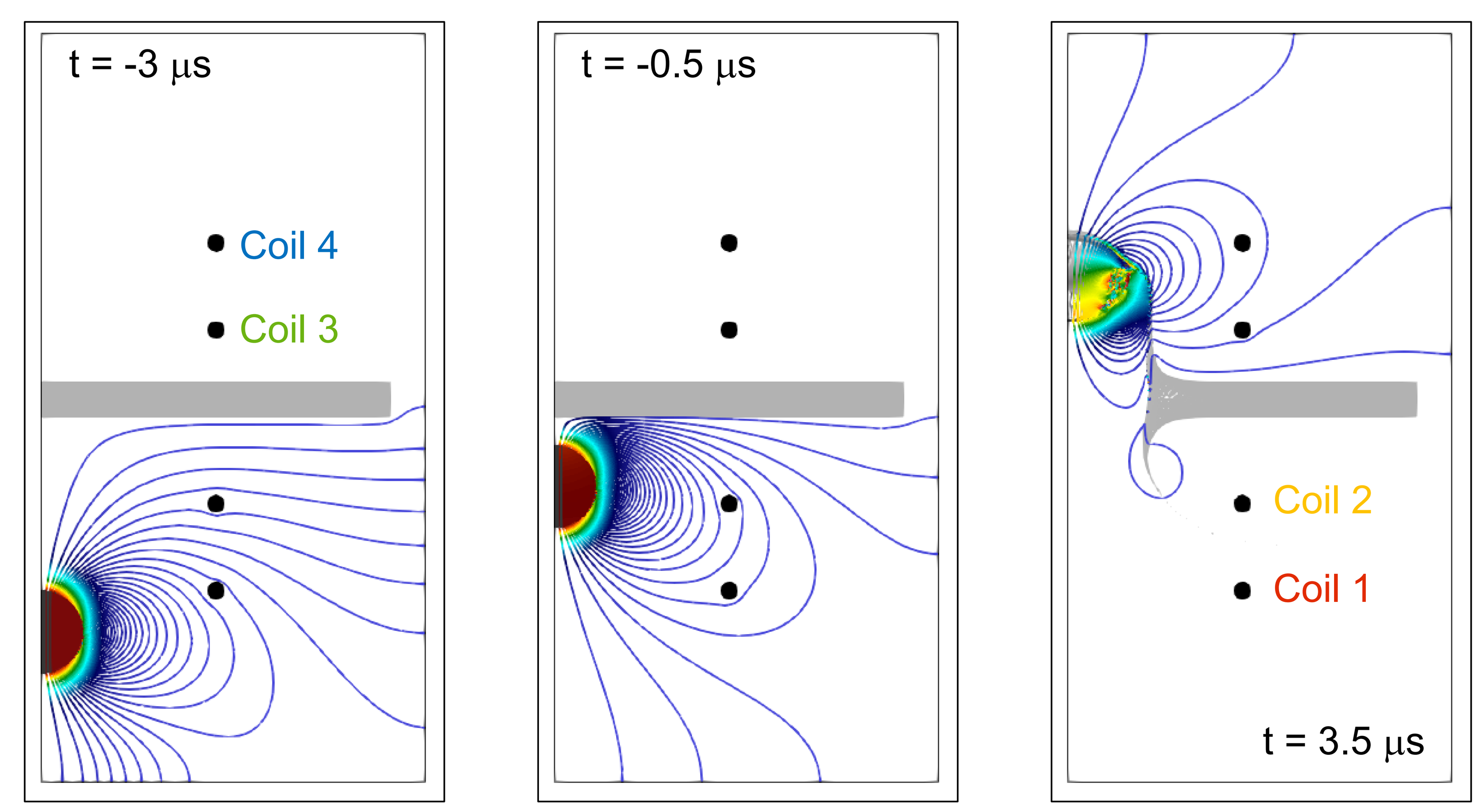


Magnetohydrodynamics

Various MHD flavors available in ALEGRA

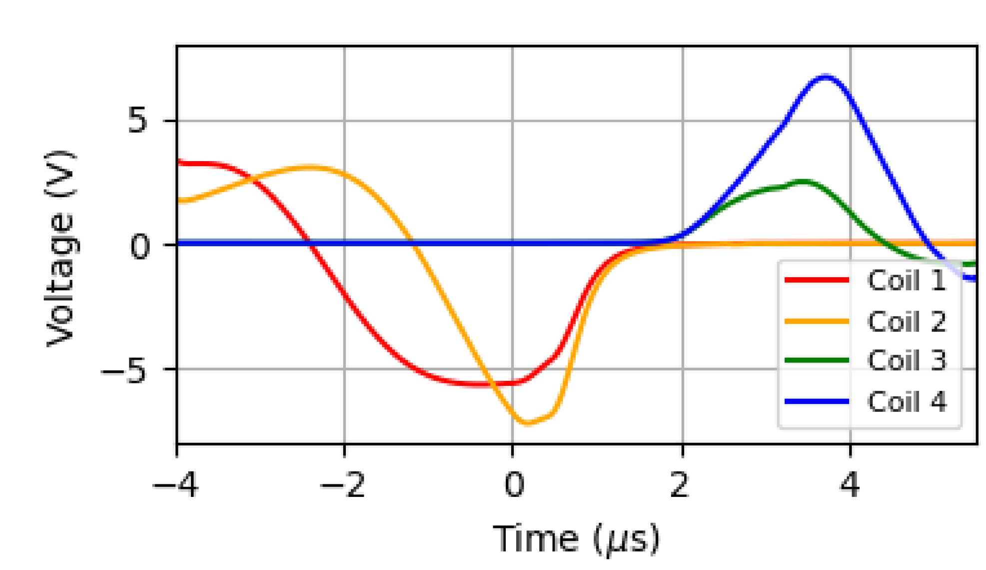
	Joule Heating	Magnetic Forces	EM wave propagation	Solver expense	Time step	Production
Generalized MHD	yes	yes	yes	very high	hydro	no
Resistive MHD	yes	yes	no	low(2D) high(3D)	fast magnetosonic	yes
Low Rm MHD	yes	no	no	low	hydro	yes

Example 2: hypervelocity impact of a magnet (2D)



Above: magnetic field evolution during normal impact of neodymium-alloy sphere magnet on aluminum plate at 6.68 km/s with 4 induction coils.

Right: voltage signals induced in coupled coils during simulated impact (contact at t = 0).



Quasi-static Electromechanics

- Solves coupled electromechanics equations with quasi-static electric field assumption.
- Dielectric, piezoelectric, and ferroelectric models specify stress and polarization in terms of strain and electric field.
- Allows modeling of sensors, power supplies.

Advanced features

- Radiation transport: multigroup diffusion, implicit Monte Carlo.
- Eulerian XFEM for interfaces.
- Performance portability for next-generation (GPU) architectures.
- Fully integrated with DAKOTA software.

Implicit solvers (multiphysics)

- Trilinos
  - Transient magnetics
  - Quasi-static electrodynamics
  - Heat conduction
- Hypre
- Sundials DAE solver for circuit coupling

References

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