SAND2012-6731P

RKPM in Sierra/SolidMechanics

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Sierra/SolidMechanics Team, SNL

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Summer 2012: Preliminary Implementation Effort

GAME PLAN

- Begin with Lagrangian RKPM formulation for explicit dynamics
  - Semi-Lagrangian formulation to follow (FY13?)
  - Implicit / quasi-static implementation to follow (FY13?)
- Division of work
  - RKPM routines developed by UCLA team using in-house driver code
  - RKPM software routines transferred directly to Sierra/SM
  - Interface to Sierra functionality provided by Sandia
  - Mike Hillman and Dave Littlewood serve as points of contact for interface development
- Leverage existing Sierra/SM functionality
  - Preprocessing with spheregen.py (expand as necessary)
    - Element-to-particle conversion to follow (FY13?)
  - ACME neighbor search
  - Follow general SPH / Peridynamics / GPA code structure
- Follow Sierra/SM Team Sprint Schedule

Goal: Implement Lagrangian RKPM in Sierra/SM

STORY 1

Create basic Sierra classes for encapsulating RKPM functionality. Implement RKPM parser and neighborhood search.

Done means: Regression test verifying RKPM parsing and neighborhood search.

STORY 2

Implement RKPM functions for computing deformation gradient. Implement temporary hard-coded elastic material model.

Done means: Regression test verifying calculation of deformation gradient.

STORY 3

Implement RKPM functions for converting stresses to forces. Create a verification test for 1D wave propagation in an elastic beam.

Done means: Regression test for 1D wave propagation in a beam.

STORY 4 (STILL IN PROGRESS)

Enable use of LAME material models with RKPM. Implement RKPM calculation of critical time step.

Done means: Updated 1D wave propagation test using LAME material model and RKPM critical time step.

STRETCH GOAL

Validate with Taylor bar impact simulation.

Reproducing Kernel Particle Method (RKPM)

- Collaboration with JS Chen's group at UCLA
- Progress this sprint:
  - Pass information from input deck to RKPM section
  - Connect to existing neighbor search routines
  - Create a data structure for storing RKPM data
  - Fill data structures with Sierra framework data, pass to UCLA routines
  - UCLA routine to prune neighbor list

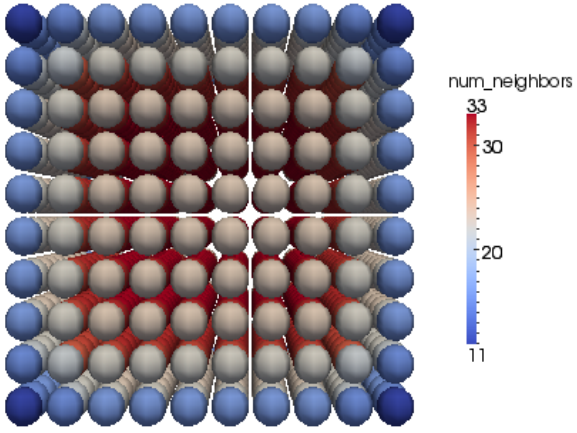
UCLA Team

Mike Hillman
Edouard Yreux
Dr. Shen-Wie Chi
Dr. Marcus Ruter
Prof. JS Chen

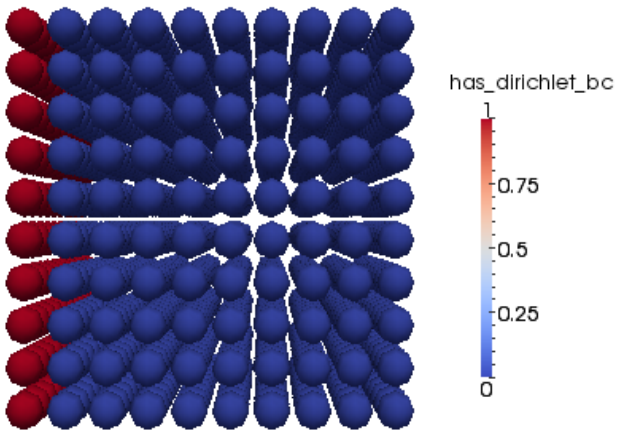
RKPM section added to input deck

```
begin RKPM section my_section
  support size = 1.5
  basis order = 1
  kernel type = 3
  kernel shape = sphere
end RKPM section my_section
```

Nearest neighbor search



Flagging of nodes with Dirichlet B.C.



Reproducing Kernel Particle Method (RKPM)

- Progress this sprint:
  - Voronoi data for Stabilized Conforming Nodal Integration
  - Implementation of shape function routine
  - Calculation of the smoothed gradient
  - Calculation of the deformation gradient
  - Verification test for deformation gradient

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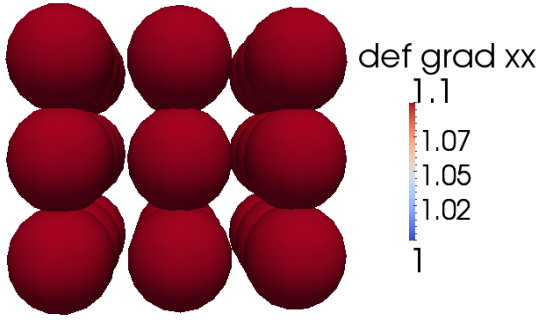
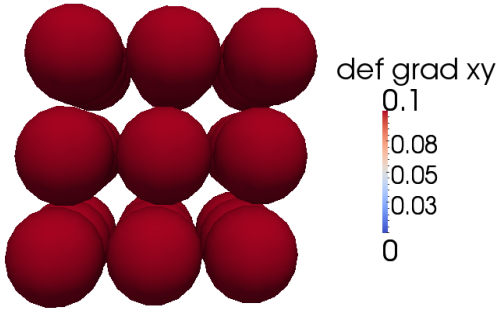
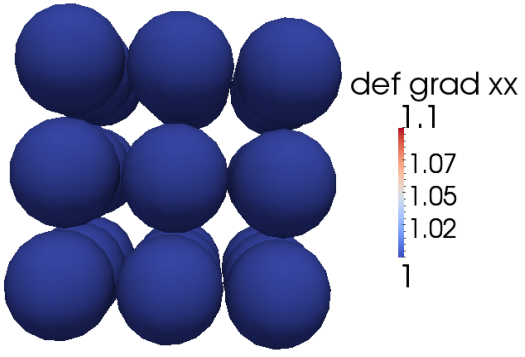
Deformation gradient test



Plane Strain Compression



Simple Shear



Rigid Body Rotation

Reproducing Kernel Particle Method (RKPM)

- Progress this sprint:
  - Convert stress to nodal forces
  - Verification by means of elastic wave propagation
  - Material is temporarily hard-coded
  - Comparison to analytic solution in progress

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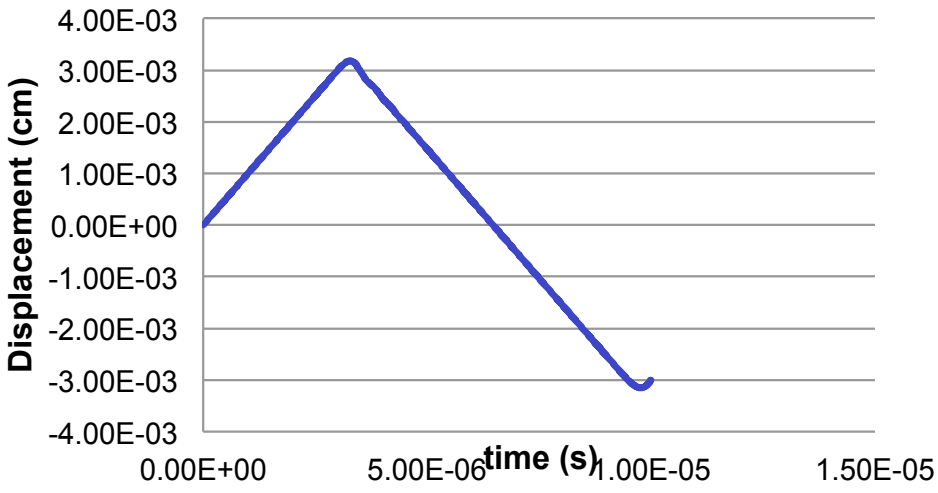
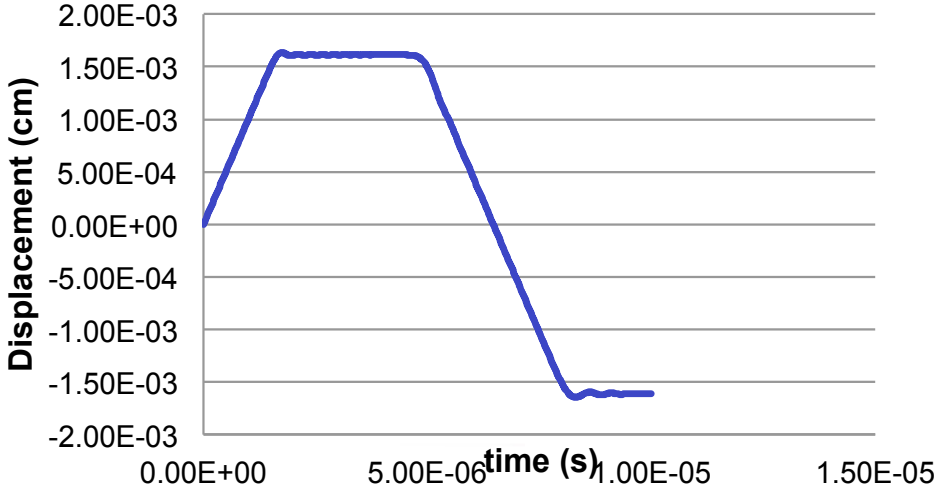
Displacement at End of Bar

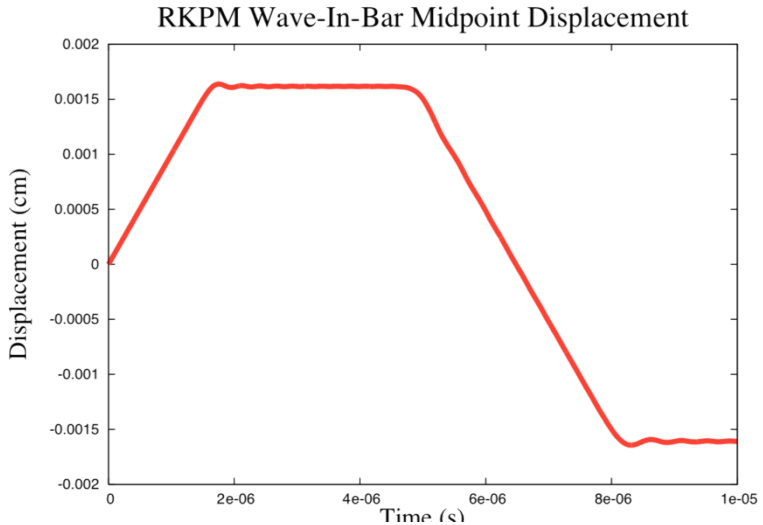


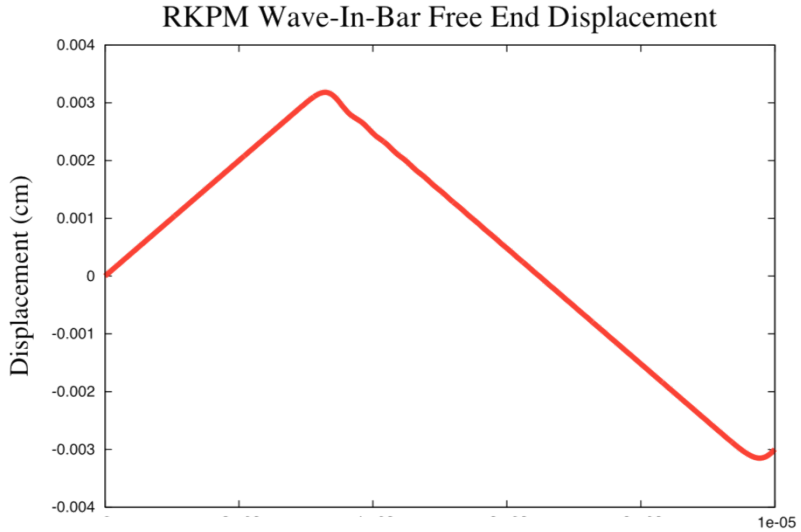
Displacement at Midpoint of Bar

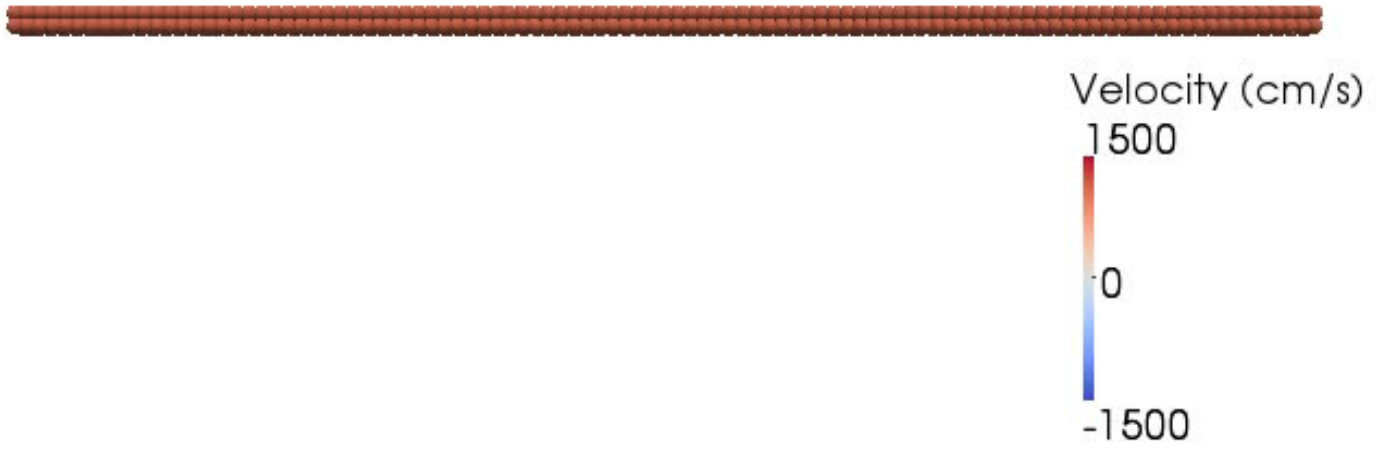


1D Wave Propagation in Elastic Bar

- Hard-coded elastic material model
- Poisson's ratio set to zero to mimic 1D wave propagation
- Initial velocity applied to bar, fixed displacement on right-hand side
- Comparison against analytic solution







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Lessons Learned

- Collaboration model worked well overall
  - UCLA team develops RKPM routines in-house
  - Sandia provides interface to Sierra/SM
  - Follow Sierra/SM sprint schedule
- Impediments to collaboration
  - Export restrictions on Sierra/SM source code
  - Poor access to Sandia hardware/software for Mike Hillman

Possible Tasks for FY13

- Semi-Lagrangian formulation for large-deformation problems
- Verification and validation testing
- Application to material failure
- User guidelines, example problems
- Sierra/SM functionality: restart, rebalance, element-to-particle conversion…
- Implicit time integration