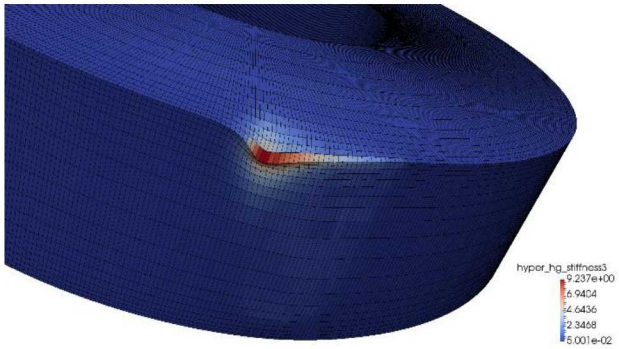
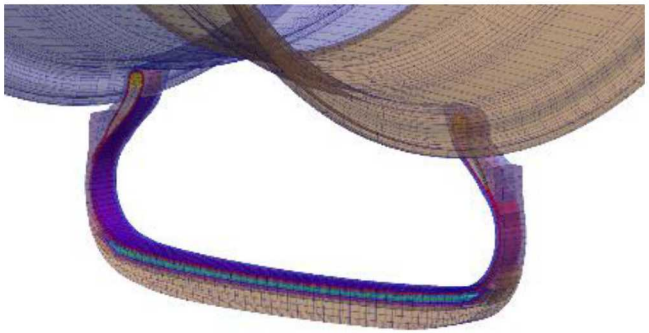
SAND2020-4556PE

Exceptional service in the national interest

Sandia National Laboratories





Sierra Solid Mechanics 4.43.4

Tuesday, December 13th, 2016

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

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & 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.

Sandia National Laboratories

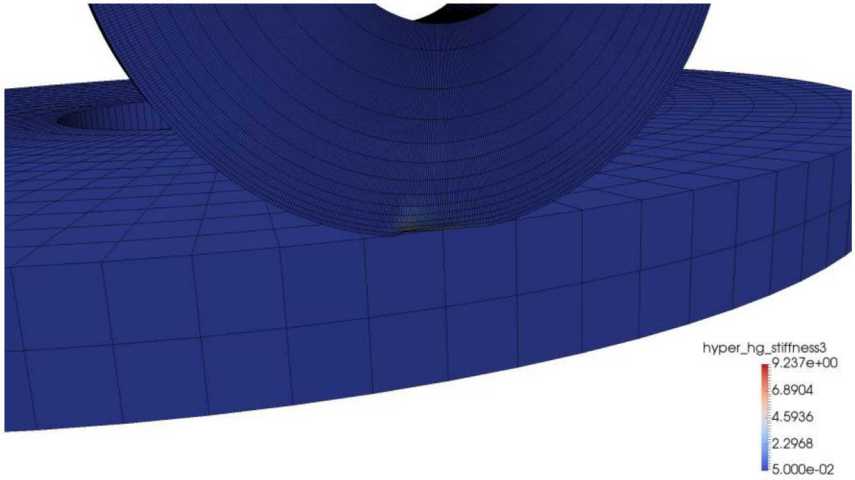
GOODYEAR

Goodyear: Assess nonlinear hourglass

Sandia National Laboratories

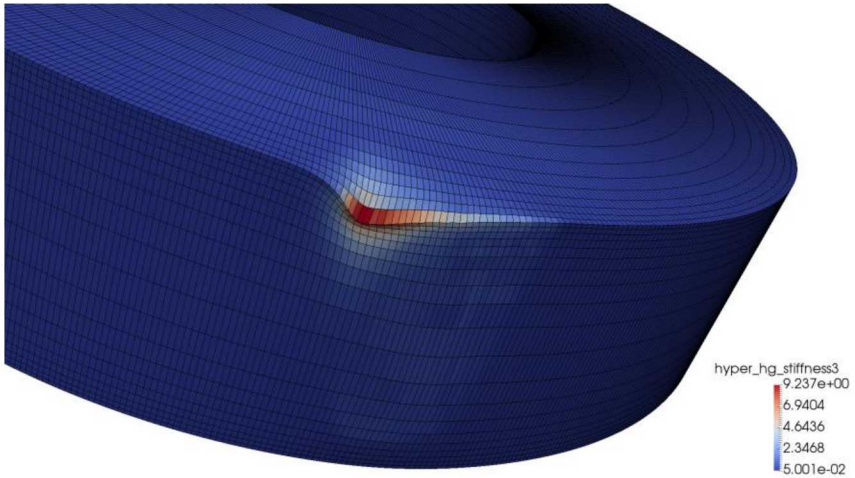
Background:

Last sprint a new hyperelastic hourglass was implemented that stiffens under large hourglass strains.



This Sprint:

- Compared different formulations on Groschwheel problem
  - fully-integrated
  - selective-deviatoric
  - uniform-gradient
    - total hourglass
    - hyperelastic hourglass
- Equations documented in theory manual
- New hourglass formulation + total Lagrange UG hex gives symmetric stiffness matrices!
- Initial recommended parameters:
  hourglass_exponent = 2
  hourglass_transition_strain = 0.015



Future Work:

- Potential replacement for “strongly objective” and “total hourglass”

Equations

- Total Lagrange hourglass operator
- Modal hourglass strains
- Seth-Hill strain measure (introduces nonlinearity)
- Element Hyperelastic hourglass energy
- Hourglass force

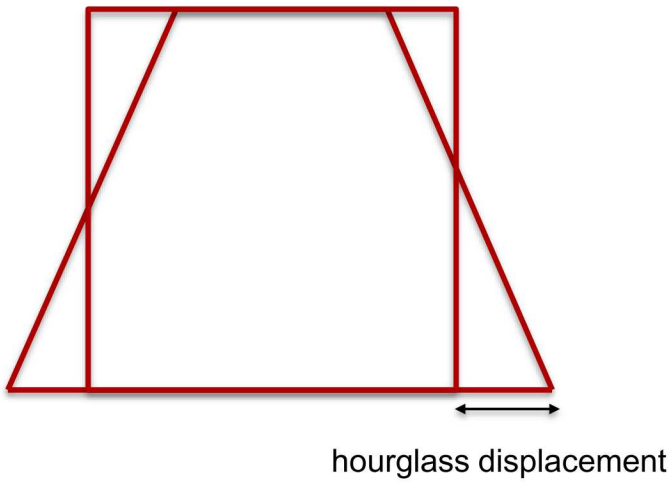
$$H_\alpha^I = \frac{1}{\delta}\left[\Gamma_\alpha^I - \frac{1}{V}X_j^J\Gamma_\alpha^J B_j^I\right]$$

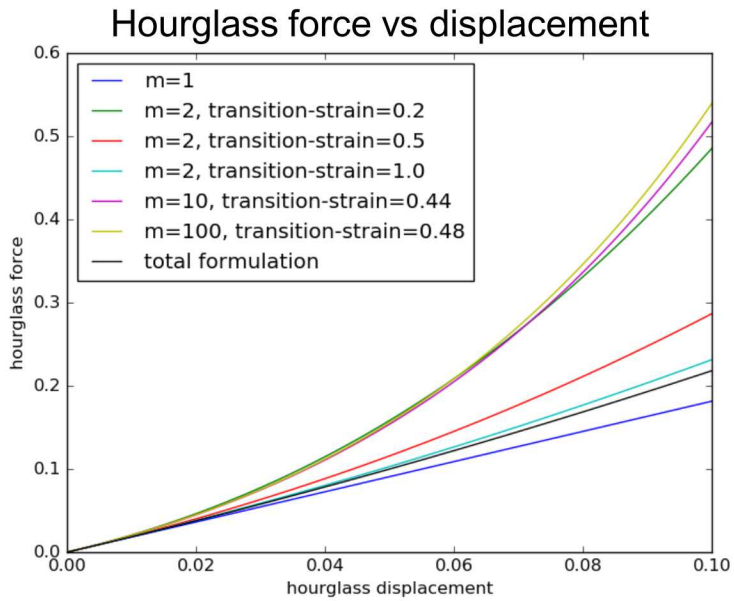
$$\varepsilon_\alpha = \sqrt{\sum_{i=1}^{3}\epsilon_{i\alpha}\epsilon_{i\alpha}} \quad \epsilon_{i\alpha} = \sum_{a=1}^{8} H_\alpha^I x_i^I$$

$$e_m(\varepsilon) = \frac{1}{m}\left((\varepsilon+1)^m - 1\right)$$

$$\hat{\psi}_e(\mathbf{x}) = V\epsilon\mu_{tan}\varepsilon_0^2\left(\sum_{\alpha=1}^{4}\left[e_m\left(\frac{\varepsilon_\alpha}{\varepsilon_0}\right)\right]^2\right)$$

$$f_{\mathrm{HG}}^{iI} = -\frac{d\psi_e}{dx_i^I}$$

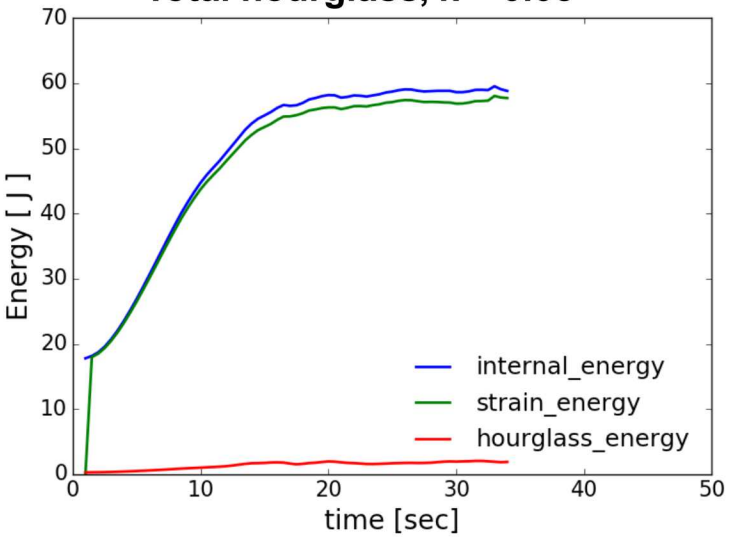




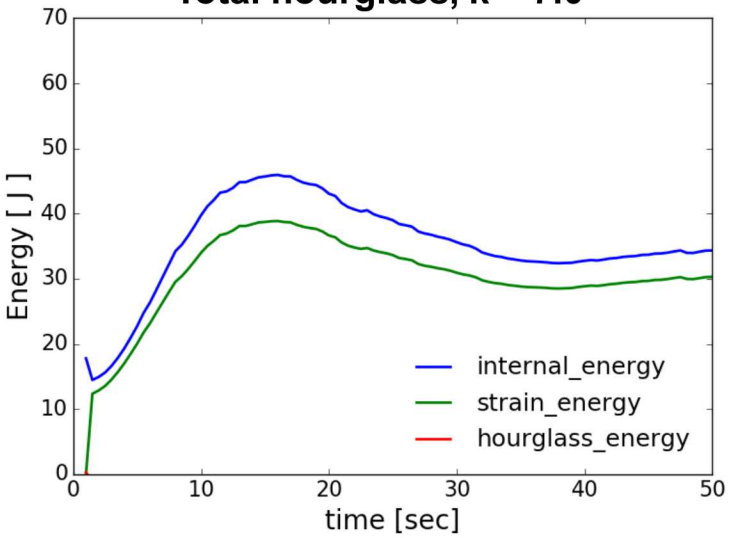
Energy comparisons

Sandia National Laboratories

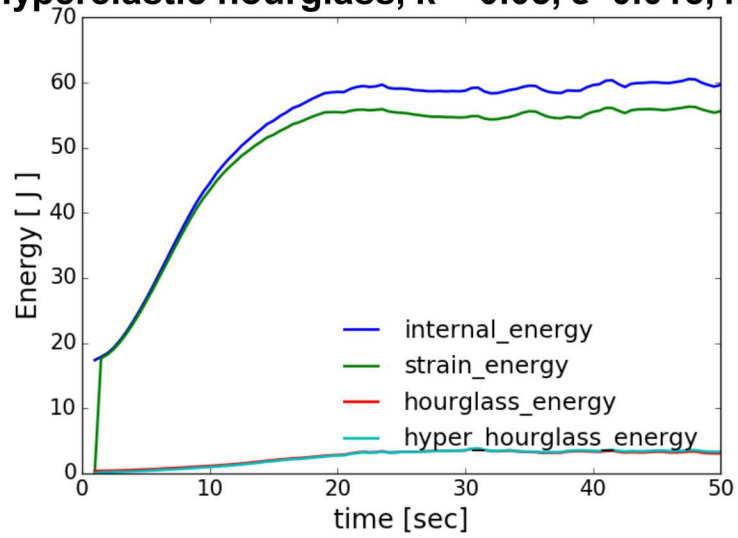
Total hourglass, k = 0.05



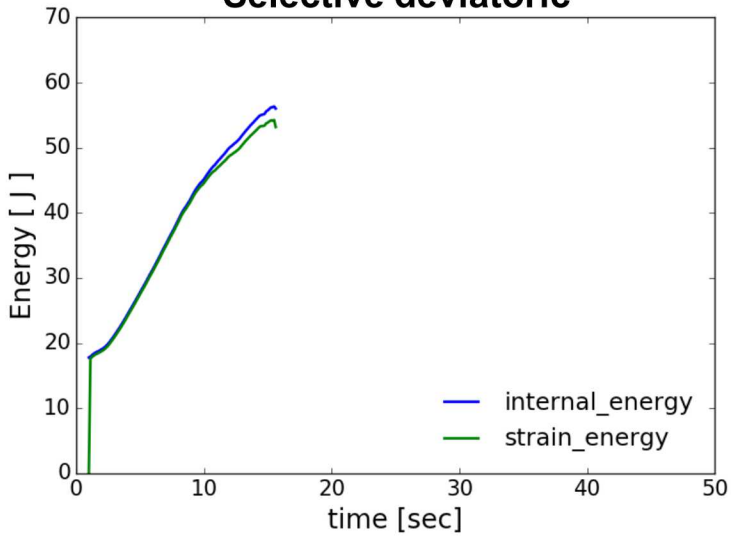
Total hourglass, k = 7.0



Hyperelastic hourglass, k = 0.05, ε=0.015, m = 2



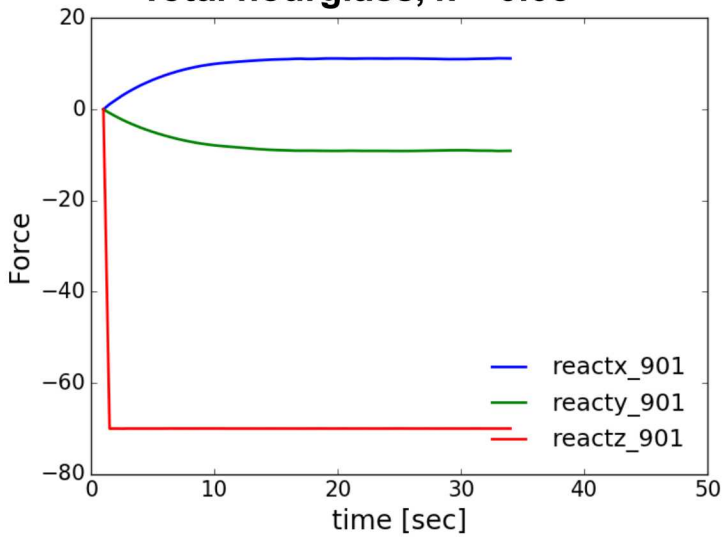
Selective deviatoric



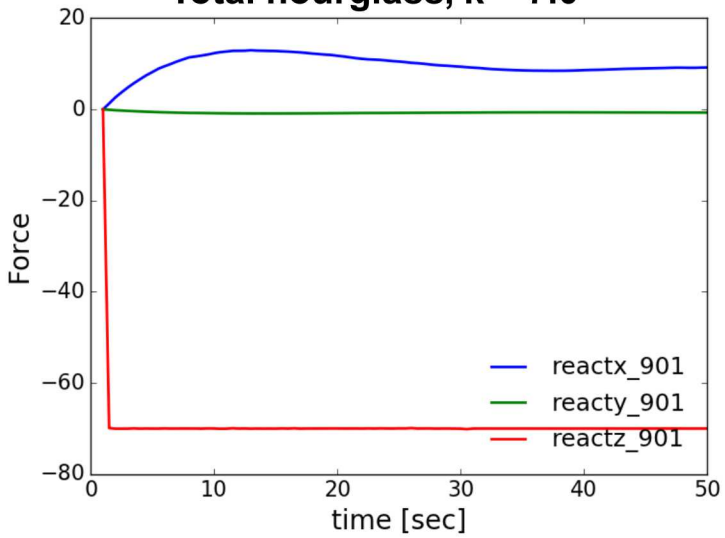
Rigid body reaction force

Sandia National Laboratories

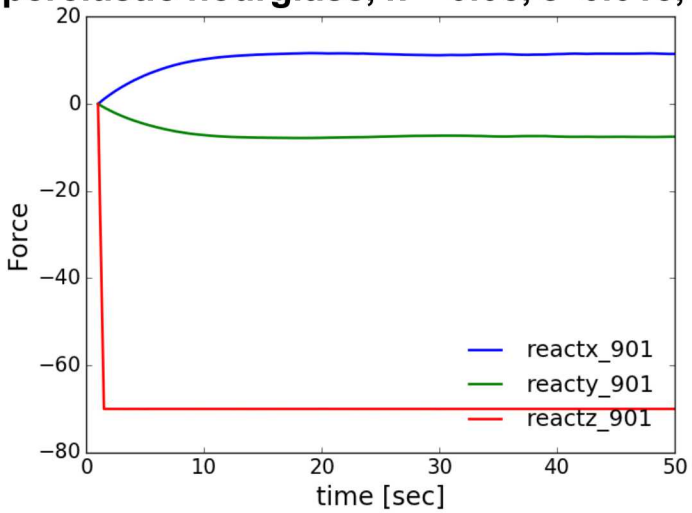
Total hourglass, k = 0.05



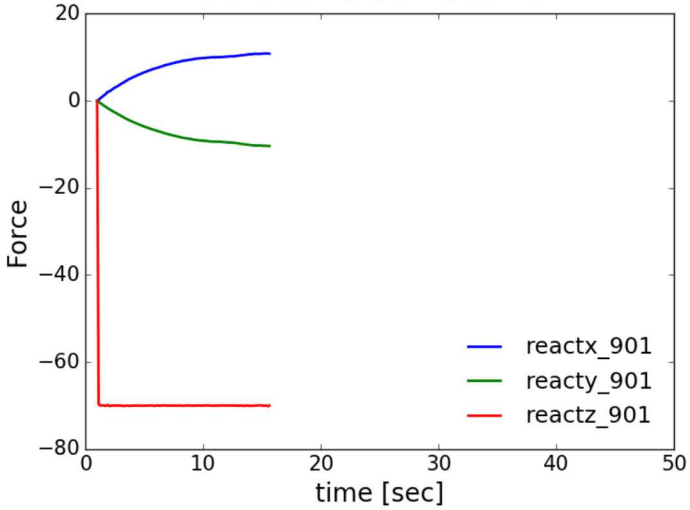
Total hourglass, k = 7.0



Hyperelastic hourglass, k = 0.05, ε=0.015, m = 2



Selective deviatoric



GY energy balance: Reassess XP06 model

Sandia National Laboratories

Background:

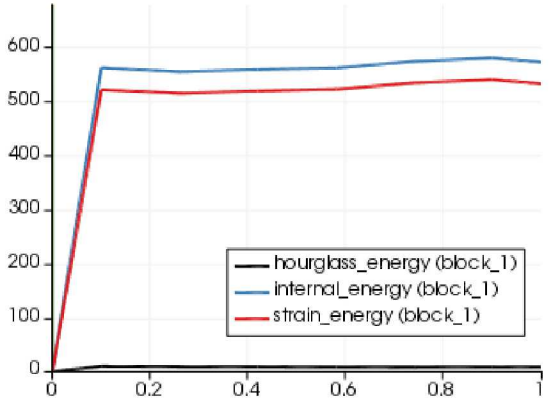
- Goodyear test XP06 showed a significant relative imbalance in strain and internal energies

XP06 tire wedge model

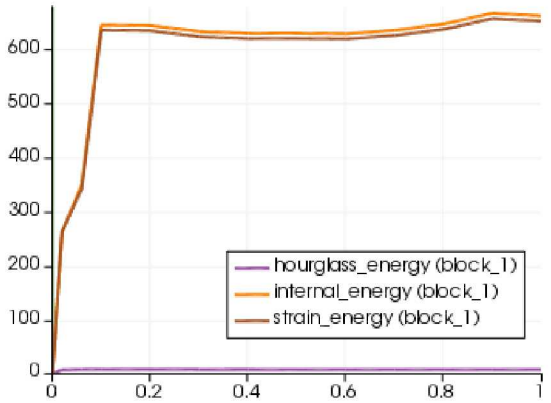
This Sprint:

- Assessed XP06 model for energy balance and adjusted analysis settings as needed
  - Move initial rim overlap using contact, pressure loading, and rim movement into separate steps
  - Apply pressure loading over multiple implicit solution steps
- Achieved substantially improved energy balance relative to original input deck
- Responded to Goodyear with recommendations for achieving better energy balance agreement

Initial result:
94.5% energy balance



Final result:
99.7% energy balance



GY: Noise Modeling Void mapping directional improvements

Background

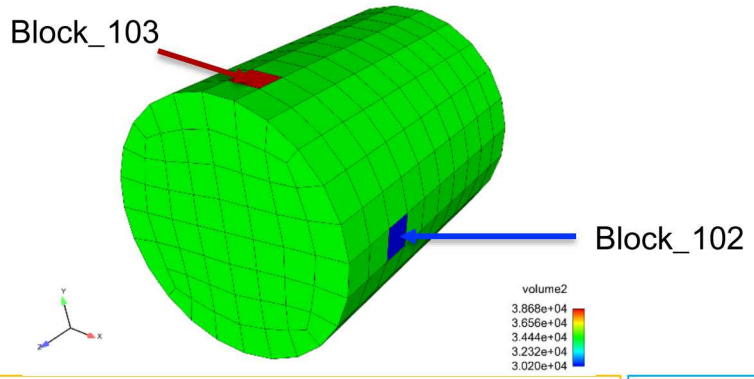
- Goodyear is modeling the noise of rolling a tire on the road by modeling the rolling in SM, calculating the volume change in void elements, and passing this volume change to SD
- More options have been requested for specifying the search direction for variable interpolation

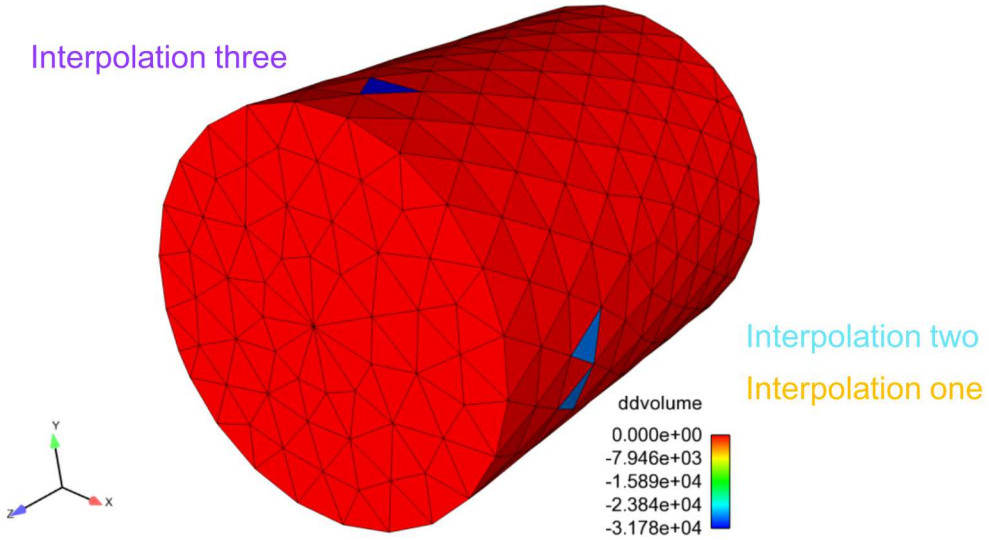
This Sprint

- Worked with Goodyear and determined their desired use case is already supported
- Added a test showing this use case

Future Work

- Continue to work with GY for noise modeling






```
begin variable interpolation one
  source variable = element volume_second_derivative
  target variable = face trans_ddvol_face
  target surface = surface_5000
  search tolerance = 3.0
  source element block = block_102
  proximity search type = ray search
  ray search direction = 1 0 0
  transfer type = sum to nearest element
end
```

```
begin variable interpolation two
  source variable = element volume_second_derivative
  target variable = face trans_ddvol_face
  target surface = surface_5000
  search tolerance = 3.0
  source element block = block_102
  proximity search type = ray search
  ray search direction = 0 1 0
  transfer type = sum to nearest element
end
```

```
begin variable interpolation three
  source variable = element volume_second_derivative
  target variable = face trans_ddvol_face
  target surface = surface_5000
  search tolerance = 3.0
  source element block = block_103
  proximity search type = ray search
  ray search direction = 0 1 0
  transfer type = sum to nearest element
end
```

Sandia National Laboratories

AWE

Co-rotational Superelements

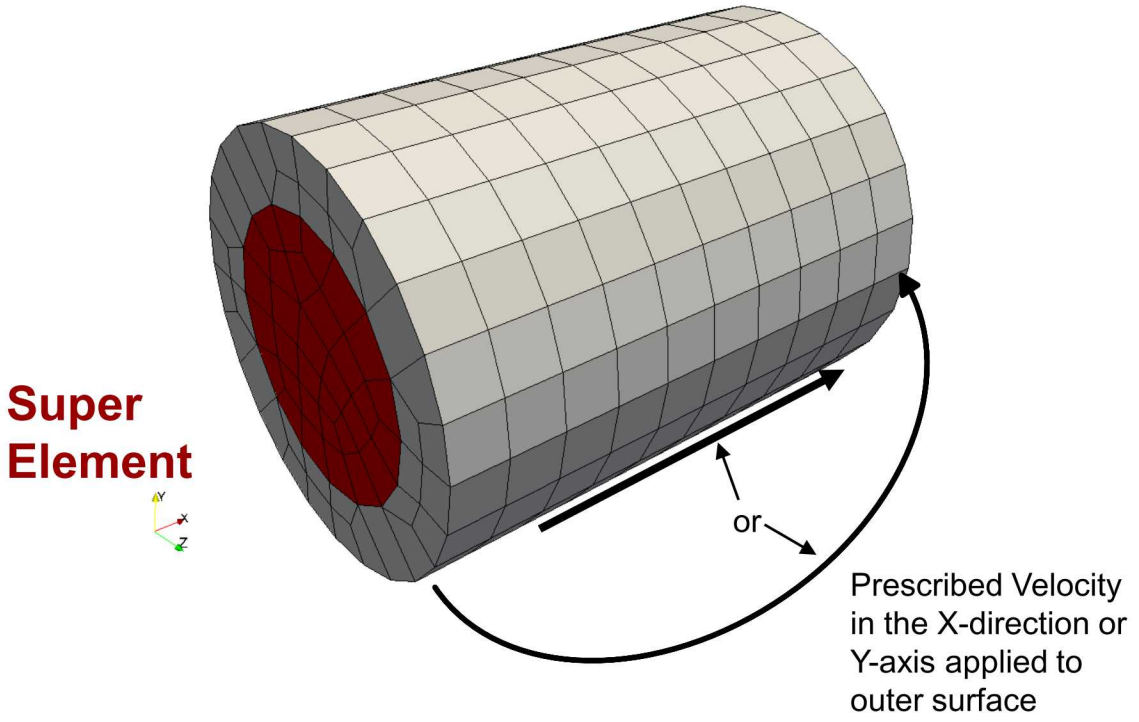
Sandia National Laboratories

Background:

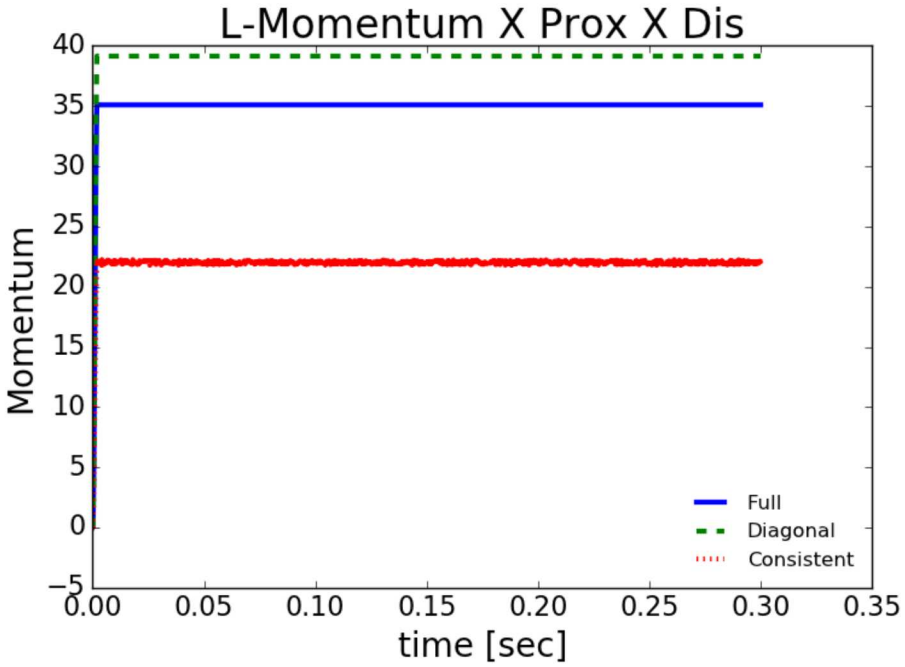
- AWE would like to use Craig-Bampton Reduction superelements, created in SD, in nonlinear SM analyses. This requires a consistent mass matrix for the superelement.
- In previous sprints a co-rotational capability was added to SM superelements, for both the diagonal and consistent mass matrices

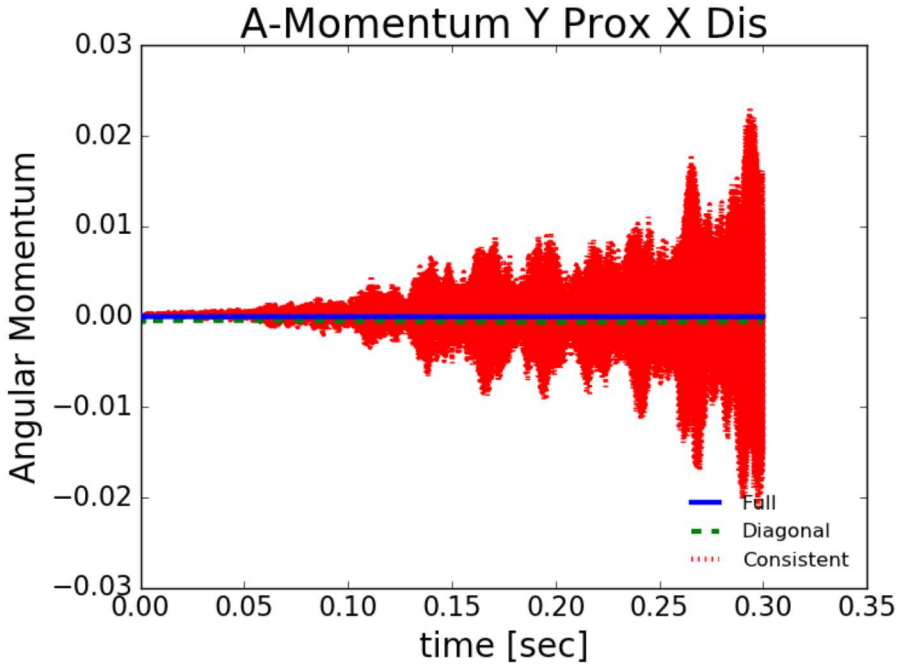
This Sprint:

- Tested momentum (and energy) conservation for large displacements and rotations
- Momentum (and energy) might be conserved for equivalenced superelements, but our reporting is incorrect.
- MPC connections to superelements do not work with the consistent mass matrix.

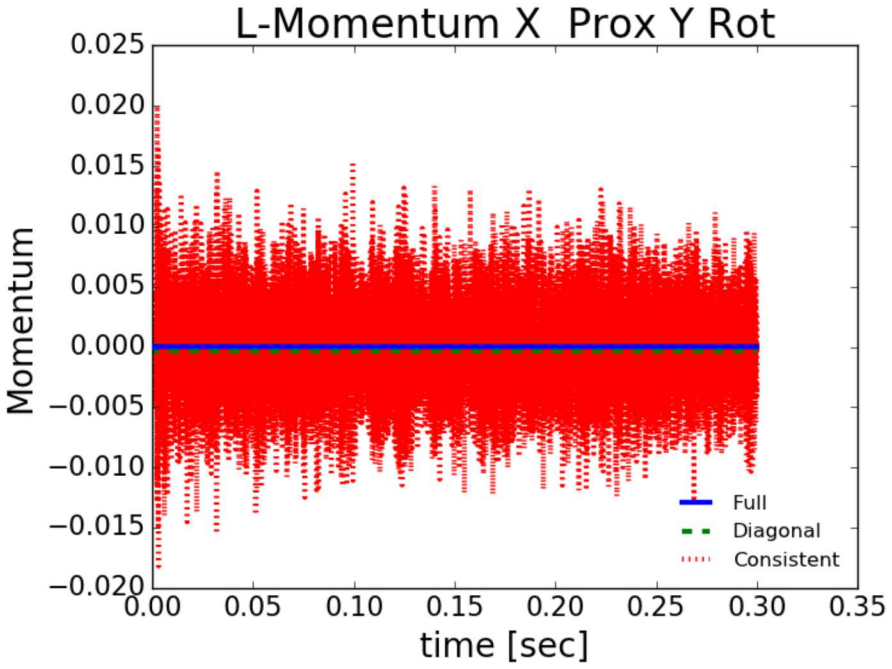


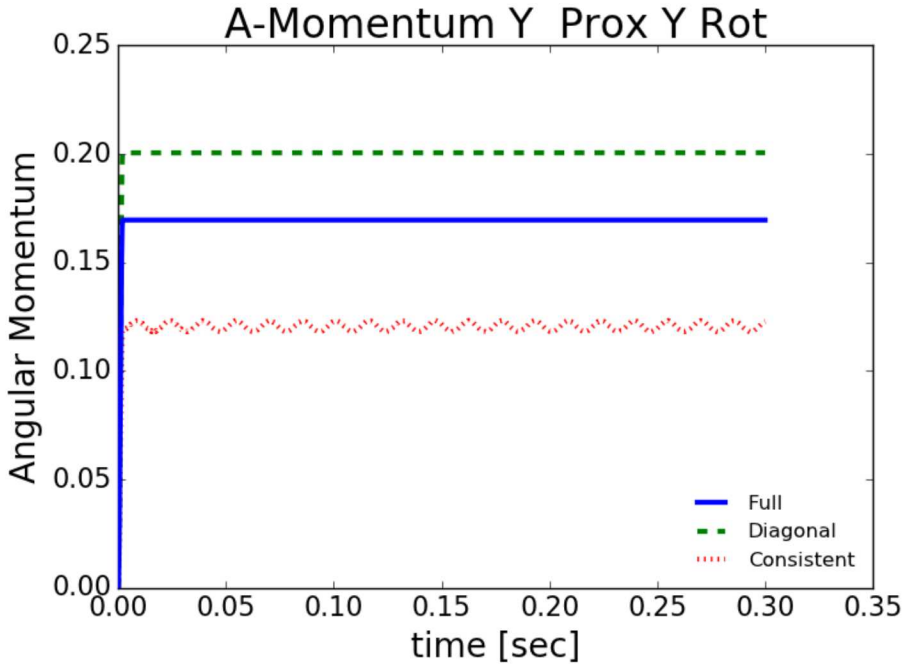
Prescribed x-velocity using fully integrated hex element and proximity search for super element



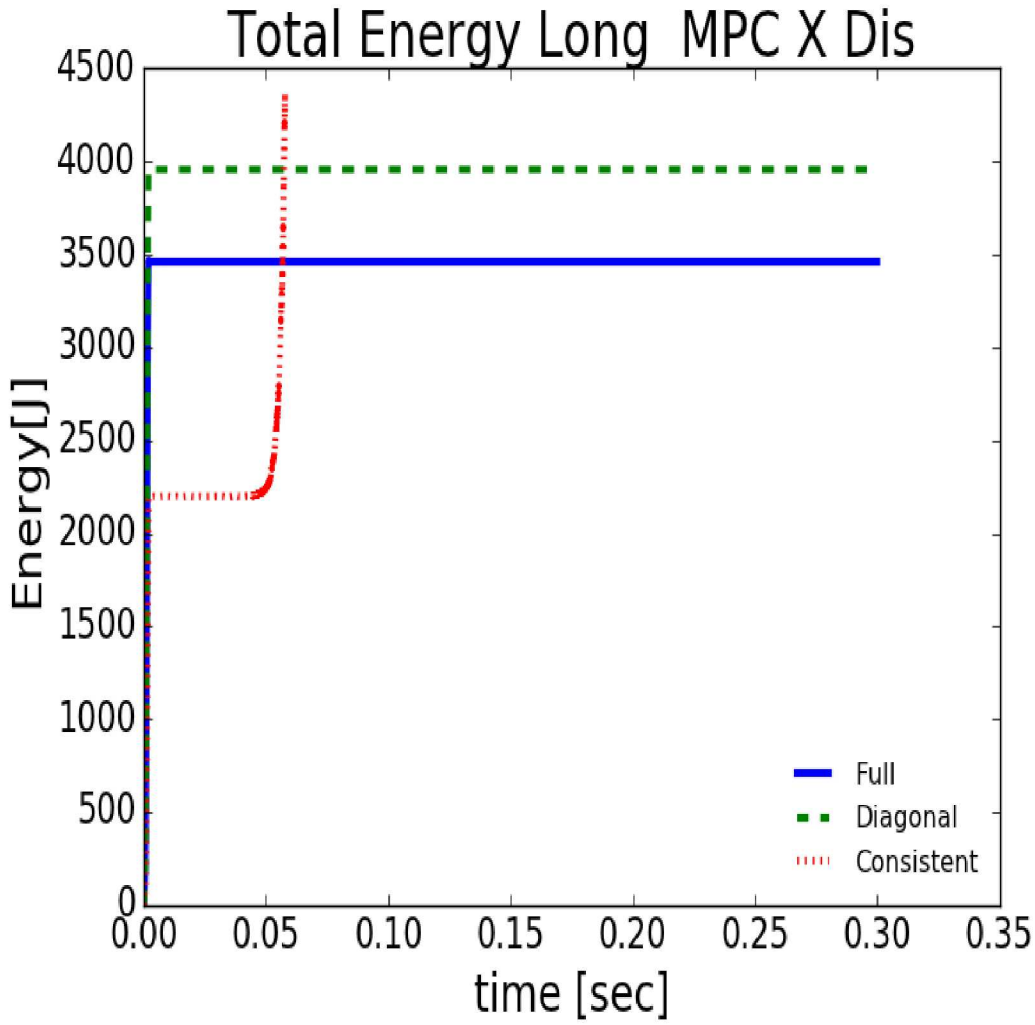


Prescribed y-rotation using fully integrated hex element and proximity search for super element

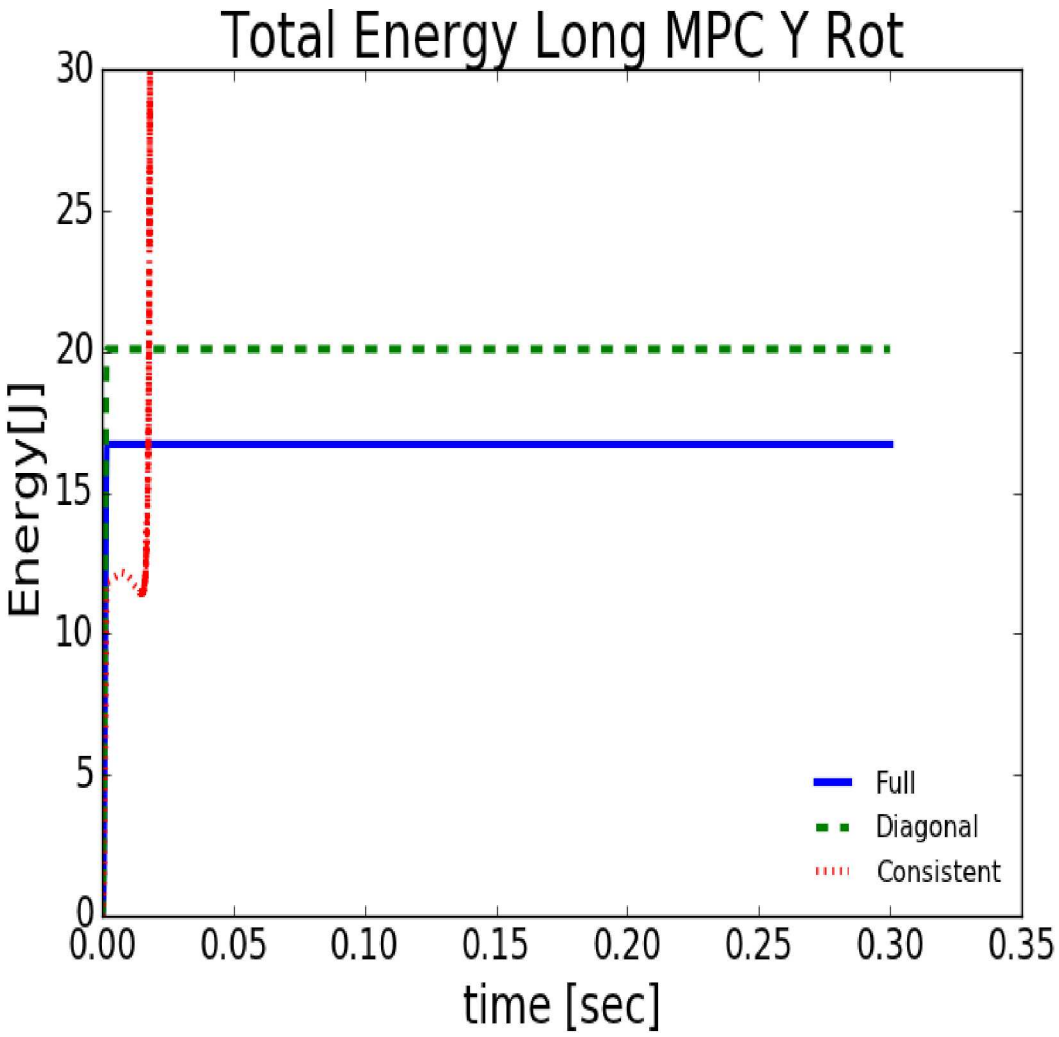




Prescribed x-velocity using Fully integrated Hex Element and Tied MPC for Super element



Prescribed y-rotation using Fully integrated Hex Element and Tied MPC for Super element



Sandia National Laboratories

NAVY

NAVY: Integrate Nemo changes since 4.42 release

Sandia National Laboratories

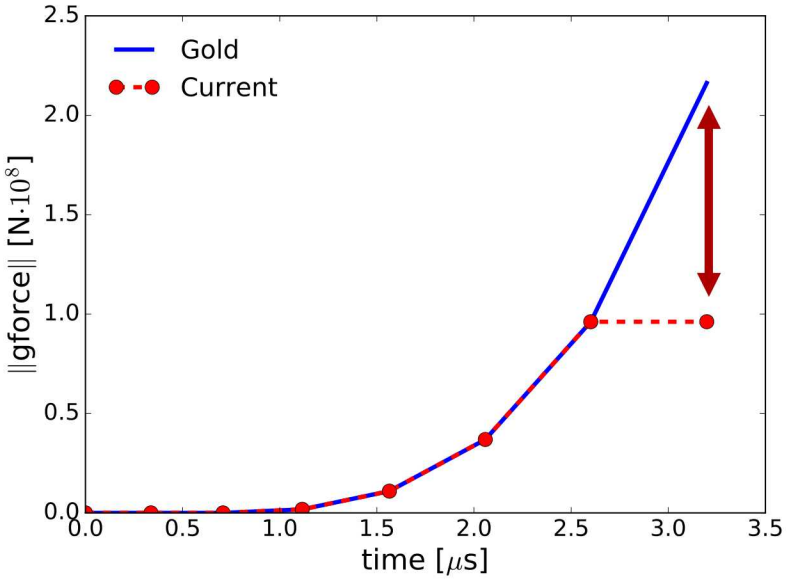
Background:

Update Nemo to ensure consistent testing and that changes to coupling codes do not affect expected behavior

This Sprint:

- Pulled in Nemo changes from 4.43.1 – 4.43.3
- Re-applied patch to Nemo for synchronized output
  - Sent patch to Navy for inclusion in current sprint branch
  - Sent output/restart synchronization test suite
- Updated tests as needed/appropriate
- Discovered one test with abnormal behavior (see right)

PistonProblems/solid_short:
Last pressure not sent before exit flag



Future Work:

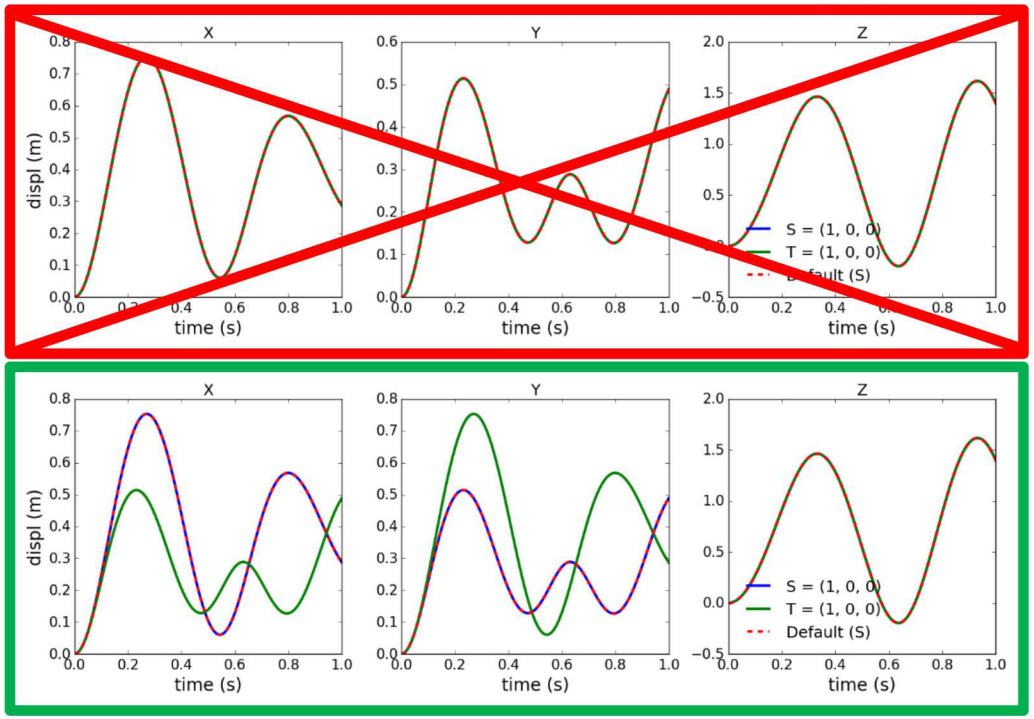
- Debug issue with failing test (right) – should be fixed in latest Nemo update
- Support second order convergence in time and space of coupled products

NAVY user support: fix definition of user mount orientation

Sandia National Laboratories

Background:

Received defect report from Tom Moyer regarding unexpected behavior of user mounts with different specified orientations. (Sierra ticket #15929)

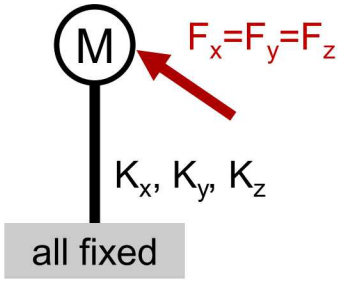


Resolution:

- Created small example of issue
- Fixed bug in definition of user mount orientation based on Tom's report
- Updated relevant tests
- Added new regression test

```
BEGIN USER MOUNT SECTION TomNM
    mount type = 5 # "test spring"
    Parameters = 1.0 2.0 3.0 0.0 0.0 0.0
    {switch(version)}
    {case(1)}
    S AXIS = 1.0 0.0 0.0
    {case(2)}
    T AXIS = 1.0 0.0 0.0
    {default}
    {endswitch}
END
```

Test Setup



Expected results:

- Case 1 and default should be identical
- Case 1 and 2 should have a 90° shift in response
- No change in Z-direction

Navy: proper partial Tied MPC behavior

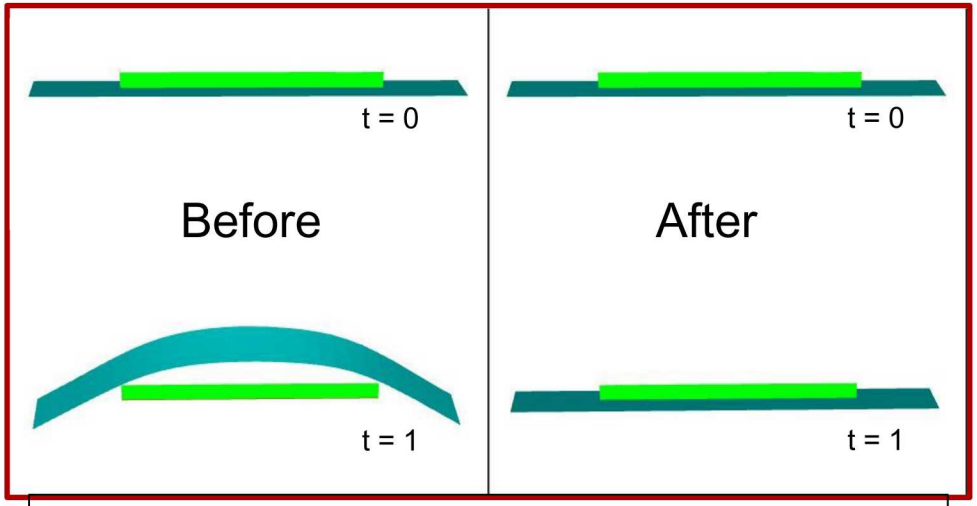
Sandia National Laboratories

Background

- SM allows partially-tied MPCs (e.g. tying in only one direction)
- Customer discovered error, e.g.,

```
begin tied mpc
      components = Y
      …
```

had broken free-fall behavior



Thanks to Dr. Tom Moyer for example and alerting us

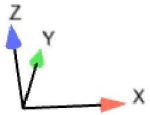
Completed:

- Fixed bug: needed separate "constraint mass" for each nodal DOF in constraint
- Warning if tied nodes disagree on presence of rotational DOFs if Tied MPC has a rotational component
- Found unphysical behaviors you can (correctly) specify with Tied MPCs

Future

- Consider what interface/behavior of Tied MPCs would discourage inadvertently specifying non-physical behavior

Navy: proper partial Tied MPC behavior



Sandia National Laboratories

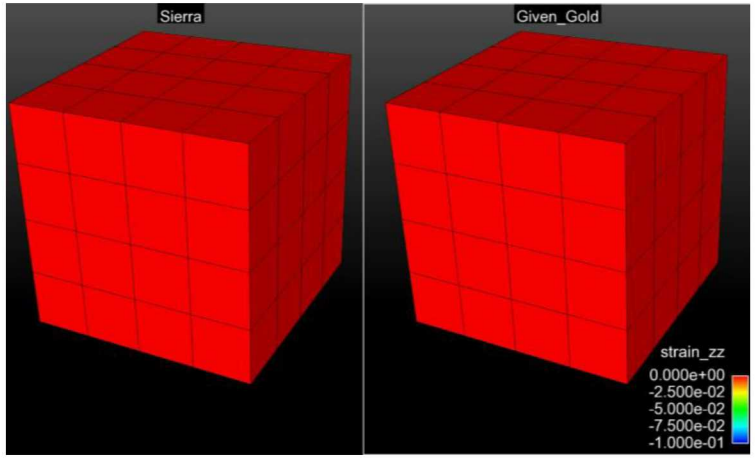
HASI

HASI: Add AFC Concrete material model to Vivace

Sandia National Laboratories

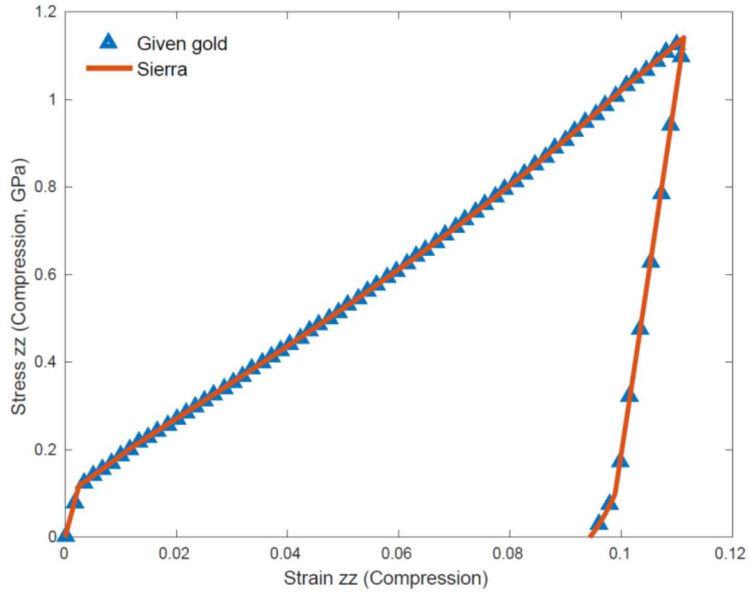
Background:

A new material model was provided by ERDC to include in the Vivace material library.



This Sprint:

- Added the model to the library
- Added 5 tests to the nightly test suite
- Evaluated test coverage of the model



Future Work:

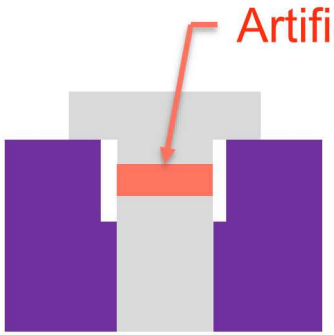
- Update documentation in user manuals
- Additional tests to improve coverage/verification

Current view: top level - itar/vivace/src/lame - Viva_AFCConcrete.C (source / functions)		Hit	Total	Coverage
Test: vivace.info	Lines:	263	270	97.4 %
Date: 2016-11-30	Functions:	18	19	94.7 %

Sandia National Laboratories

USER SUPPORT

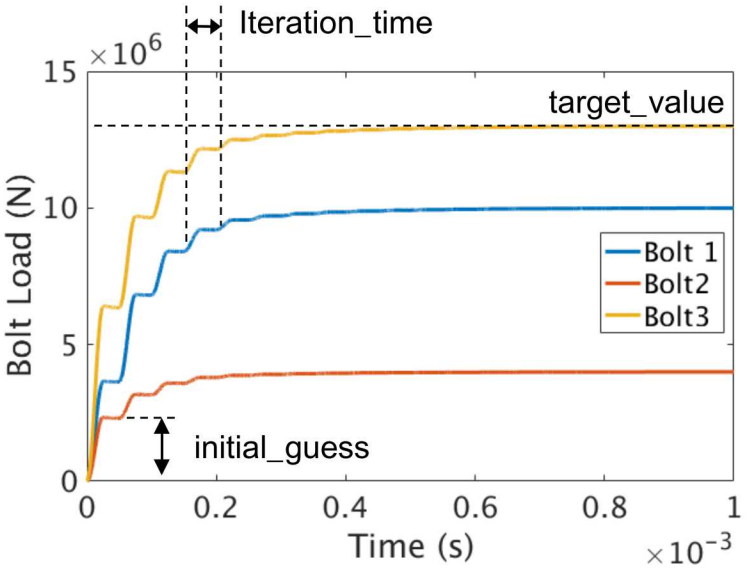
Applying Preload to Multiple Bolts



Objective: At each bolt find the artificial strain α_i to achieve bolt load F_i

Implementation uses a precompiled 'library' user subroutine.
See new Sierra/SM Example Problems Manual, Section: 3.3
for full details and example.

'Solver' is a basic predictor/corrector in time.




```
begin user output
  surface = surface_400
  compute global bolt_force_400 as sum of nodal force_contact(z)
end

begin user output
  block = block_401
  subroutine real parameter:   target_value     = 1.3e+7
  subroutine real parameter:   initial_guess    = -2.95e-4
  subroutine real parameter:   iteration_time   = 5.0e-5
  subroutine string parameter: target_variable  = global bolt_force_400
  subroutine string parameter: working_variable = element art_strain
  element block subroutine = aupst_preload_solver
  compute at every step
end
```

User Community Notes & Ideas

SM Cohort Groups

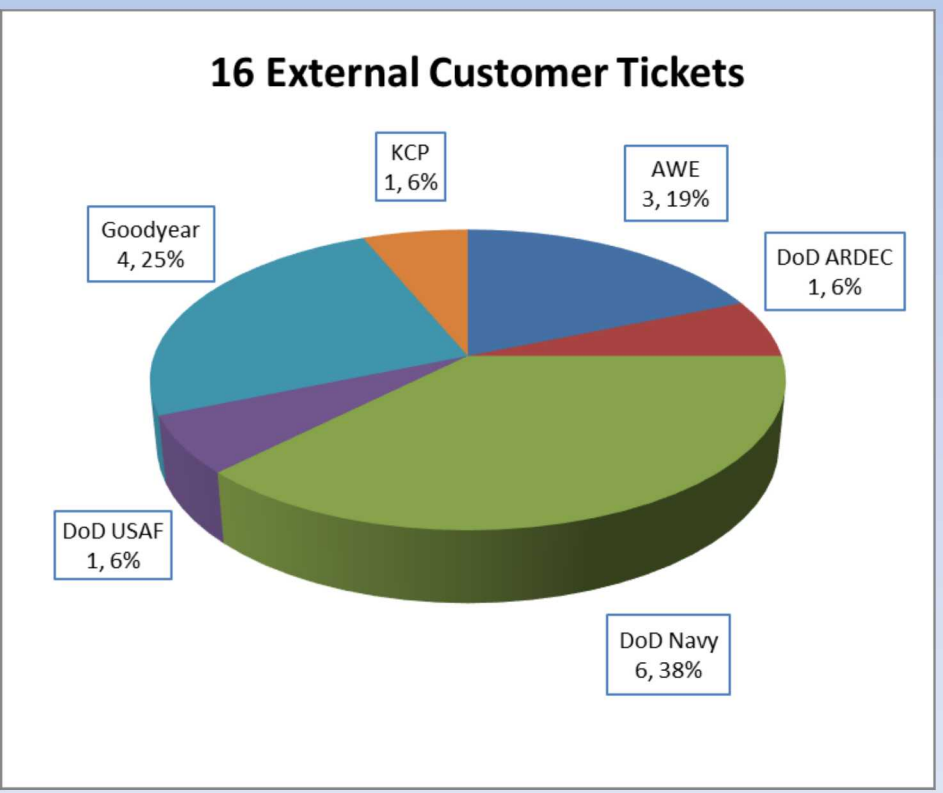
Sandia National Laboratories

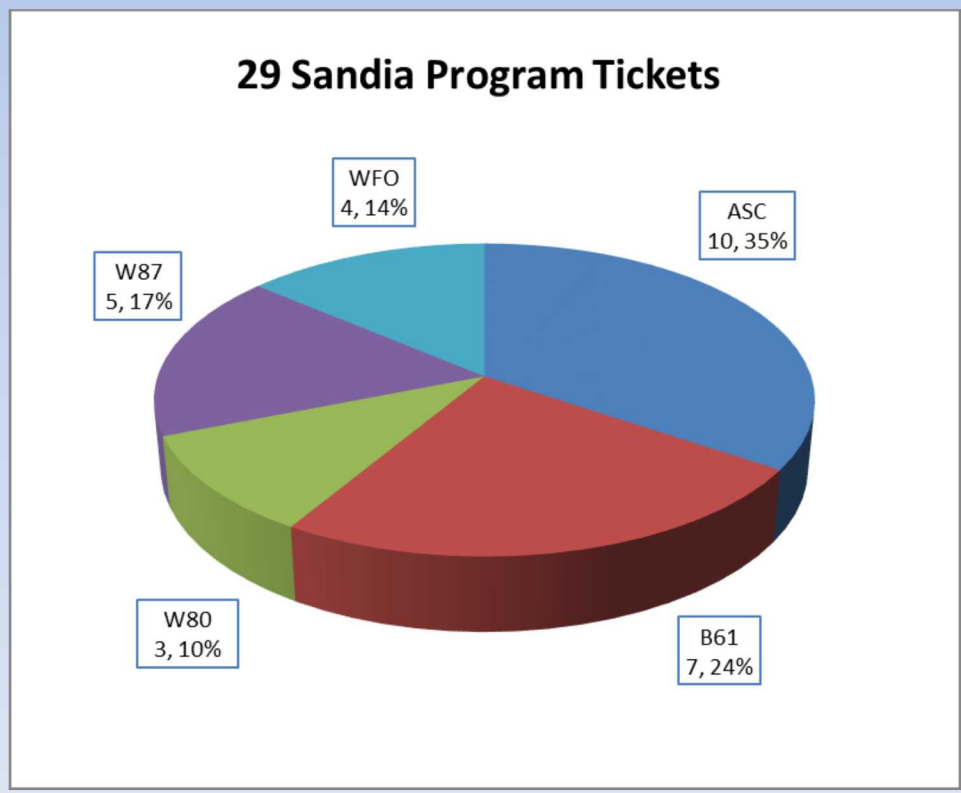
- **8000 Analysts [82/8300] – POCs: A. Brown / K. Manktelow**
  - New log-file mass scaling output is great – would prefer more readable tabular format
  - Would like more support for TET10 and Composite Tet (Transfers and Tied MPCs)
  - Users are in favor of continued improvement of implicit solutions (contact, solver, etc.)
- **AWE – POCs: J. Concannon**
  - Made some good advances with the use of inertia relief for our milestone. Test model now works with no additional constraining springs, which is an improvement over our reference commercial code.
  - Thank you for the impressively quick (15mins from ticket raised) implementation of the mass calculation output in static implicit, this feature was invaluable in comparing/debugging our Sierra model in 1)
- **No feedback at this time:**
  - 1556 Analysts – POCs: S. Gomez
  - Goodyear
  - 1554/1555 Analysts – POCs: J. Pott / E. Fang / N. Breivik
  - Navy (NESM) – POCs: J. Stergiou
  - 2000 Analysts
  - ERDC– POCs: R. Moral
  - KCP
  - ARL
  - 6000 Analysts – POCs: J. Bignell

Sierra/SM User Support

45 *tickets: 22 closed + 23 open (24 new, 34 remain)*

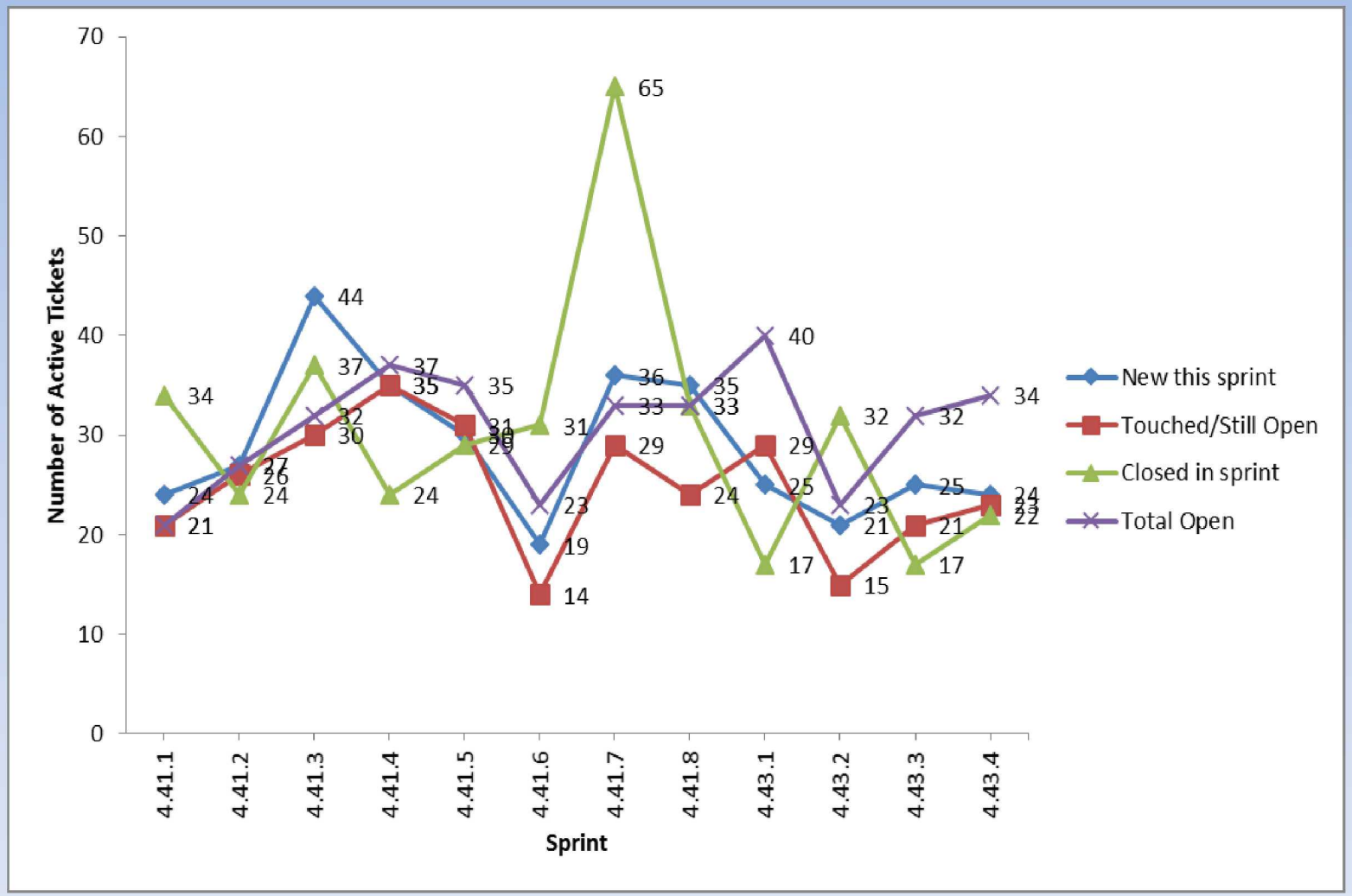
- 8 code changes (6 bugs/16.25 hrs, 2 enhancements/1.5 hrs)
- 14 user questions/helped analyst (5.25 hrs)
- Total Hours: 23.0 (closed tickets only)
- Backlog: 218 tickets (101 defects + 117 enhancements)





Sierra/SM User Support

Sprint Defect Ticket History



Sandia National Laboratories

NON SANDIA CUSTOMER SPECIFIC

Improving LCOV

Sandia National Laboratories

	Old Coverage	Current Coverage
adagio/src/element/Builder.C	79.6%	89.8%
DEM_element.C	71.9%	75.4%
Agio_ARSCylinderContact.C	58.5%	70.1%
Agio_ARSPlanarContact.C	75.6%	88.9%
Adagio Coverage	**89.1%**	**89.7%**

Sandia National Laboratories

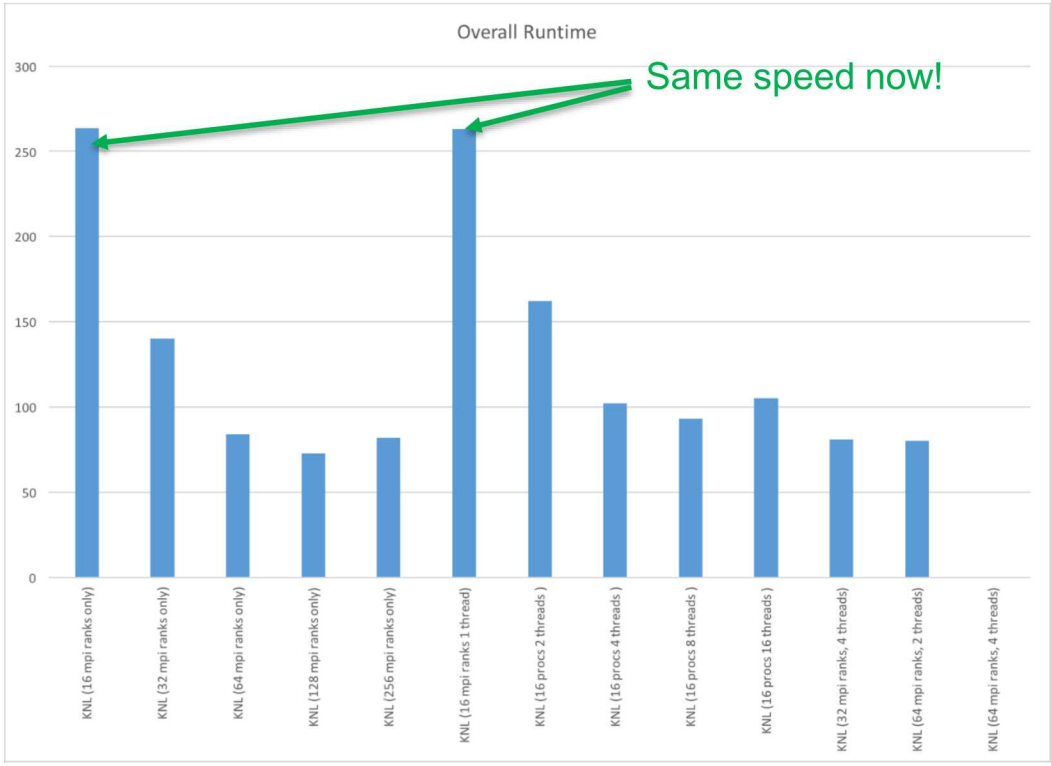
NEXT GENERATION PLATFORMS

NGP: KNL Slow OpenMP Debugging

Sandia National Laboratories

Background

- Last sprint, we were able to run on KNL and compare performance of pure MPI vs MPI+OpenMP
- We found that when running with OpenMP, the overall runtime was ~3X slower than with MPI alone! (16 MPI ranks vs 16 MPI ranks+1 OpenMP thead)



This Sprint

- Worked with Cray to determine why we were getting this 3X slowdown
- Modified submit script with recommended settings from Cray

Future Work

- Determine what parts of the code are not scaling with OpenMP threads
- Thread remaining unthreaded code (element death, etc.)

```
aprun -d <num_threads> -j 1 -cc depth -N <num_mpi_ranks> -n <num_mpi_ranks> -e OMP_PROC_BIND=spread -e
OMP_PLACES=threads <path_to_exec> -I test.i

msub -V -l nodes=1:knl,walltime=1:0:0 -N sierra -los=CLE_quad_cache <path_to_aprun_script>.sh
```