SAND2007-5783P

Sandia National Laboratories Solid Mechanics Training: Exercises

Picatinny Arsenal
September 24-28, 2007
Picatinny, NJ

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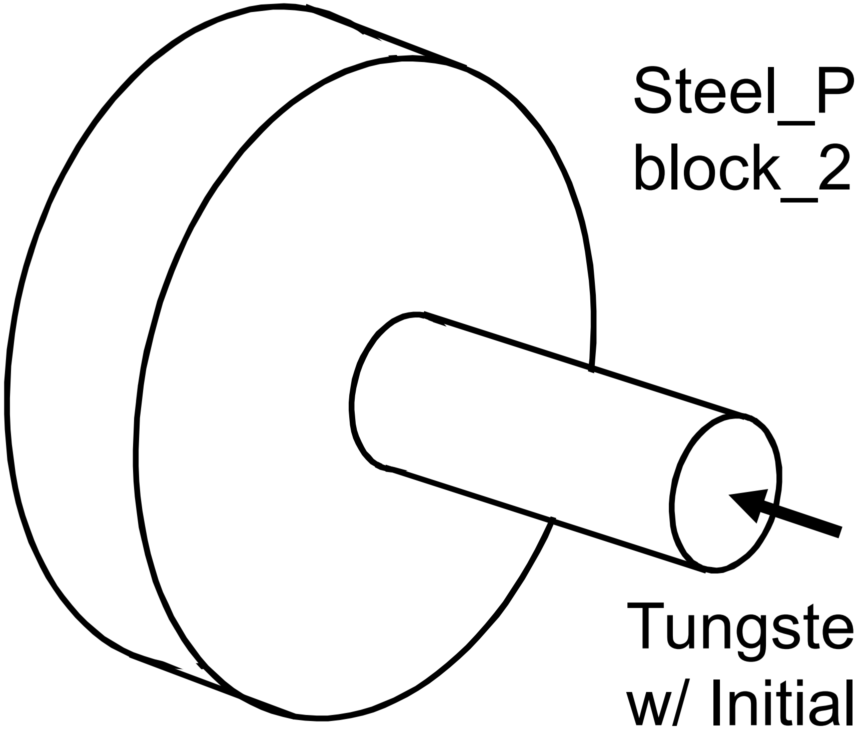
Rod Impacting Plate Example



Steel_Plate
block_2

Tungsten_Rod
w/ Initial velocity = -1e5
block_1

Models for Rod Impacting Plate Example

1. Elastic-plastic material model
   a. Rod & Plate mesh w/ Hex8
   b. Rod & Plate mesh w/ Tet4
   c. a. + different initial velocity
   d. c. + contact changes
   e. d. + additional I/O
   f. Rod & Plate mesh w/ Nodal-Based Tet
   g. f. + remeshing

Models for Rod Impacting Plate Example

2. Johnson Cook material model
   a. w/o Element death
   b. w/ Element death
   c. w/ Element death, conversion to particles
   d. w/ Element death, conversion to particles, particle-element interaction
   e. w/ SPH rod, w/ element death, conversion to particles, particle-element interaction

Models for Rod Impacting Plate Example

3. KC-Concrete material model for plate, elastic-plastic material model for rod
   a. Rod & Plate mesh w/ Hex8, element death
   b. w/ rebar using existing mesh edges

Hands-on Session 1:
Rod-impacting-plate problem

Introduce the problem

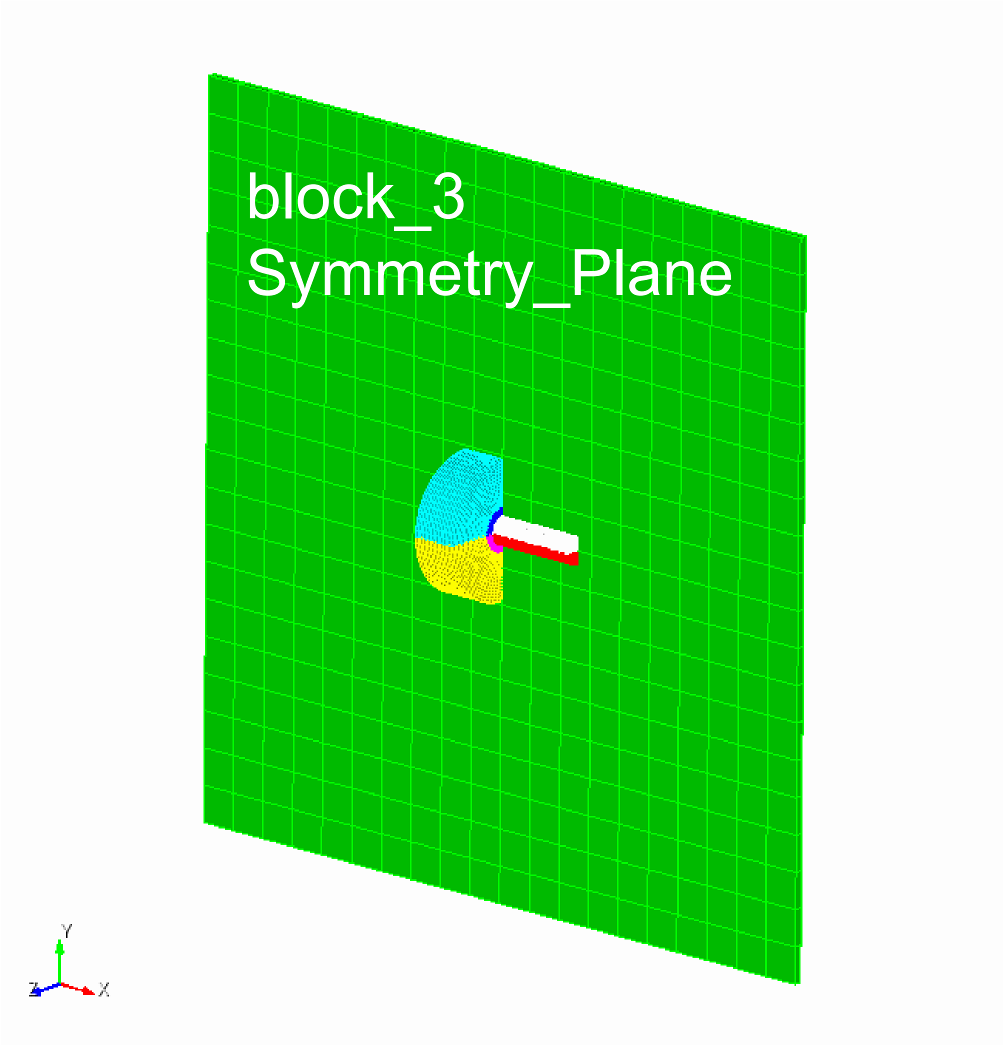
New working directory *hex_elastic_plastic*

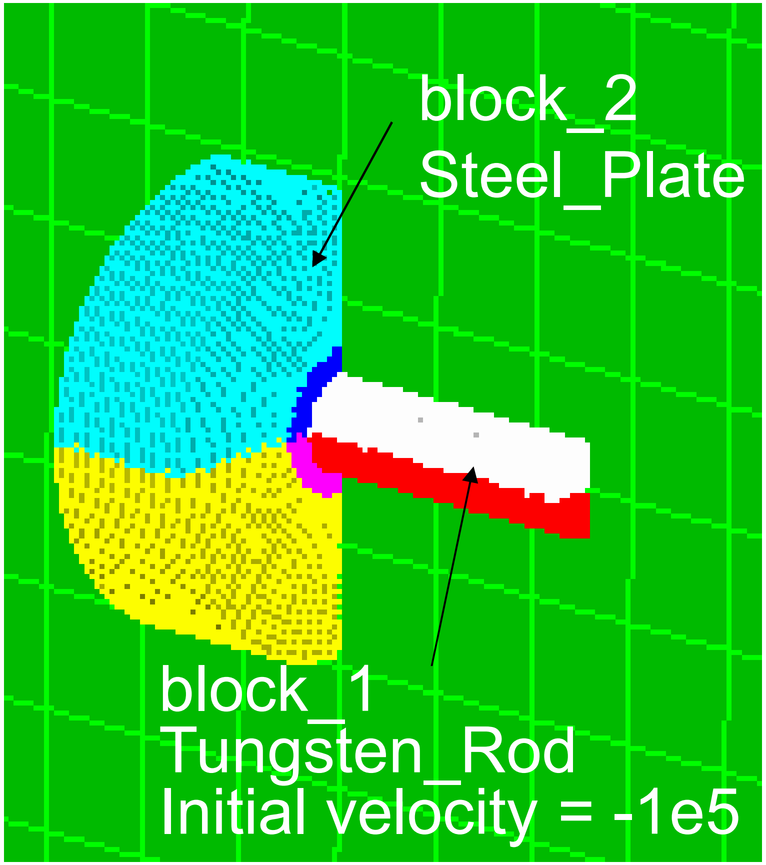
Cubit session

Presto: review already created input file

Paraview session

P016_Penetration_Element_Death





New working directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_elastic_plastic

Copy ‘taylor.sat’, ‘taylor_hex.i’ into new directory

% cp taylor.sat hex_elastic_plastic

% cp taylor_hex.i hex_elastic_plastic

Move into new directory

% cd hex_elastic_plastic

Cubit – Begin Session, Import Geometry

Start a Cubit session:

% cubit

(helpful but not necessary) Set Cubit's default directory to current working directory:

File > Set Directory > hex_elastic_plastic > OK

Import sat file (taylor.sat):

File > Import … > taylor.sat > Open > Finish

Cubit – Geometry Manipulation

Webcut geometry for better mesh control

webcut volume 2 with cylinder radius 0.6 axis x

webcut volume 2 4 3 with plane yplane

Merge Plate to enable a contiguous mesh

merge volume 2 4 6 5

Merge Rod to enable a contiguous mesh

merge volume 3 7

Cubit – Meshing

Mesh Contact_Plate:

volume 1 size 1

mesh volume 1

Mesh Plate:

volume 2 4 6 5 size 0.084

mesh volume 2 4 6 5

Mesh Rod:

volume 7 3 size 0.047625

mesh volume 7 3

Cubit – Assign Block ID and Export

Assign Block IDs:

block 1 volume 3 7

block 2 volume 2 5 6 4

block 3 volume 1

Export Genesis mesh:

export mesh "taylor_hex.g" overwrite

or

File > Export … > taylor_hex.g

File Type > Genesis (.g* *.gen* *.G* *.GEN*) > Save > Finish*

Quit Cubit

exit

Simba – Import Mesh File

Start-up Simba session:

% simba

In Assembly View:

Right click top folder > Import Model … > Select new model type > ExodusII

Select > taylor_hex.g > Finish

Simba – Define Materials (1)

In Model details

expand Materials

➲

Simba – Define Materials (2)

In Model details

Right Click Materials > New material …

New material name > Tungsten_Rod > OK

Select Tungsten_Rod, change type to elastic-plastic > Apply

Density = **16.98**

Youngs Modulus = **3.177e12**

Poissons Ratio = **0.28**

Beta = **1.**

Hardening Modulus = **1.564e10**

Yield Stress = **1.506e10**

Apply

Simba – Define Materials (3)

In Model details,

Right Click Materials > New material …

New material name > Steel_Plate > OK

Select Steel_Plate, change type to elastic-plastic > Apply

Density = **`7.823`**

Youngs Modulus = **`2.133e12`**

Poissons Ratio = **`0.279`**

Beta = **`1.`**

Hardening Modulus = **`3.972e10`**

Yield Stress = **`7.8e9`**

Apply

Simba – Define Materials (4)

In Model details,

Right Click Materials > New material …

New material name > Symmetry_Plane

Select Symmetry_Plane

Density = **`7.823`**

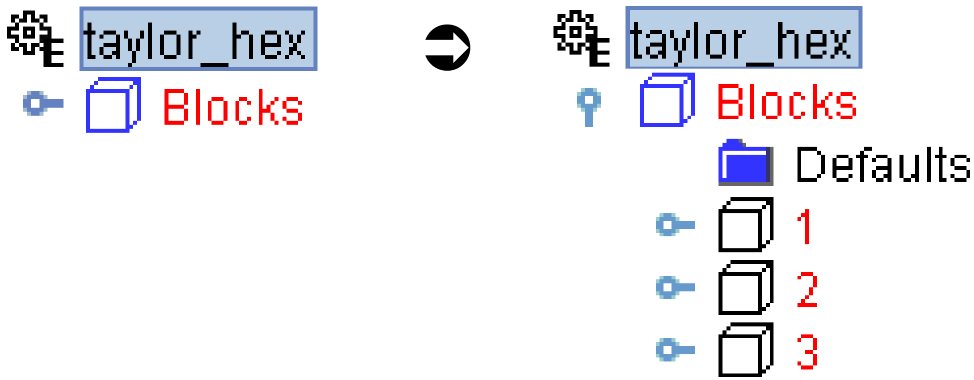
Youngs Modulus = **`2.133e3`**

Poissons Ratio = **`0.3`**

Apply

Simba – Assign Materials to Block IDs

Expand Blocks



(note: red color indicates incomplete data)

Right click 1 > Set material properties … > Tungsten_Rod > Apply

Right click 2 > Set material properties … > Steel_Plate > Apply

Right click 3 > Set material properties … > Symmetry_Plane > Apply

Simba – Create Nodesets for B/Cs (1)

In Assembly View

right click taylor_hex > View model

Click radio button on block 3 to hide

Blocks | Node sets | Side sets | Assembly

Name	Id	Type	Material	C	H
1	1	HEX8	Tungsten_Rod		
2	2	HEX8	Steel_Plate		
3	3	HEX8	Symmetry_Plane		✔

Mouse Mode > Selects surfaces > shift click planes of symmetry on rod and plate > Create new node set > z_sym > OK

Simba – Create Nodesets for B/Cs (2)

In Assembly View

Click radio button on block 3 to show

Blocks | **Node sets** | **Side sets** | **Assembly**

Name	Id	Type	Material	C	H
1	1	HEX8	Tungsten_Rod		
2	2	HEX8	Steel_Plate		
3	3	HEX8	Symmetry_Plane		

Select surfaces > shift click front and rear faces of block 3 > Create new node set > fixed > OK

File > Close

Simba – Assign B/C

Select z_sym (1000) > boundary – no displacement > Z > Apply

Select fixed (1001) > boundary – no displacement > XYZ > Apply

Simba - Initial Velocities

Select Block 1 > Initial velocity direction > **`1 0 0`**

Magnitude = **`-1.e5`** > *Apply*

Simba - Contact

Right click Contacts > New contact

Contact type > *Frictionless*

Surface 1 > *Select Block > 1*

Surface 2 > *Select Block > 2*

Normal Tolerance = *0.015*

Tangential Tolerance = *0.015 > Apply*

Right click Contact Checks [Needs update] > Update QA Checks

Simba - Define Problem Time and Time Step Parameters

Right click OtherAnalysisInfo > Add analysis method > Presto

Expand OtherAnalysisInfo and sierra-presto

OtherAnalysisInfo > sierra-presto > TimestepControl > termination time = **`60e-6`** *> Apply*

OtherAnalysisinfo > sierra-presto > TimestepControl > New_Time_stepping_block

Start time = **`0`**

Step interval = **`1`** *> Apply*

Simba - Results Output

OtherAnalysisinfo > sierra-presto > presto > OutputControl > Other text for scope

```
at time 0, increment = 6.e-7
nodal variables = ACCELERATION as ACCL
nodal variables = VELOCITY as VEL
nodal variables = DISPLACEMENT as DISPL
element variables = VON_MISES as VONMISES
```

Apply

Simba – Export Genesis and Input File

In Assembly view

Right click taylor_hex > Export > Export Presto

Select > hex_elastic-plastic > Save

File > Quit

Note: This will overwrite the existing taylor_hex.g file

Presto: A peek at the input file

Verify in sierra scope: **`finite element model`** block must refer to ‘taylor_hex.g’

```
Begin finite element model \#
          rod_impacting_plate
  database name = taylor_hex.g
  …
end
```

Run Presto

% sierra presto –i taylor_hex.i –V 2.7beta4

Paraview 3.02

Run Paraview

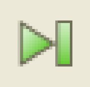
% paraview

File > Open > taylor_hex.e > OK

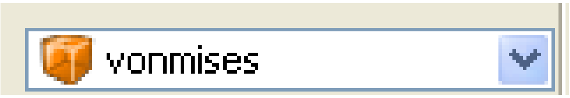
In Object Inspector > Properties

Select VONMISES

Turn off Block 3 > Apply

Last Frame 

Use Active Variable Control to select VONMISES



Paraview 3.02

To plot mesh on contour plot

Filters > Alphabetical > Extract Edges > Apply

Click on greyed out eye next to taylor_hex.e

Click *Play* to animate

Adjust contours & legend

Object Inspector > Display > Rescale to Data Range

Toggle *Color Legend Visibility*

Click *Play* to animate

Hands-on Session 2:
Rod-impacting-plate problem

New working directory: *tet_elastic_plastic*

Cubit: change element type from hex to tet

Presto: copy & modify ‘taylor_hex.i’

Paraview session

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New Working Directory

Create sub-directory in 'training_rod_impacting_plate' directory

% cd ~/training_rod_impacting_plate

% mkdir tet_elastic_plastic

Copy 'taylor_hex.g', 'taylor_hex.i' (& rename) from 'hex_elastic_plastic' directory into new directory

% cp hex_elastic_plastic/taylor_hex.g \# tet_elastic_plastic

% cp hex_elastic_plastic/taylor_hex.i \# tet_elastic_plastic/taylor_tet.i

Move into new directory

% cd tet_elastic_plastic

Cubit – Import Geometry

Start a Cubit session:

% cubit

Import hex genesis mesh into Cubit

File > Import…

File Type: Genesis/Exodus

select *taylor_hex.g > Open*

check *Smooth Curves/Surfaces* box > *Finish*

Delete hex mesh from volume 1 & 2 (but not volume 3)

reset vol 1 2

Cubit – Mesh with Tets

Mesh Plate

volume 2 size 0.084

volume 2 scheme tetmesh

mesh volume 2

Mesh Rod

volume 1 size 0.047625

volume 1 scheme tetmesh

mesh volume 1

Assign new element types to blocks

block 1 2 element type tetra

Cubit – Export

Export Genesis mesh:

export mesh "taylor_tet.g" overwrite

or

File > Export …

File name: taylor_tet.g

File type: | *Genesis (*.g* *.gen* *.G* *.GEN*)* |

Save

Finish

Quit Cubit session:

File > Exit

Presto

Sierra scope: **`database name`** must now refer to 'taylor_tet.g' in the **`finite element model`** block

```
Begin finite element model \#
         rod_impacting_plate
  database name = taylor_tet.g
  …
end
```

Presto region scope: change output database name

```
Begin results output rod_impacting_plate
  database name = taylor_tet.e
  …
End
```

Presto

Run Presto

% sierra presto –i taylor_tet.i –V 2.7beta4

Hands-on Session 3:
Rod-impacting-plate problem

New working directory: *hex_elastic_plastic_iv*

Presto: Changing the initial velocity

Paraview session

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New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_elastic_plastic_iv

Copy ‘taylor_hex.g’, ‘taylor_hex.i’ from ‘hex_elastic_plastic’ directory into new directory

% cp hex_elastic_plastic/taylor_hex.g hex_elastic_plastic_iv

% cp hex_elastic_plastic/taylor_hex.i hex_elastic_plastic_iv

Move into new directory

% cd hex_elastic_plastic_iv

Presto

Define a new direction in the sierra scope:

```
Define direction glancing_blow \#
    with vector 1 1 0
```

Use direction **`glancing_blow`**, change **`initial velocity magnitude`** in Presto region scope:

```
Begin initial velocity
  block = block_1
  direction = glancing_blow
  magnitude = -0.5e5
End
```

Presto

Run Presto

% sierra presto –i taylor_hex.i –V 2.7beta4

Hands-on Session 4:
Rod-impacting-plate problem

New working directory:
hex_elastic_plastic_contact

Presto: Changing contact options

Paraview session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_elastic_plastic_contact

Copy ‘taylor_hex.g’, ‘taylor_hex.i’ from ‘hex_elastic_plastic_iv’ directory into new directory

% cp hex_elastic_plastic_iv/taylor_hex.g hex_elastic_plastic_contact

% cp hex_elastic_plastic_iv/taylor_hex.i hex_elastic_plastic_contact

Move into new directory

% cd hex_elastic_plastic_contact

Presto: Modifying Contact Definition

Replace surface definition w/ block skinning in **`contact definition`** block:

```
Begin contact definition acme

   ~~contact surface block_1 contains block_1~~
   ~~contact surface block_2 contains block_2~~

   Skin all blocks = on exclude block_3

   … friction models …

   …

End contact definition acme
```

Presto: Modifying Contact Definition

Add constant friction model in **`contact definition`** block:

```
Begin contact definition acme
    … surface definitions …
    begin frictionless model nofriction
    end
    begin constant friction model half
      friction coefficient = 0.5
    end
    …
End contact definition acme
```

Presto: Modifying Contact Definition

Invoke contact tracking in contact **`search options`**:

```
Begin contact definition acme

   …

   … friction models …

   begin search options
     global search increment = 5
   end

   …

End contact definition acme
```

Presto: Modifying Contact Definitions

Use friction model '**`half`**' in place of '**`nofriction`**' in interaction definition:

```
Begin contact definition acme
   ...
   Begin interaction rod_plate
     surfaces = block_1 block_2
     friction model = half
     kinematic partition = 0.5
     normal tolerance = 0.015
     tangential tolerance = 0.015
   end
End contact definition acme
```

Presto

Run Presto

% sierra presto –i taylor_hex.i –V 2.7beta4

Hands-on Session 5:
Rod-impacting-plate problem

New working directory: *hex_elastic_plastic_io*

Presto: Requesting nodal and element output

Changing the frequency of output, restart

Paraview session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_elastic_plastic_io

Copy ‘taylor_hex.g’, ‘taylor_hex.i’ from ‘hex_elastic_plastic_contact’ directory into new directory

% cp hex_elastic_plastic_contact/taylor_hex.g hex_elastic_plastic_io

% cp hex_elastic_plastic_contact/taylor_hex.i hex_elastic_plastic_io

Move into new directory

% cd hex_elastic_plastic_io

Presto

Request nodal contact force, element stresses in **`results output`** block in Presto region scope:

```
Begin results output results
  database name = taylor_hex.e
  ...
  nodal variables = force_contact as fcon
  element variables = rotated_stress \#
    as sig
End
```

Hands-on Session 6:
Rod-impacting-plate problem

New working directory: *nbtet_elastic_plastic*

Presto: Using the nodal-based tet element

Paraview session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir nbtet_elastic_plastic

Copy ‘taylor_tet.g’, ‘taylor_tet.i’ from tet_elastic_plastic directory into new directory

% cp tet_elastic_plastic/taylor_tet.g \# nbtet_elastic_plastic

% cp tet_elastic_plastic/taylor_tet.i \# nbtet_elastic_plastic

Move into new directory

% cd nbtet_elastic_plastic

Presto - Node Based Tet Model

Add a 'solid section' in the sierra scope
(before the **finite element model** block)

```
Begin solid section nodal_tet
  Strain incrementation = node_based
  Node based alpha factor = 0.1
  Node based beta factor = 0.25
End
```

Presto - Node Based Tet Model

Use the solid section `nodal_tet` for block 1 and 2 in the `finite element model`

```
Begin finite element model \#
              rod_impacting_plate
  begin parameters for block block_1
     …
     section = nodal_tet
  end
  begin parameters for block block_2
     …
     section = nodal_tet
  end
End
```

Hands-on Session 7:
Rod-impacting-plate problem

New working directory:
nbtet_elastic_plastic_remesh

Presto: Using the nodal-based tet element w/ remeshing

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir nbtet_elastic_plastic_remesh

Copy ‘taylor_tet.g’, ‘taylor_tet.i’ from *nbtet_elastic_plastic* directory into new directory

% cp nbtet_elastic_plastic/taylor_tet.g \# nbtet_elastic_plastic_remesh

% cp nbtet_elastic_plastic/taylor_tet.i \# nbtet_elastic_plastic_remesh

Move into new directory

% cd nbtet_elastic_plastic_remesh

Presto - Node Based Tet Model w/ Remeshing

Turn on remeshing in the Presto region scope

```
Begin remesh
   Block = block_1
End
```

```
Begin remesh
   Block = block_2
End
```

Hands-on Session 8:
Rod-impacting-plate problem

New working directory: *hex_johnson_cook*

Presto: Using Johnson-Cook material model

Paraview session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_johnson_cook

Copy ‘taylor_hex.g’, ‘taylor_hex.i’ from ‘hex_elastic_plastic’ directory into new directory

% cp hex_elastic_plastic/taylor_hex.g hex_johnson_cook

% cp hex_elastic_plastic/taylor_hex.i hex_johnson_cook

Move into new directory

% cd hex_johnson_cook

Presto: Use Johnson Cook Material Model

Add stress-strain model for **`material`** **`Tungsten_Rod`**

```
Begin parameters for model johnson_cook
    shear modulus = 1.241E12
    hardening constant = 1.765e9
    hardening exponent = 1.200e-1
    yield stress = 1.506e10
    melt temperature = 1.723e3
    poissons ratio = .28
    rate constant = 1.6e-2
    reference temperature = 2.943e2
    thermal exponent = 1
    rhocv = 4.e11
End
```

Presto: Use Johnson Cook Material Model

Add stress-strain model for **`material`** **`Steel_Plate`**

```
Begin parameters for model johnson_cook
    youngs modulus = 2.132922145E12
    poissons ratio = 0.279
    yield stress = 7.8e9
    hardening constant = 7.8e9
    hardening exponent = 0.106
    rhocv = 4.0645086E11
    rate constant = 0.004
    thermal exponent = 1
    reference temperature = 298
    melt temperature = 1783.000093
End
```

Presto: Use Johnson Cook Material Model

Use the **johnson_cook** stress-strain model for the material Rod and Plate in the **finite element model** block

```
Begin finite element model \#
               rod_impacting_plate
  begin parameters for block block_1
     material tungsten_rod
     solid mechanics use model johnson_cook
  end
  begin parameters for block block_2
     material steel_plate
     solid mechanics use model johnson_cook
  end
  …
End
```

Hands-on Session 9:
Rod-impacting-plate problem

New working directory:
hex_johnson_cook_death

Presto: Using Johnson-Cook material model w/ element death

Paraview session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_johnson_cook_death

Copy ‘taylor_hex.g’, ‘taylor_hex.i’ from ‘hex_johnson_cook’ directory into new directory

% cp hex_johnson_cook/taylor_hex.g hex_johnson_cook_death

% cp hex_johnson_cook/taylor_hex.i hex_johnson_cook_death

Move into new directory

% cd hex_johnson_cook_death

Presto: Hex model with Johnson Cook Material Model, element death, no particles

Add element death block for Rod in Presto region scope:

```
Begin element death rod
    block = block_1
    death steps = 5
    criterion is element value of \#
        state_johnson_cook(2) >= .5
    death on inversion = on
End
```

Note: `state_johnson_cook(2)` refers to the 2nd state variable of the johnson-cook material model (which is **eqps**)

See Presto manual for lists of material model state variables

Presto: Hex model with Johnson Cook Material Model, element death, no particles

Add element death block for Plate in Presto region scope:

```
Begin element death plate
     block = block_2
     death steps = 5
     criterion is element value of \#
          state_johnson_cook(2) >= .5
     death on inversion = on
End
```

Presto: Hex model with Johnson Cook Material Model, element death, no particles

Update the contact definition for element death

```
update all surfaces for element death = on
```

Request “equivalent plastic strain” and “death status” in results output

```
element variables = mat%johnson_cook(2) \#
 as eqps
element variables = death_dummy_var \#
 as death_status
```

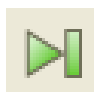
Paraview 3.02

File > Open > taylor_hex.e > OK

In Object Inspector > Properties

Select DEATH_STATUS and VONMISES

Turn off Block 3 > Apply

Last Frame 

Use Active Variable Control to select VONMISES

Paraview 3.02

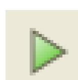
Plot active elements only

Filters > Alphabetical > Threshold

Scalars DEATH_STATUS

Lower Threshold = 0.5

> Apply

Click Play  *to animate*

Hands-on Session 10:
Rod-impacting-plate problem

New working directory:
hex_johnson_cook_death_particles

Presto: Using Johnson-Cook material model
w/ element death, conversion to particles

Ensight session

New Working Directory

Create sub-directory in 'training_rod_impacting_plate' directory

% cd ~/training_rod_impacting_plate

% mkdir hex_johnson_cook_death_particles

Copy 'taylor_hex.g', 'taylor_hex.i' from 'hex_johnson_cook_death' directory into new directory

% cp hex_johnson_cook_death/taylor_hex.g hex_johnson_cook_death_particles

% cp hex_johnson_cook_death/taylor_hex.i hex_johnson_cook_death_particles

Move into new directory

% cd hex_johnson_cook_death_particles

Presto: Hex model with Johnson Cook Material Model, element death, particles

Add 'sph sections' in sierra scope
(before the `finite element model` block)

```
Begin sph section sph_1
  formulation = mass_particle
  problem dimension = 3
End
```

```
Begin sph section sph_2
  formulation = mass_particle
  problem dimension = 3
End
```

Presto: Hex model with Johnson Cook Material Model, element death, particles

Add particle conversion to **`element death`** block for Tungsten_Rod in Presto region scope:

```
Begin element death rod
  block = block_1
  death steps = 5
  criterion is element value of \#
          state_johnson_cook(2) >= .5
  death on inversion = on

  convert elements to particles with \#
    section = sph_1 material \#
    tungsten_rod johnson_cook
End
```

Presto: Hex model with Johnson Cook Material Model, element death, particles

Add particle conversion to **`element death`** block for Steel_Plate in Presto region scope

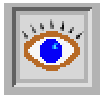
```
Begin element death plate
  block = block_2
  death steps = 5
  criterion is element value of \#
          state_johnson_cook(2) >= .5
  death on inversion = on

  convert elements to particles with \#
    section = sph_2 material \#
    steel_plate johnson_cook
End
```

Ensight8

Delete any spread results files

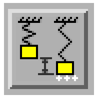
Post process in Ensight8

File > Open … > taylor_hex.e > OK*

Select Block ID 3 – hex8, toggle visibility 

Select Node sets and Side sets, toggle visibility

Select Case 1

Select Displacements  *> Displace by displ_vec > Close*

Select Failed Elements  *> Element variable > death_status < 0.5 > Apply*

Flipbook Animation  > Load

Note: Paraview and/or Presto could be enhanced to view a series of results files (on the list of things-to-do)

Hands-on Session 11:

Rod-impacting-plate problem

New working directory: *hex_johnson_cook_death_particles_interaction*

Presto: Using Johnson-Cook material model w/ element death, conversion to particles, particle-to-element interaction

Ensight session

New Working Directory

Create sub-directory in 'training_rod_impacting_plate' directory

% cd ~/training_rod_impacting_plate

% mkdir hex_johnson_cook_death_particles_interaction

Copy 'taylor_hex.g', 'taylor_hex.i' from 'hex_johnson_cook_death_particles' directory into new directory

% cp hex_johnson_cook_death_particles/taylor_hex.g hex_johnson_cook_death_particles_interaction

% cp hex_johnson_cook_death_particles/taylor_hex.i hex_johnson_cook_death_particles_interaction

Move into new directory

% cd hex_johnson_cook_death_particles_interaction

Presto: Hex model with Johnson Cook Material Model, element death, particles, interaction

Replace surface definition w/ block skinning in **`contact definition`** block:

```
Begin contact definition acme

   ~~contact surface block_1 contains block_1~~
   ~~contact surface block_2 contains block_2~~

   Skin all blocks = on

   ...

End contact definition acme
```

Presto: Hex model with Johnson Cook Material Model, element death, particles, interaction

Add particles to be automatically skinned & add to **`contact definition`** as a node set

```
Begin contact definition acme
    Skin all blocks = on
    contact node set sph_nodes1 contains \#
      block_1_particles_nodes sphere \#
      radius = 0.01 icosahedron
    contact node set sph_nodes2 contains \#
      block_2_particles_nodes sphere \#
      radius = 0.01 icosahedron
    ...
End contact definition acme
```

Presto: Hex model with Johnson Cook Material Model, element death, particles, interaction

Invoke contact search tolerances in **`contact definition`** block:

```
Begin contact definition acme
   ...
   begin search options
     normal tolerance = 0.002
     tangential tolerance = 0.002
   end
  ...
End contact definition acme
```

Presto: Hex model with Johnson Cook Material Model, element death, particles, interaction

Invoke higher accuracy for contact enforcement in **`contact definition`** block:

```
Begin contact definition acme
   ...
   begin search options
     normal tolerance = 0.002
     tangential tolerance = 0.002
   end
   begin enforcement options
      momentum balance iterations = 10
   end
  ...
End contact definition acme
```

Presto: Hex model with Johnson Cook Material Model, element death, particles, interaction

Add contact interactions to be considered for block_1

```
Begin contact definition acme
   ...
   Begin interaction
     master = block_1
     slave = sph_nodes1
   end
   begin interaction
      master = block_1
      slave = sph_nodes2
   end interaction
End contact definition acme
```

Presto: Hex model with Johnson Cook Material Model, element death, particles, interaction

Add contact interactions to be considered for block_2

```
Begin contact definition acme
   ...
   Begin interaction
     master = block_2
     slave = sph_nodes1
   end
   begin interaction
      master = block_2
      slave = sph_nodes2
   end interaction
End contact definition acme
```

Presto: Hex model with Johnson Cook Material Model, element death, particles, interaction

Add contact interactions to be considered for block_3

```
Begin contact definition acme
   ...
   Begin interaction
     master = block_3
     slave = sph_nodes1
   end
   begin interaction
     master = block_3
     slave = sph_nodes2
   end interaction
End contact definition acme
```

Here is where the symmetry_plane is needed

Ensight8

Delete any spread results files

Post process in Ensight8

- File > Open … > taylor_hex.e* > OK
- Select Block ID 3 – hex8, toggle visibility
- Select Node sets and Side sets, toggle visibility
- Select Case 1
- Select Displacements > Displace by displ_vec > Close
- Select Failed Elements > Element variable > death_status < 0.5 > Apply
- Flipbook Animation > Load

To display shaded contours and mesh use the following

Hands-on Session 12:
Rod-impacting-plate problem

New working directory: *hex_johnson_cook_sph*
SEACAS mesh tools: Generate SPH particles
Presto: Using SPH model for the rod
Ensight session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_johnson_cook_sph

Copy ‘taylor_hex.g’, ‘taylor_hex.i’ (& rename) from ‘hex_johnson_cook_death_particles_interaction’ directory into new directory

% cp hex_johnson_cook_death_particles_interaction/ taylor_hex.g hex_johnson_cook_sph

% cp hex_johnson_cook_death_particles_interaction/ taylor_hex.i   hex_johnson_cook_sph/ taylor_hex_sph.i

Move into new directory: *% cd hex_johnson_cook_sph*

SEACAS meshing tools: Rod as SPH

Create genesis file of rod only

```
% grepos  taylor_hex.g  b1.g
        list blocks
        delete mat 2 3
        exit
```

Create genesis file of plate and contact_plate

```
% grepos  taylor_hex.g  b23.g
        list blocks
        delete mat 1
        exit
```

SEACAS meshing tools: Rod as SPH

Create SPH “mesh” for Rod
note: b1.sph1 will be an exodusI file (hence the conversion), nodeset 1 gets automatically created (matches block 1)

% sphgen3d   b1.g   b1.sph1

% ex1ex2v2   b1.sph1   b1sph.g

Combine genesis files

% gjoin2

First input file > b1sph.g
Second input file > b23.g
Equivalance or Command (Enter Help for info) ? End
Finish
Output file > taylor_hex_sph.g

Presto: Rod as SPH

Add an SPH section in the sierra scope
(before the **`finite element model`** block):

```
Begin sph section sph_rod
  sphere initial radius = 0.05
  problem dimension = 3
  constant sphere radius
End
```

Presto: Rod as SPH

Sierra scope: **`database name`** must now refer to 'taylor_hex_sph.g' in the **`finite element model`** block:

```
Begin finite element model \#
    rod_impacting_plate
  database name = taylor_hex_sph.g
  …
End
```

Presto region scope: change output database name

```
Begin results output rod_impacting_plate
  database name = taylor_hex_sph.e
  …
End
```

Presto: Rod as SPH

Use the SPH section in the parameters for block 1 in the **`finite element model`** block :

```
Begin finite element model \#
                  rod_impacting_plate
  …
  begin parameters for block block_1
      material johnson_cook(or Tungsten_Rod)
      section = sph_rod
      Solid Mechanics use model johnson_cook
  end
  …
End
```

Presto: Rod as SPH

Comment out (or delete) **`element death`** block for Tungsten_Rod in Presto region scope:

```
# Begin element death rod
#   block = block_1
#   death steps = 5
#   criterion is element value of \#
#               state_johnson_cook(2) >= .5
#   death on inversion = on

#   convert elements to particles with \#
#     section = sph_1 material \#
#     tungsten_rod johnson_cook
#   End
```

Presto: Rod as SPH

Add SPH to `contact definition :`

```
Begin contact definition acme
  Contact node set sph_nodes contains \#
     nodelist 1 (or nodelist_1)
  ...
  Begin interaction
    master = block_2
    slave = sph_node (or sph_nodes)
  End
  Begin interaction
    master = block_3
    slave = sph_node (or sph_nodes)
  End
  ...
End contact definition acme
```

Presto: Rod as SPH

Comment out (or delete) any reference to '**`sph_nodes1`**' in the **`contact definition`** :

```
Begin contact definition acme

   contact node set sph_nodes1 contains \#
    block_1_particles_nodes sphere \#
    radius = 0.01 icosahedron

   Begin interaction
    master = block_1
    slave = sph_nodes1
   end

  …
End contact definition acme
```

etc…

Presto: Rod as SPH

Run Presto

% sierra presto –i taylor_hex_sph.i –V presto_2.7beta

Hands-on Session 13:
Rod-impacting-plate problem

New working directory: *hex_concrete*

Cubit session: using journal file

Presto: verify already existing input file w/ KC-concrete model, element death

Ensight session

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New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_concrete

Copy ‘concrete_no_rebar.jou’, ‘concrete_no_rebar.i’ into new directory

% cp concrete_no_rebar.jou hex_concrete

% cp concrete_no_rebar.i hex_concrete

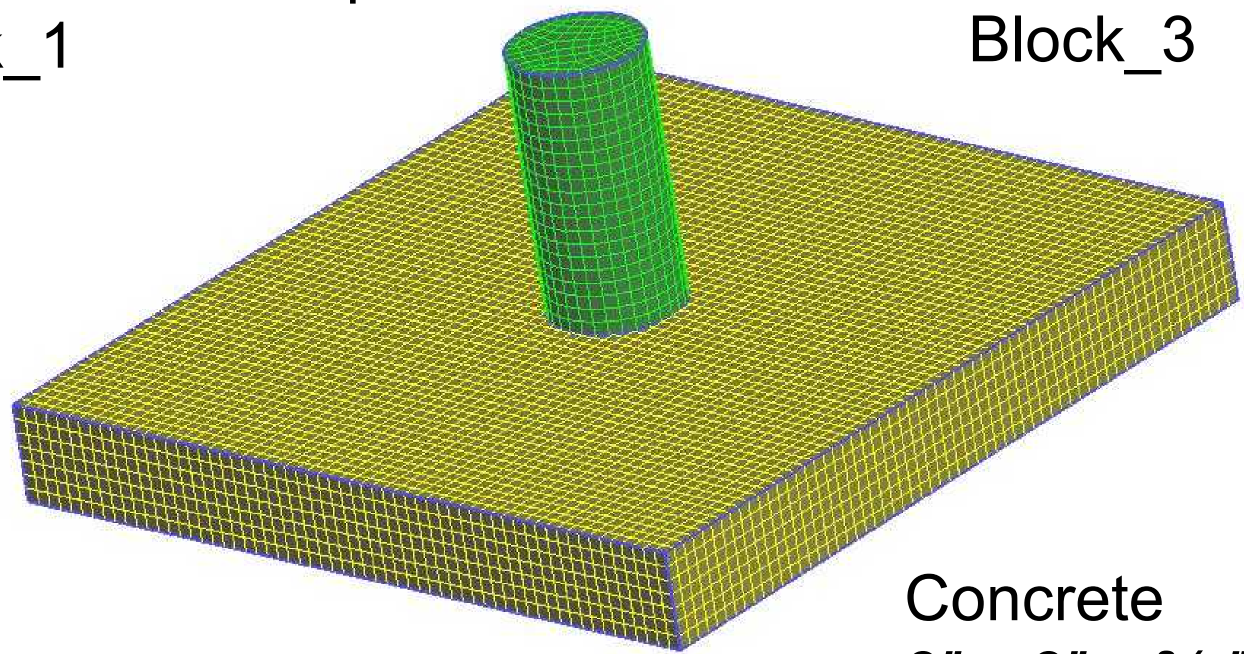
Move into new directory

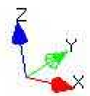
% cd hex_concrete

Rod Impacting Concrete Panel

Steel rod
w/ Prescribed Displacement
Block_1

Reinforcement
Block_3





Concrete
6″ x 6″ x ¾ ″
Block_2

Back side of Plate is simply-supported along the perimeter of a 4″ x 4″ square (centered)

Cubit: Creating mesh of Rod & Plate using Journal File

Create genesis file w/ Cubit journal file:

% cubit concrete_no_rebar.jou

Presto: Rod Impacting Concrete Panel

Verify in sierra scope: **`finite element model`** block must refer to ‘concrete_no_rebar.g’

```
Begin finite element model \#
                rod_impacting_plate
  database name = concrete_no_rebar.g
  …
end
```

Run Presto

% sierra presto –i concrete_no_rebar.i –V 2.7beta

Ensight

Delete any spread results files

% Ensight8

- File > Open … > concrete_no_rebar.e > Set file > concrete_no_rebar.e* > Load All
- Select Node sets and Side sets, toggle visibility
- Select Case 1
- Select Displacements > Displace by displ_vec > Close
- Select Failed Elements > Element variable > death_status < 1.0 > Apply
- Flipbook Animation > Load

Hands-on Session 14:
Rod-impacting-plate problem

- New working directory: *hex_concrete_rebar*
- Cubit session: using journal file w/ rebar along mesh edges
- Presto: modify input file for rebar
- Ensight session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_concrete_rebar

Copy ‘concrete_rebar.jou’, ‘hex_concrete/concrete_no_rebar.i’ into new directory

% cp concrete_rebar.jou hex_concrete_rebar

% cp hex_concrete/concrete_no_rebar.i hex_concrete_rebar/concrete_rebar.i

Move into new directory

% cd hex_concrete_rebar

Cubit: Creating mesh of Rod, Plate & Coincident Rebar using Journal File

Create genesis file w/ Cubit journal file:

% cubit concrete_rebar.jou

Presto: Rod Impacting Concrete Panel w/ coincident rebar

Add rod_block section in sierra scope:

```
Begin beam section rod_block
  …
end
```

Add parameters for block 3 in **`finite element model`** block:

```
Begin parameters from(for) block block_3
  Material steel
  Solid mechanics use model
  elastic_plastic
  Section = rod_block
End parameters from(for) block block_3
```

Presto: Rod Impacting Concrete Panel w/ coincident rebar

Run Presto

% sierra presto –i concrete_rebar.i –V 2.7beta

Ensight

Delete any spread results files

% Ensight8

- File > Open … > concrete_rebar.e > Set file > concrete_rebar.e* > Load All
- Select Node sets and Side sets, toggle visibility
- Select Case 1
- Select Displacements > Displace by displ_vec > Close
- Select Failed Elements > Element variable > death_status < 1.0 > Apply
- Flipbook Animation > Load

Hands-on Session 15:
Rod-impacting-plate problem

New working directory:
hex_concrete_rebar_embedded

SEACAS mesh tools: rebar embedded in concrete mesh

Presto: modify input file for rebar-concrete bond model

Ensight session

New Working Directory

Create sub-directory in ‘training_rod_impacting_plate’ directory

% cd ~/training_rod_impacting_plate

% mkdir hex_concrete_rebar_embedded

Copy ‘concrete_rebar.g’, ‘concrete_rebar.i’ (& rename) from hex_concrete directory into new directory

% cp hex_concrete/concrete_rebar.g hex_concrete_rebar_embedded

% cp hex_concrete/concrete_rebar.i hex_concrete_rebar_embedded/ concrete_rebar_embedded.i

Move into new directory

% cd hex_concrete_rebar_embedded

SEACAS meshing tools: Rebar Embedded in Concrete

Create genesis file of rebar only

% grepos concrete_rebar.g b3.g
list blocks
delete mat 1 2
exit

Create genesis file of Concrete plate and rod

% grepos concrete_rebar.g b12.g
list blocks
delete mat 3
exit

SEACAS meshing tools: Rebar Embedded in Concrete

Combine genesis files

% gjoin2

First input file > b12.g

Second input file > b3.g

Equivalance or Command (Enter Help for info) ? End

Finish

Output file > concrete_rebar_embedded.g

Presto: Rod Impacting Concrete Panel w/ Embedded Rebar

Add to rod_block section in sierra scope:

```
Begin beam section rod_block
  bond model = rebar_concrete
End
```

Modify **`finite element model`** block in sierra scope to refer to 'concrete_rebar_embedded.g'

```
Begin finite element model \#
                rod_impacting_plate
  database name = \#
    concrete_rebar_embedded.g
  …
end
```

Presto: Rod Impacting Concrete Panel w/ Embedded Rebar

Add to bond model type in Presto region scope:

```
Begin bond model rebar_concrete
  model type = NO_SLIP
End bond model rebar_concrete
```

Add rebar-concrete interaction in Presto region scope:

```
Begin reinforcement interaction rc
  matrix = block_2
  reinforcement = block_3
End reinforcement interaction rc
```

Presto: Rod Impacting Concrete Panel w/ Embedded Rebar

Presto region scope: Change output database name & request bond force in **`results output`** block

```
Begin results output <name>
  database name = \#
    concrete_rebar_embedded.e
  nodal variables = BOND_FORCE as FBOND
  element variables = BOND_TRACTION \#
    as BOND_STRESS
  …
End
```

Presto: Rod Impacting Concrete Panel w/ rebar coincident

Run Presto

% sierra presto –i concrete_rebar_embedded.i \#
–V 2.7beta

Ensight

Delete any spread results files

% Ensight8

- File > Open … > concrete_rebar.e > Set file > concrete_rebar.e* > Load All
- Select Node sets and Side sets, toggle visibility
- Select Case 1
- Select Displacements > Displace by displ_vec > Close
- Select Failed Elements > Element variable > death_status < 1.0 > Apply
- Flipbook Animation > Load