2D-simulations in LS-DYNA

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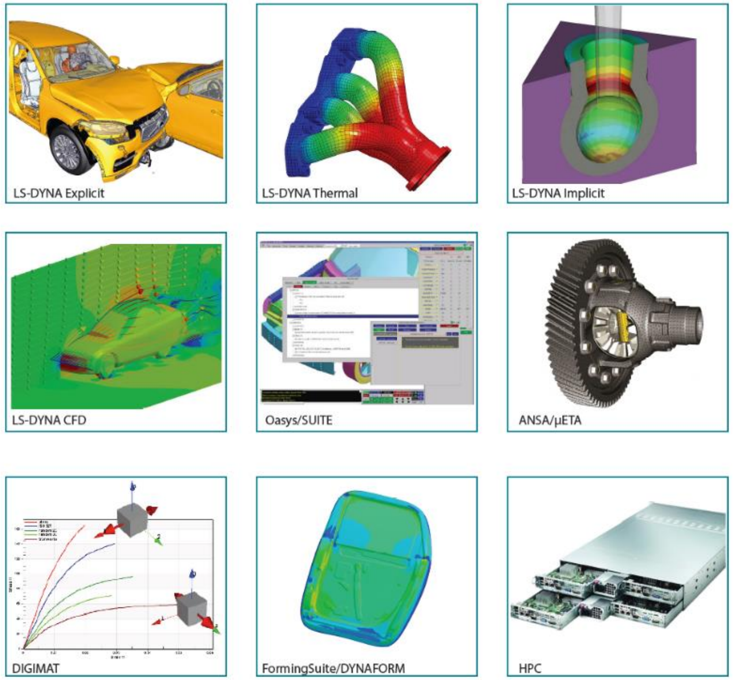
2022-02-10

Contact – DYNAmore Nordic



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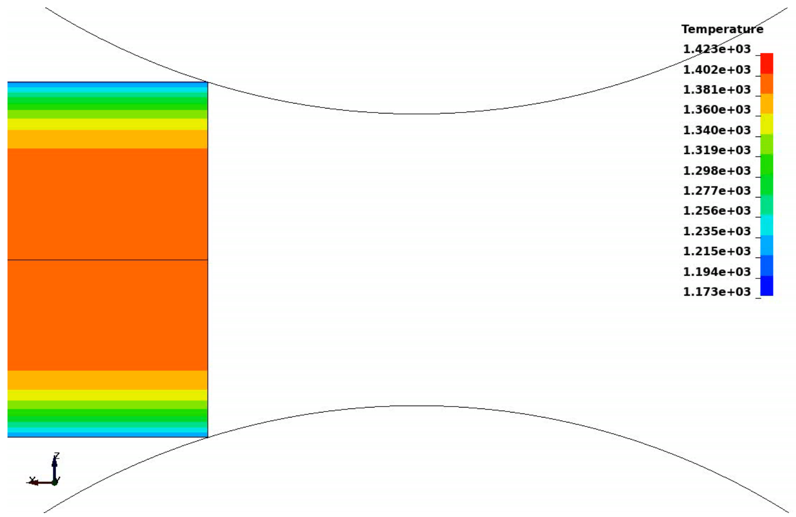
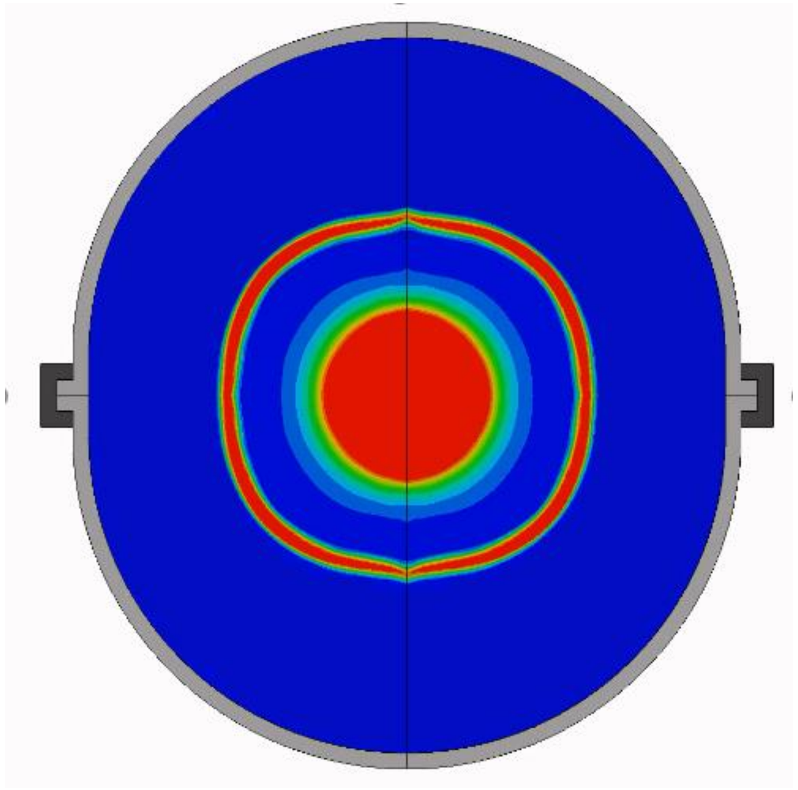
Content

- Motivation
- Overview of Types of 2D simulations
- Element formulations
- Pre-processing
- Materials
- Contacts
- Loads
- Postprocessing
- Adaptivity

Motiviation

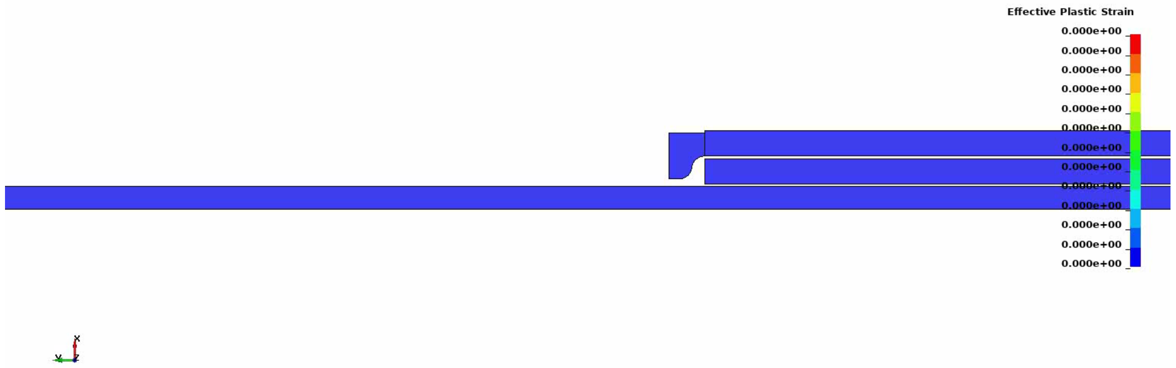
- Save simulation time for axisymmetric and plane cases
- Simple pre-processing
- High resolution through thickness



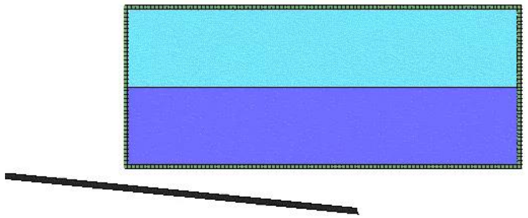


Types

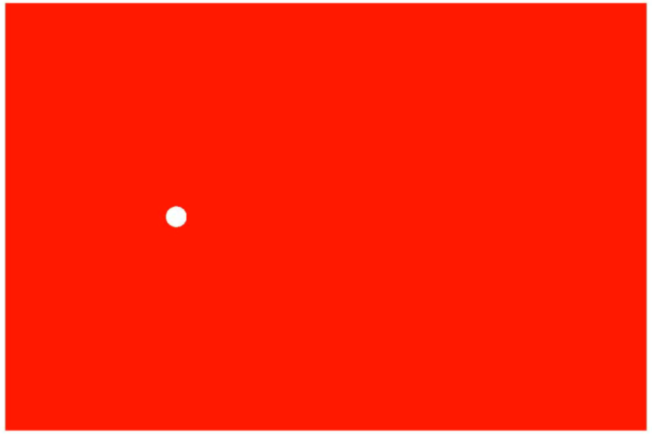
- Plane stress: σ_z=0 (thin parts)
- Plane strain: ε_z=0 (thick parts)
- Axisymmetric: Rotational symmetry



- Structure: Lagrangian formulation
- ALE: Arbitrary Lagrangian Eulerian (fluid)
- MMALE: Multi-material ALE-formulation (fluid)
- ICFD and FSI



- Explicit and Implicit

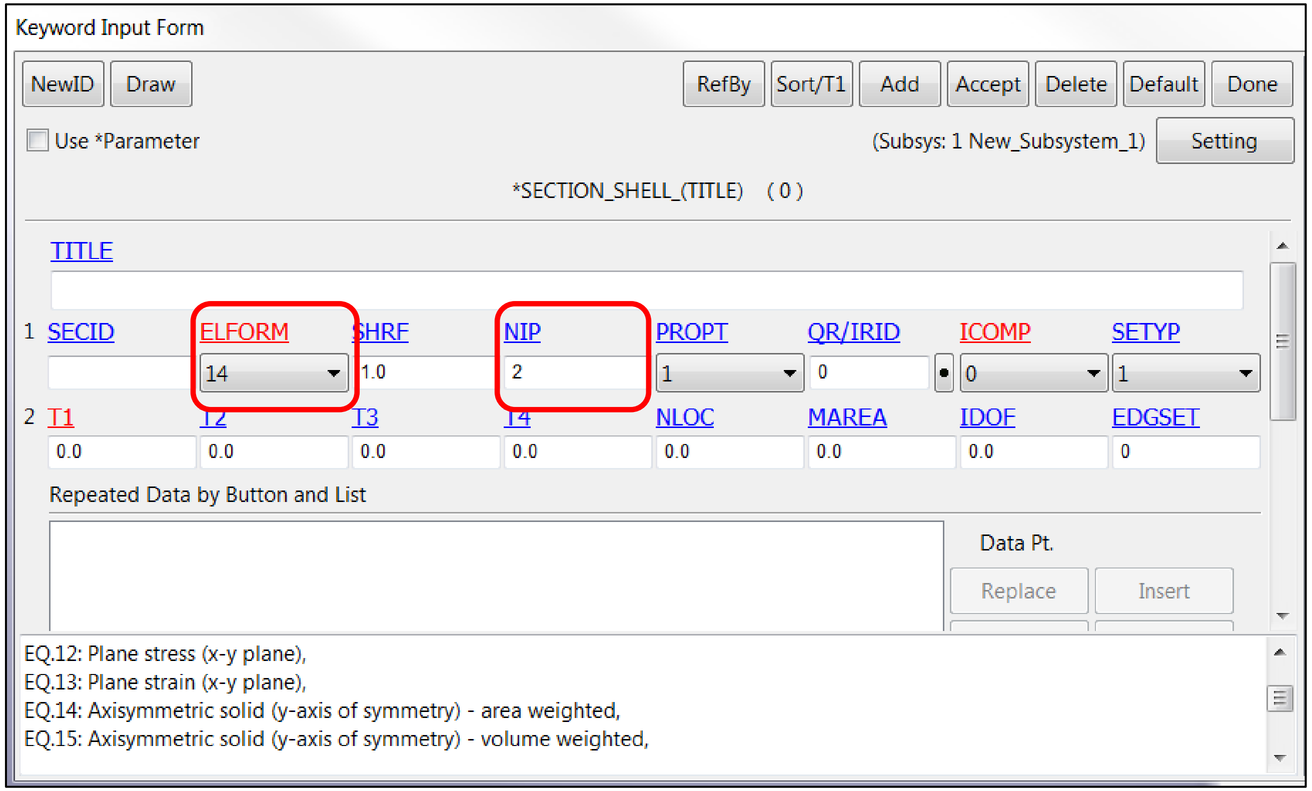


- mpp and SMP: Adaptivity is not supported in mpp
- Thermal/thermal contacts

Element formulation: *SECTION_SHELL

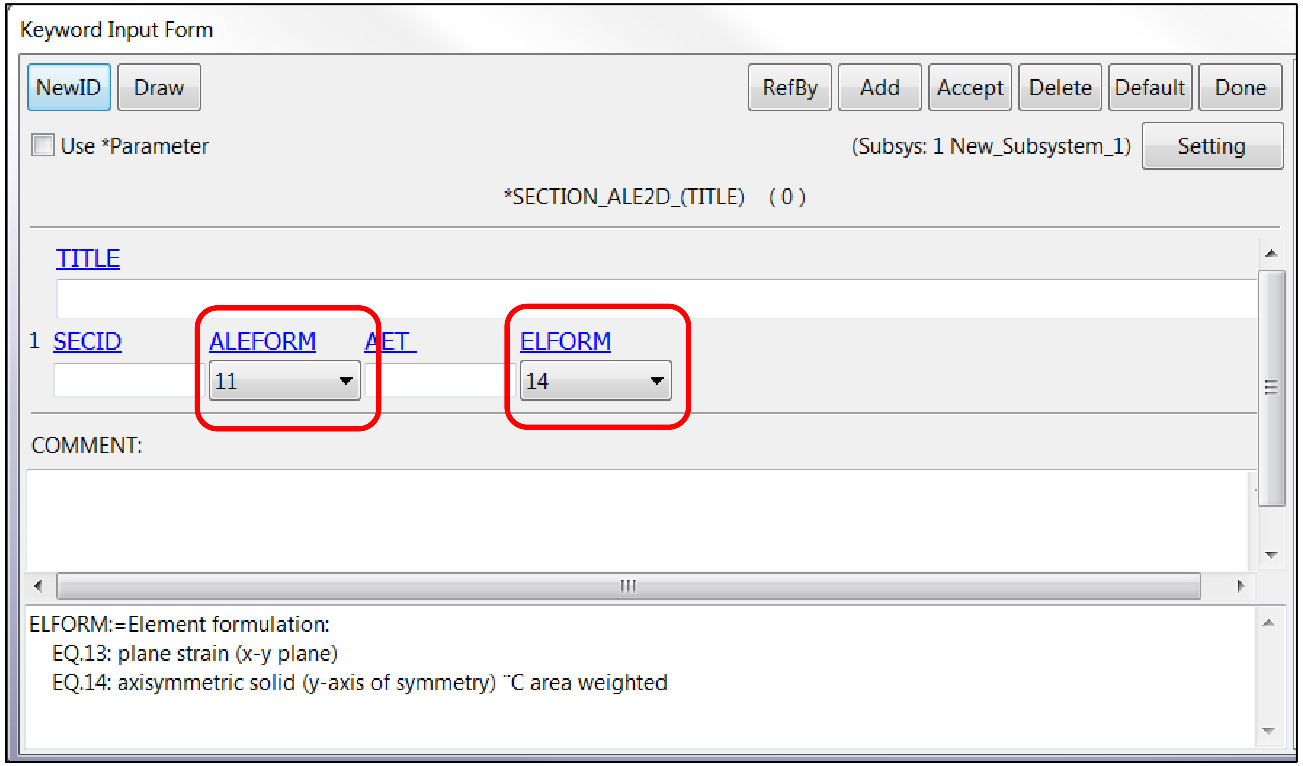
- Plane stress: **ELFORM=12**
- Plane strain: **ELFORM=13**
- Axisymmetric: **ELFORM=14**
  - Area weighted: high explosive applications
  - Unsuitable for implicit simulations
- Axisymmetric: **ELFORM=15**
  - Volume weighted: structural applications
  - Very large deformations can lead to problems at the axis of symmetry

Fully integrated 2D-elements are available for **ELFORM=13** and 15 by setting **NIP=4**.



Element formulation: *SECTION_ALE2D

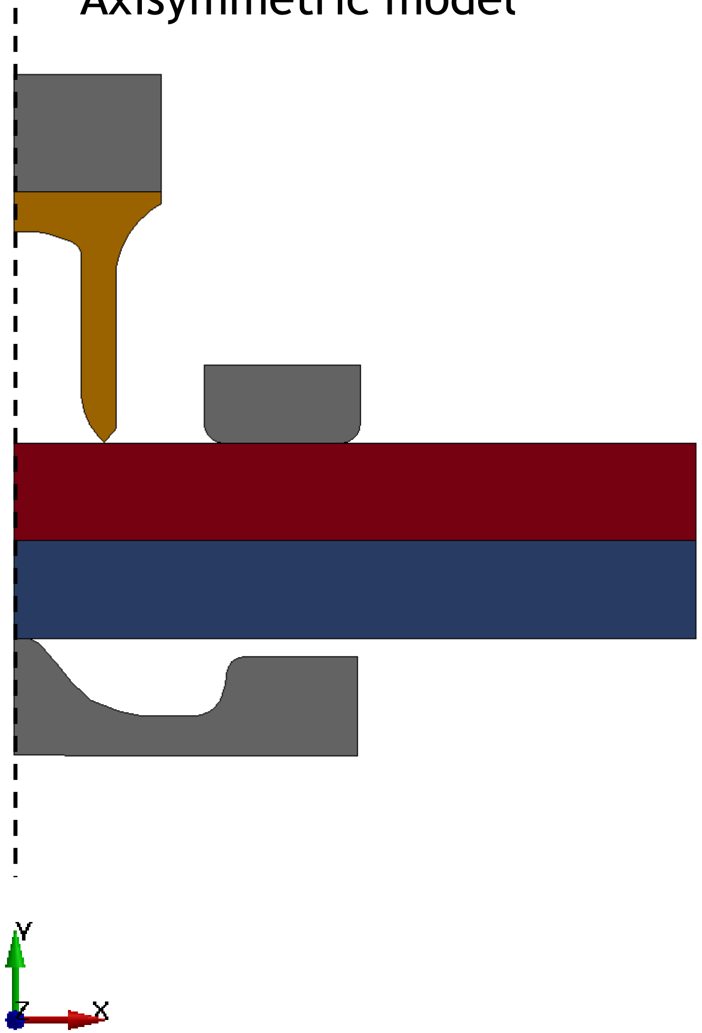
- Plane strain: **ELFORM=13**
- Axisymmetric: **ELFORM=14** area weighted
- Single material ALE: **ALEFORM=6**
- Multi-material ALE: **ALEFORM=11**



FE-model

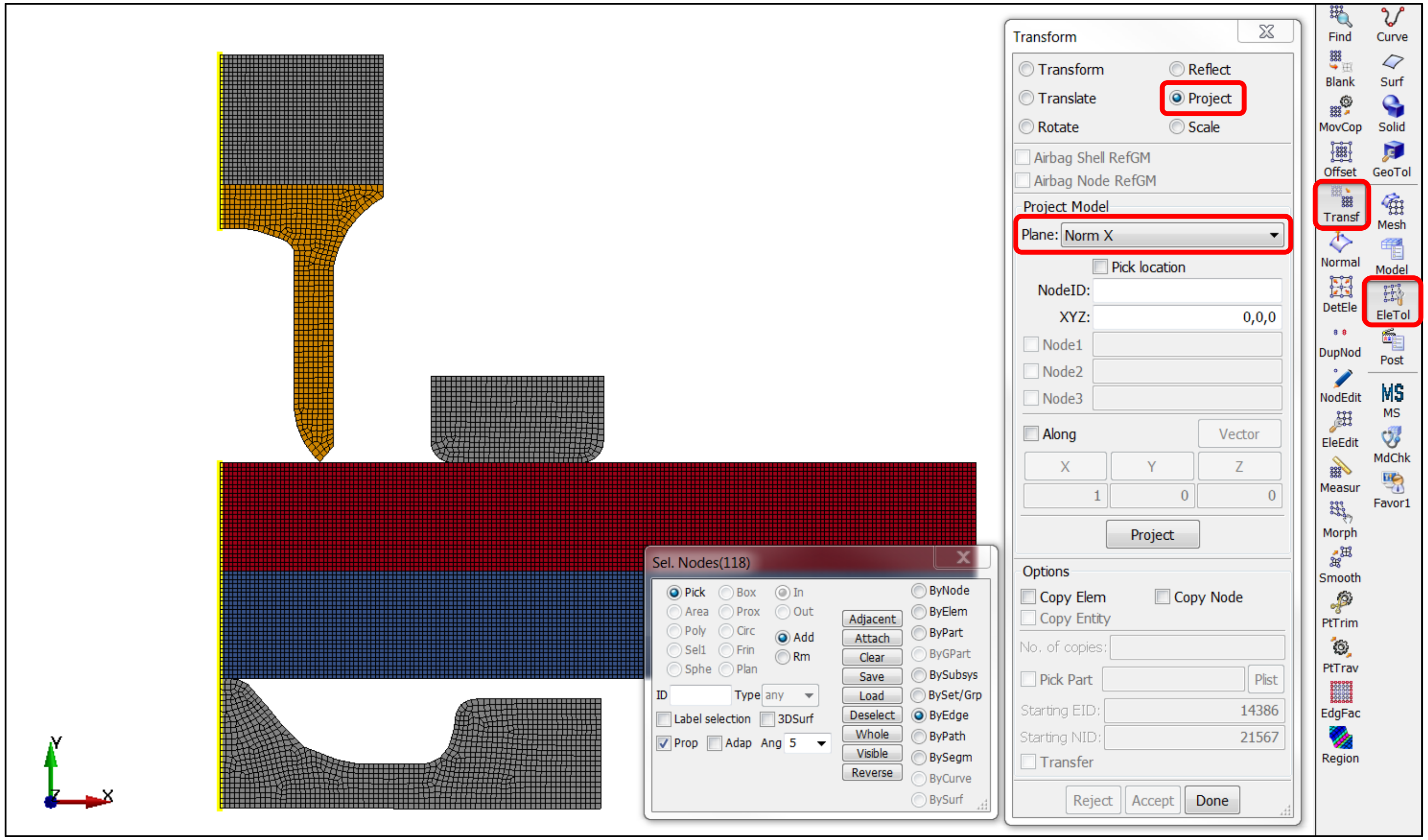
- Plane stress/strain
  - In the global xy-plane
  - Z-coordinate must be zero for all nodes
  - Element normals should be positive in the z-direction
- Axisymmetric
  - In the global xy-plane
  - Z-coordinate must be zero for all nodes
  - Element normals should be positive in the z-direction
  - The global y-axis is taken as the axis of symmetry
  - All nodes must have x-coordinate ≥ 0

Axisymmetric model



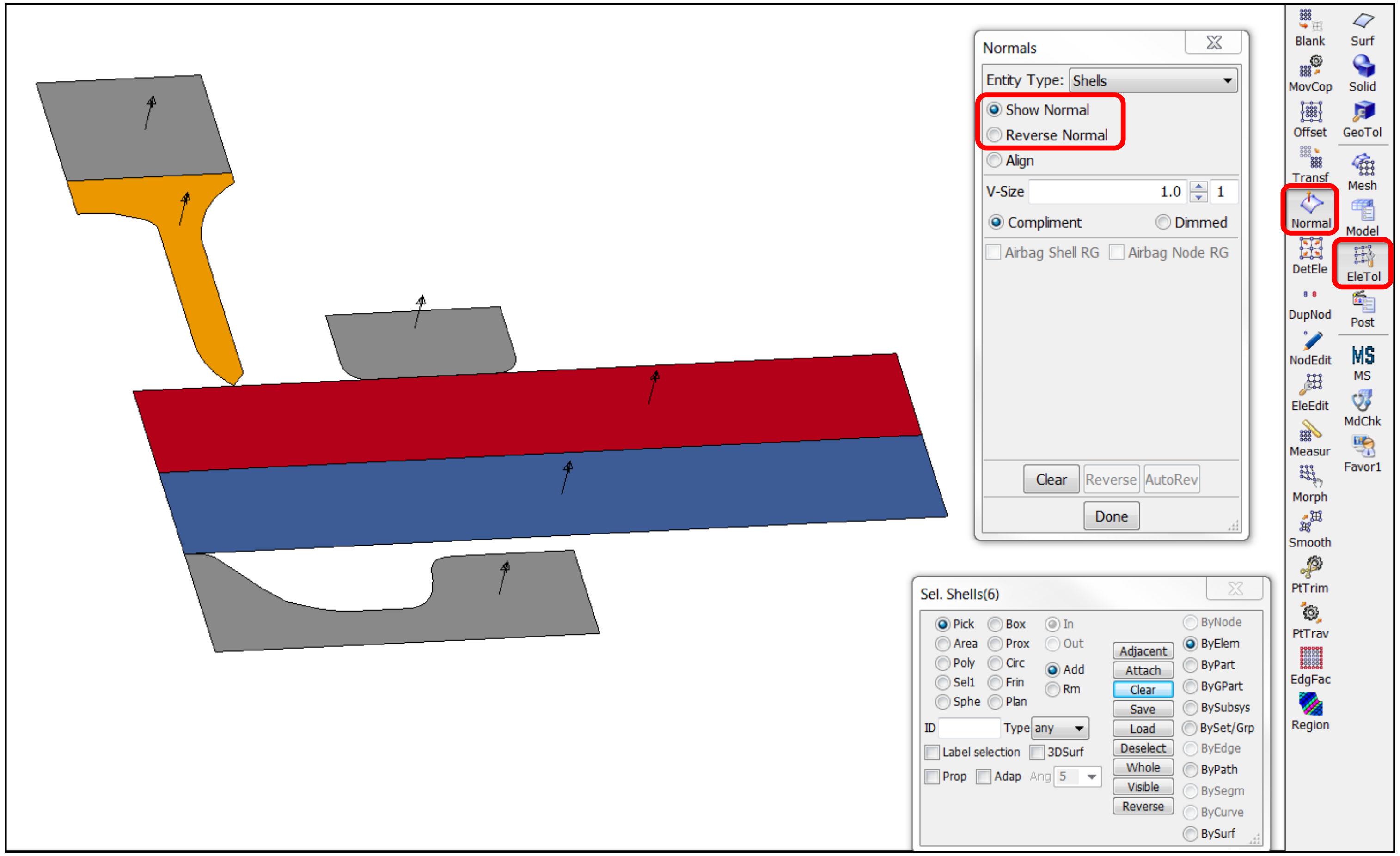
FE-model

- Project coordinates in LS-PrePost
  - Element tools
  - Transform
  - Project
    - Norm X
    - Norm Z



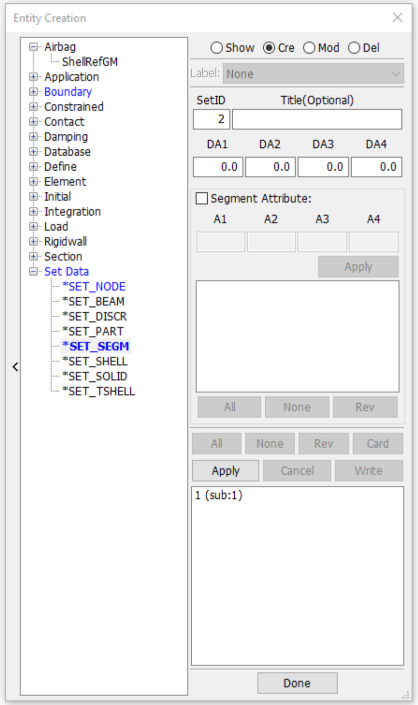
FE-model

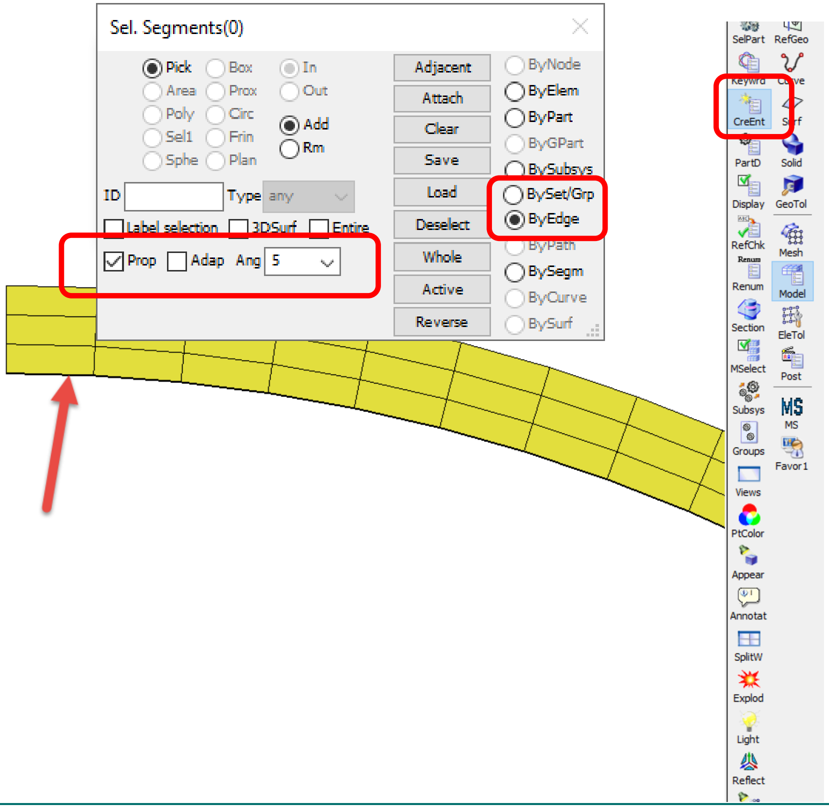
- Show/reverse element normals in LS-PrePost
  - Element tools
  - Normals

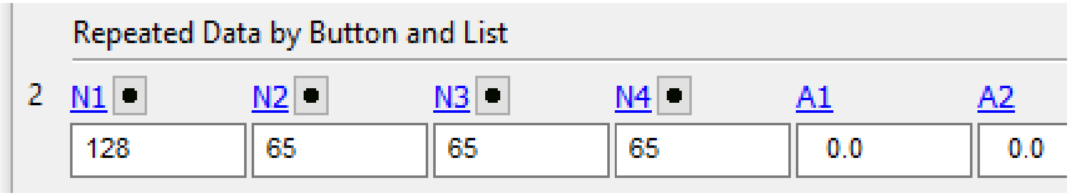


*SET_.., *BOUNDARY_..., *INITIAL_...

- Boundary conditions and initial conditions are the same as for 3D
- Segment loads in 2D is applied on an element edge
- Use the entity creator and propagate to select the element edge.







Materials, contacts and forces

- Materials
  - In most cases use the same materials as in 3D.
  - In case of anisotropic material models switch to MAT_24.
- Contacts
  - **2D_AUTOMATIC_NODE_TO_SURFACE**
  - **2D_AUTOMATIC_SINGLE_SURFACE**
  - **2D_AUTOMATIC_SURFACE_TO_SURFACE**

*Input as *SET_PART*

Static friction

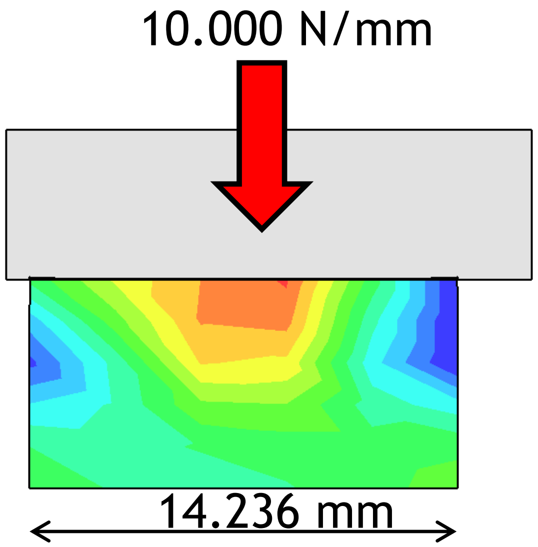
```
*CONTACT_2D_AUTOMATIC_SINGLE_SURFACE_ID
$#     cid                                                              title
         1All to all
$#    sids      sidm     sfact      freq        fs        fd        dc
         1                                   0.200
$#  tbirth    tdeath       sos       som       nds       ndm       cof      init
```

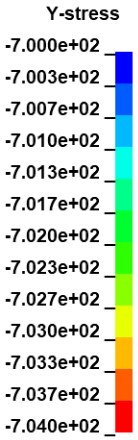
- Forces input/output
  - Plane stress/strain: force per unit thickness
  - Axisymmetric ELFORM=14: force per unit length in the circumferential direction
  - Axisymmetric ELFORM=15: force per radian

Plane strain loading

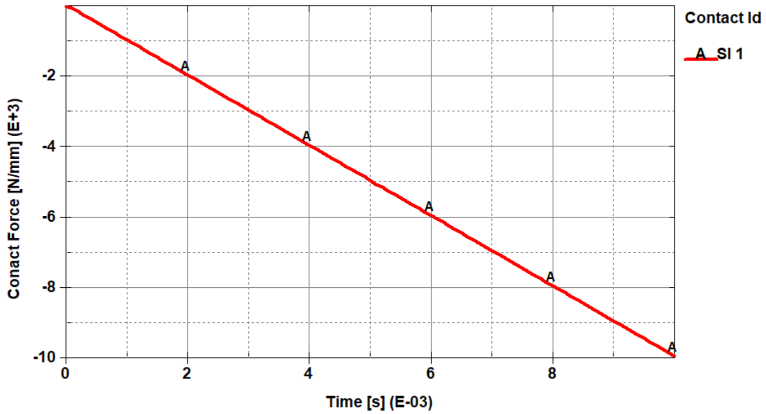
- Force

$$*\mathrm{LOAD} = \frac{Total\ force}{thickness}$$



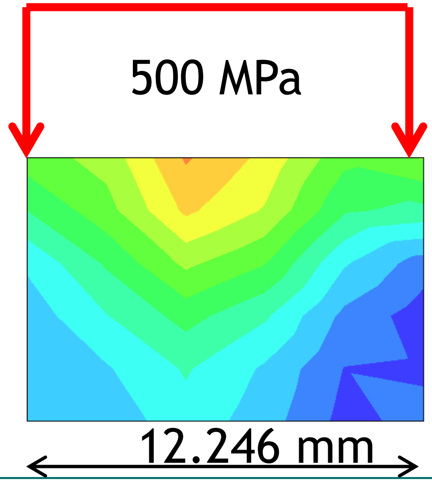


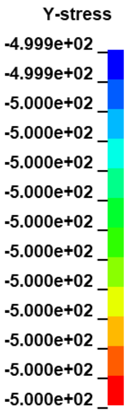
$$\frac{-10.000}{14.236} = -702.444\ MPa$$



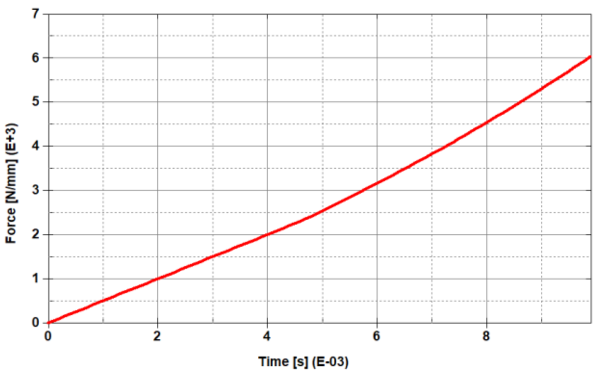
- Pressure

$$*\mathrm{LOAD\_SEGMENT} = Pressure$$





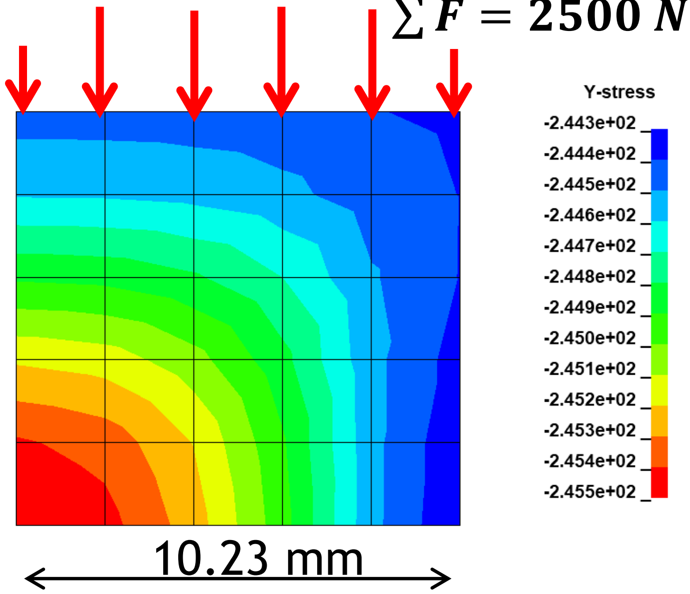
$$500 * 12.246 = 6123\ N/mm$$



Axisymmetric loading - **ELFORM=14**

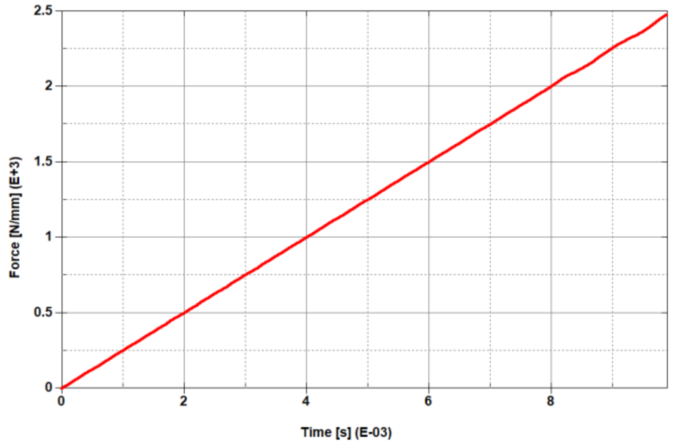
- Force

$$\sum F = 2500\ N/\text{mm}$$

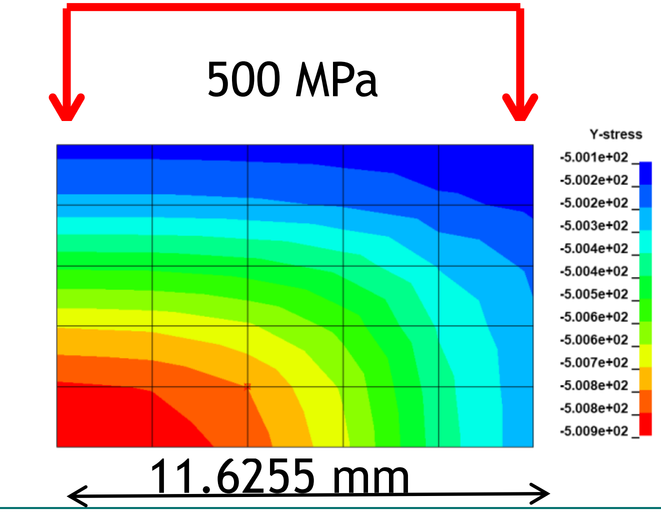


$$\text{*LOAD} = \frac{Total\ force}{R\pi}$$

$$\frac{-2500 * 10.23 * 3.1415}{\pi * 10.23^2} = 244.4MPa$$

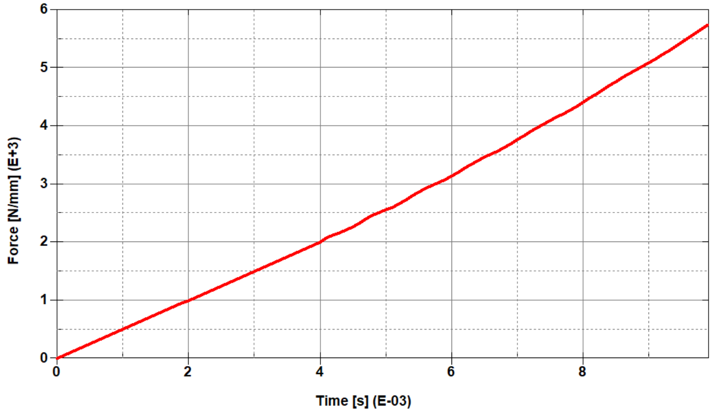


- Pressure



$$\text{*LOAD\_SEGMENT} = Pressure$$

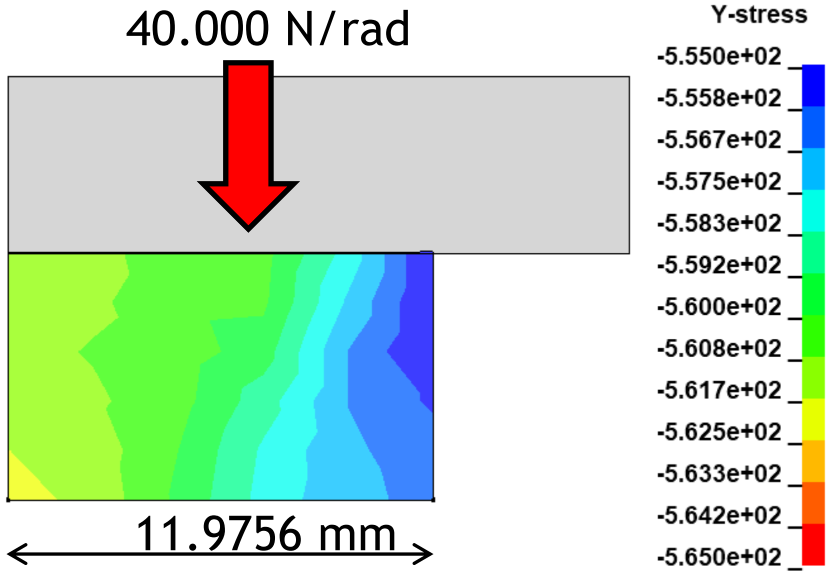
$$\frac{500 * \pi * 11.626^2}{11.626 * \pi} = 5813\ N/mm$$



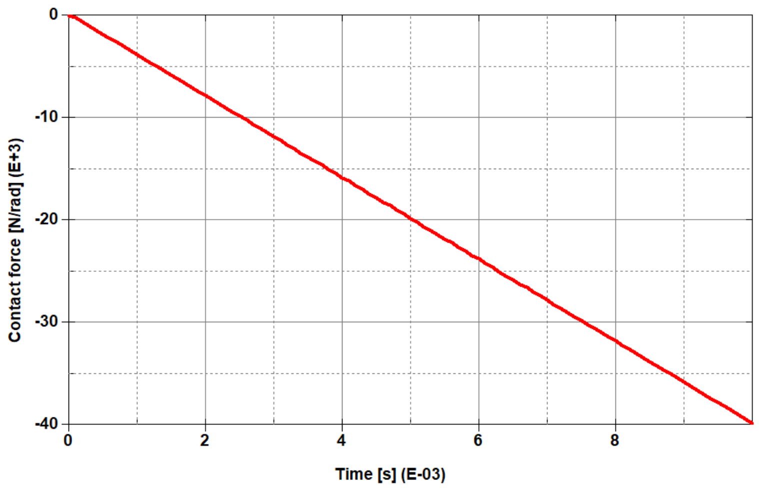
Axisymmetric loading - **ELFORM=15**

- Force

$$\textbf{*LOAD} = \frac{Total\ force}{2\pi}$$

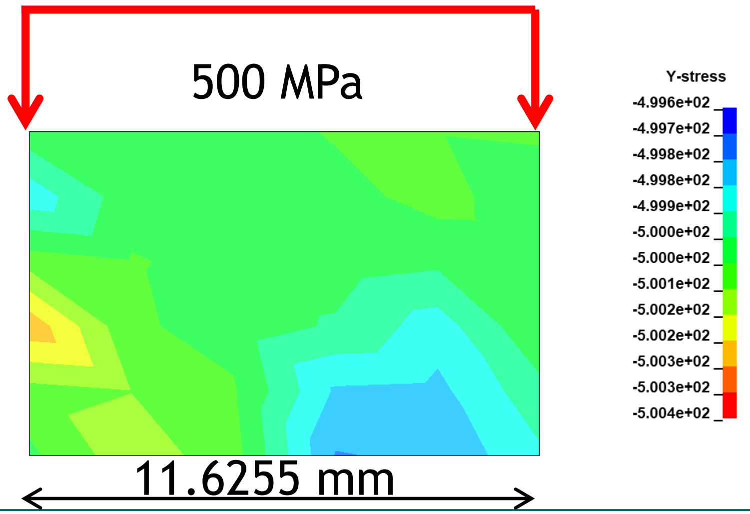


$$\frac{-40.000 * 2\pi}{\pi * 11.9756^2} = 557.8MPa$$

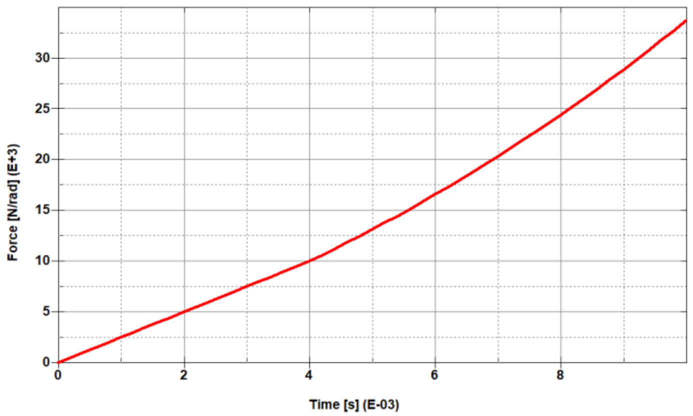


- Pressure

$$\textbf{*LOAD\_SEGMENT} = Pressure$$



$$\frac{500 * \pi * 11.626^2}{2\pi} = 33790\ N/rad$$



Masses reported in d3hsp

- Masses
  - Plane stress/strain: masses are reported per unit thickness
  - Axisymmetric: masses are reported per radian

```
************************************************************

NOTE : For 2D axisymmetric problems the following
       masses are reported per radian.
       For 2D plain strain/stress problems the
       masses are reported per unit thickness.

summary of mass
part id   =        1   mass= 0.13048125E-03
part id   =        4   mass= 0.10718788E-02
part id   =        6   mass= 0.10718788E-02
part id   =        2   mass= 0.16696606E-03 rigid body
part id   =        5   mass= 0.42347945E-03 rigid body
part id   =        3   mass= 0.62054995E-03 rigid body

t o t a l  m a s s           = 0.34852345E-02
x-coordinate of mass center = 0.21127326E+01
y-coordinate of mass center = 0.11164410E+02
z-coordinate of mass center =-0.19288202E-17



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```
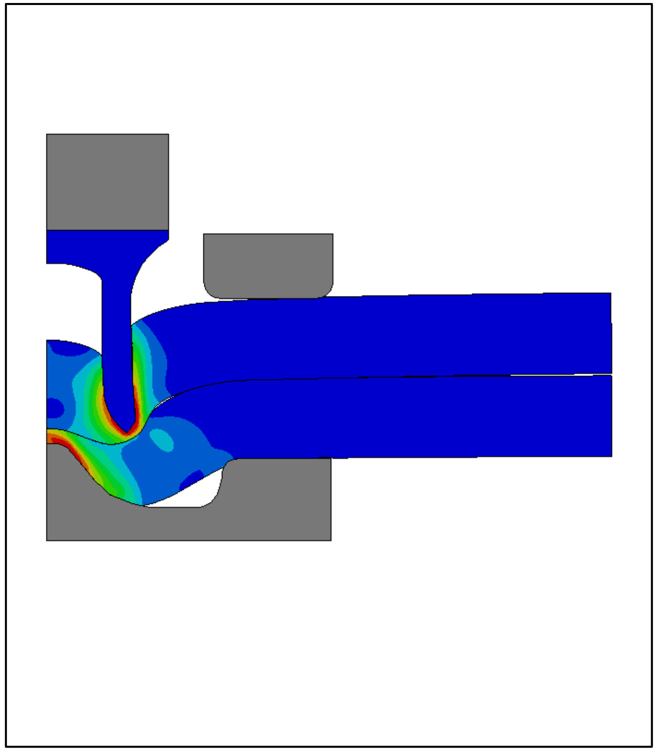
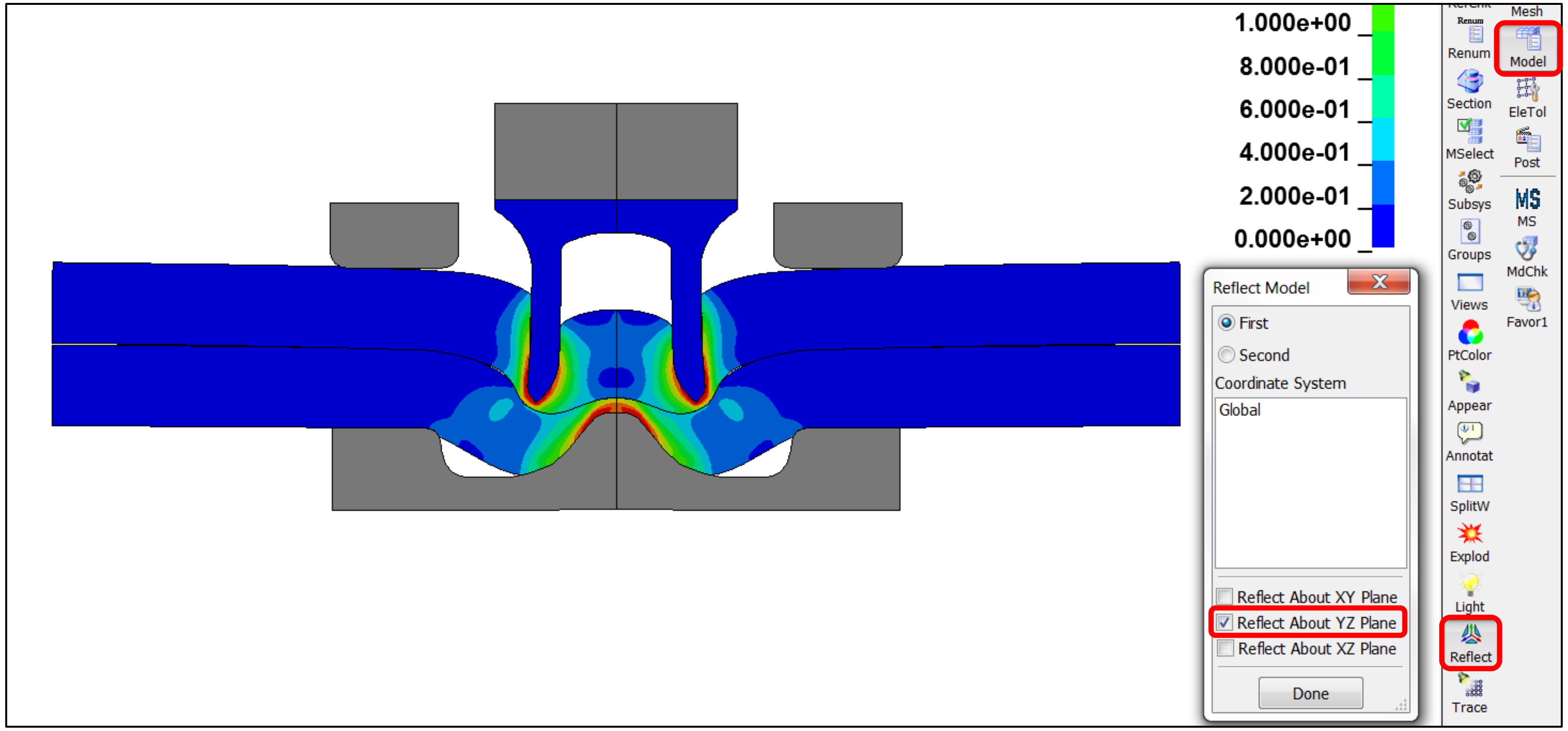

Results

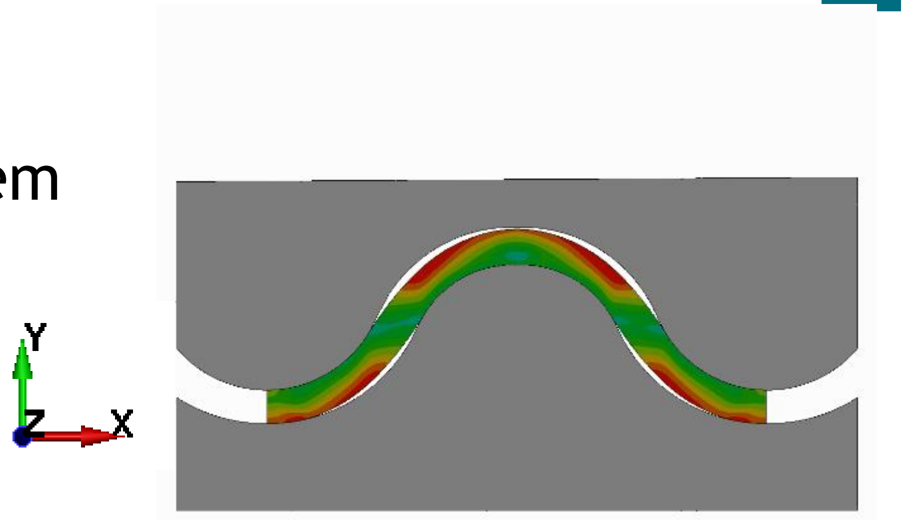
- Reflect results in LS-PrePost
  - Model > Reflect > Reflect About YZ Plane



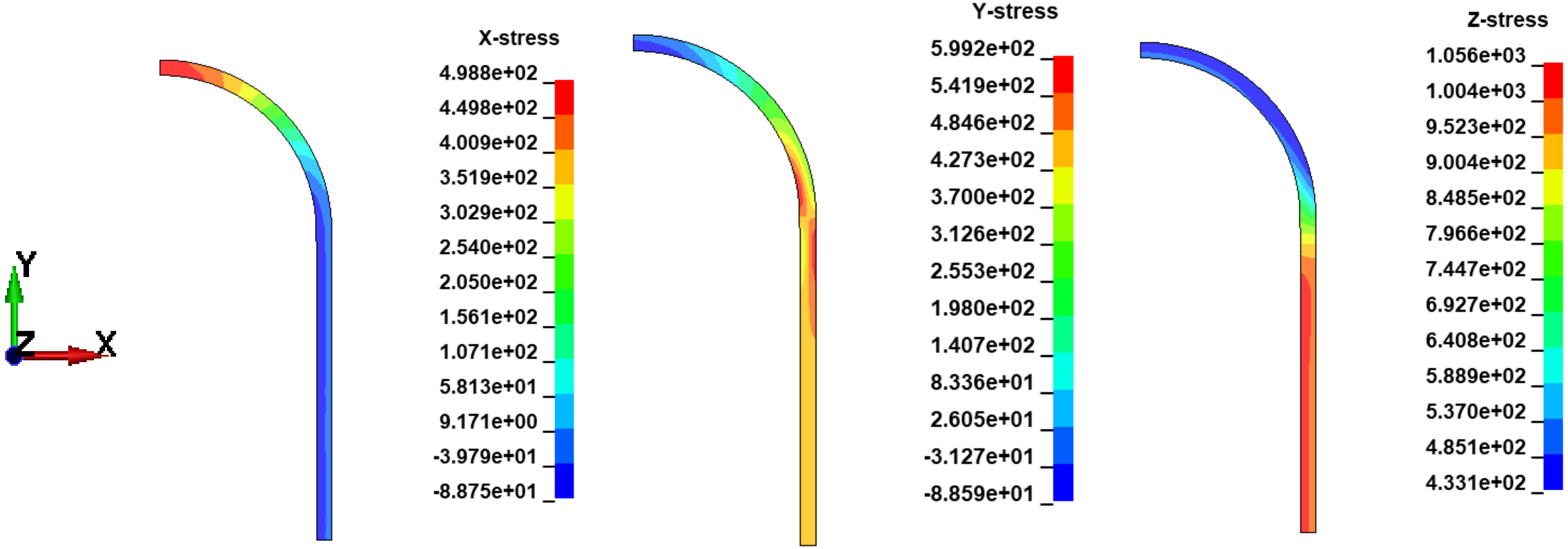


2D stress evaluation in LS-PREPOST

- Stresses are output in the global coordinate system
- Plane strain
  - Stresses follows the global axis
- Axisymmetric



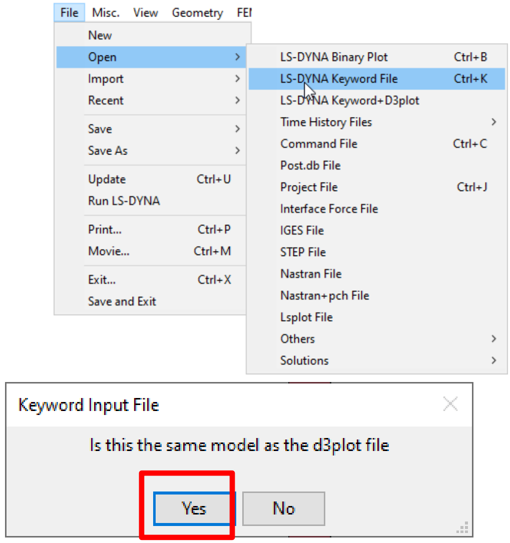
$$\sigma_r = \sigma_x$$
$$\sigma_\varphi = \sigma_z$$
$$\sigma_z = \sigma_y$$



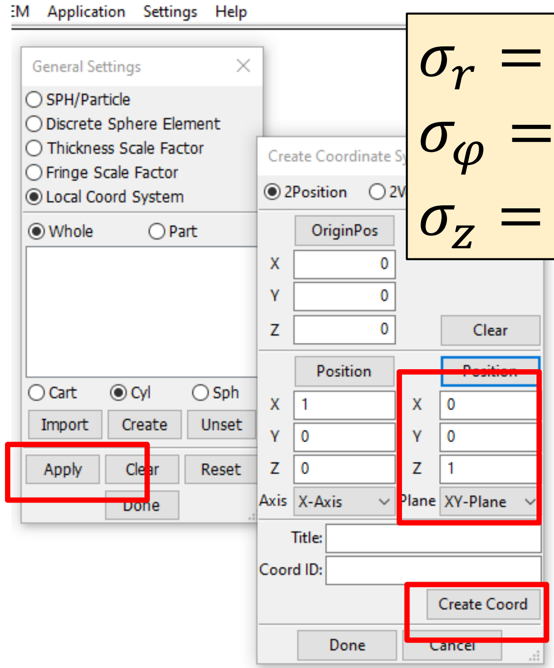
Axisymmetric/Spherical coordinates – LS-PREPOST

- In LS-PREPOST local cylindrical or spherical coordinate systems can be used to plot the stresses and strains.

Import the keyword file into the post-processing session

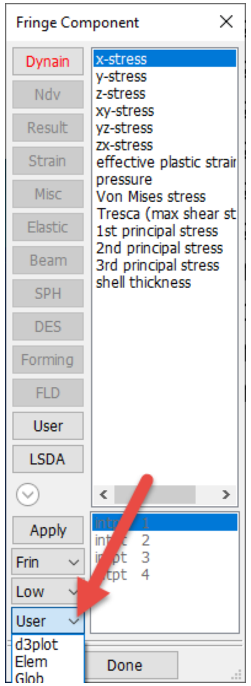


Create a local coordinate system

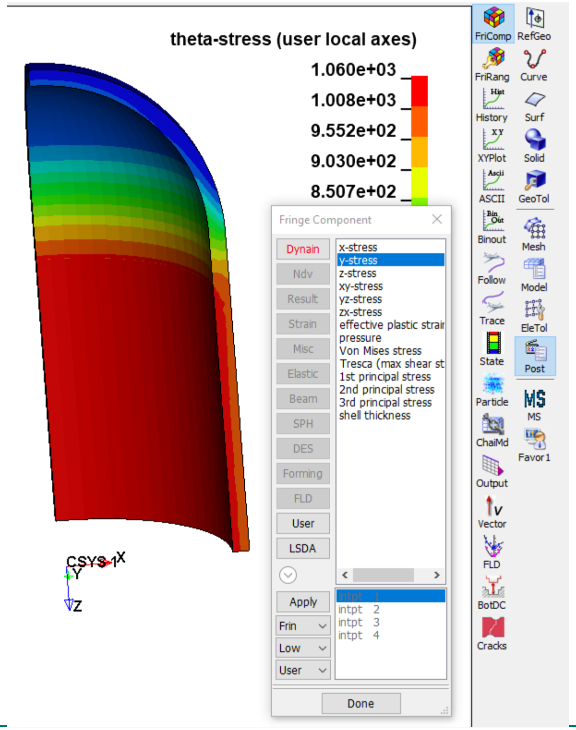


$$\sigma_r = \sigma_x$$
$$\sigma_\varphi = \sigma_z$$
$$\sigma_z = \sigma_y$$

Select user under Fringecomponent



x, y and z stress is now r, φ and z



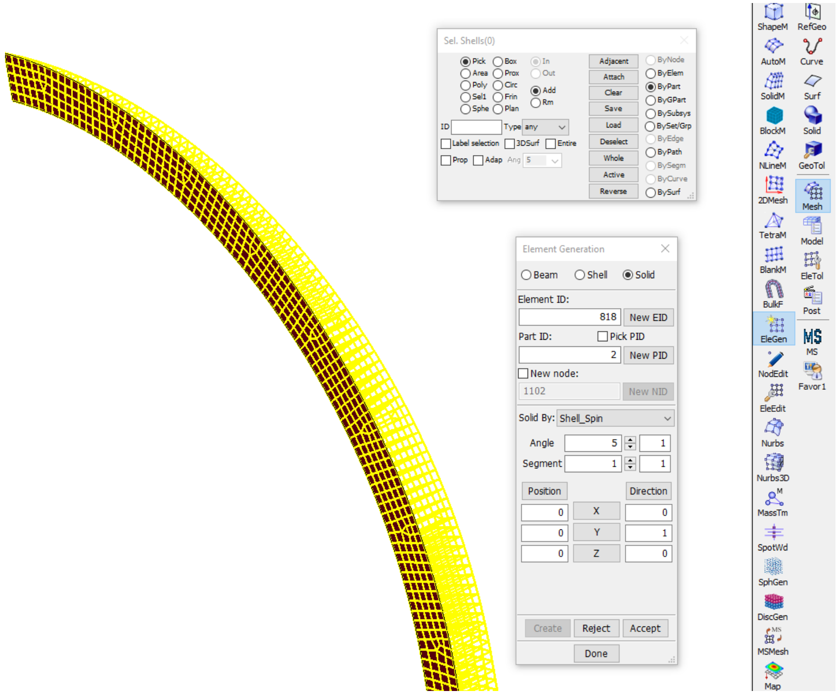
From 2D results to 3D results

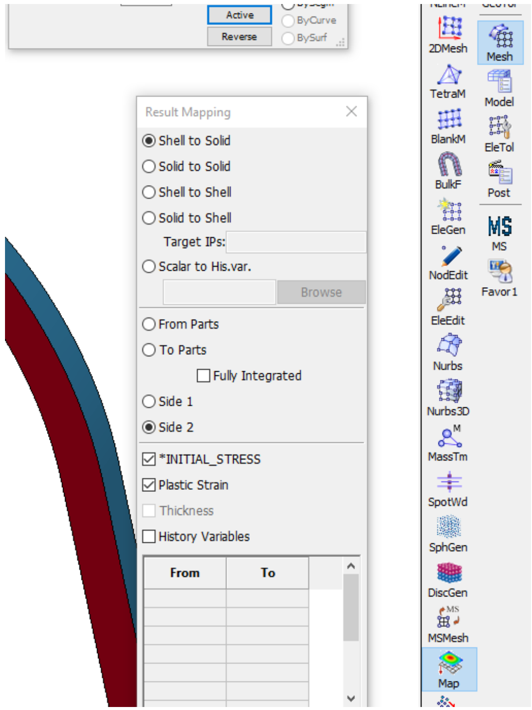
- Using the dynain file and the mapping functionality in LS-PREPOST, it is possible to generate 3D results from a 2D simulation

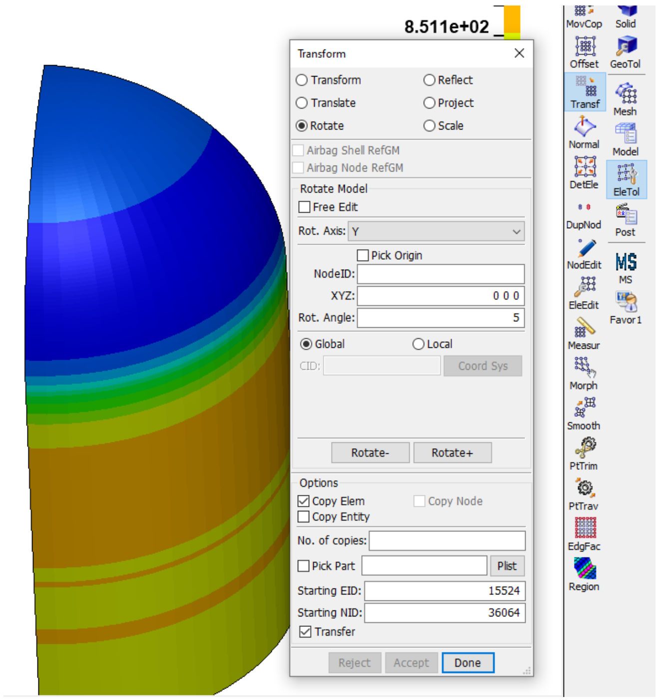
Import the dynain and create 1 row of solids using shell spin.

Map results from the shell mesh to the solid elements

Copy the elements using element tools transform

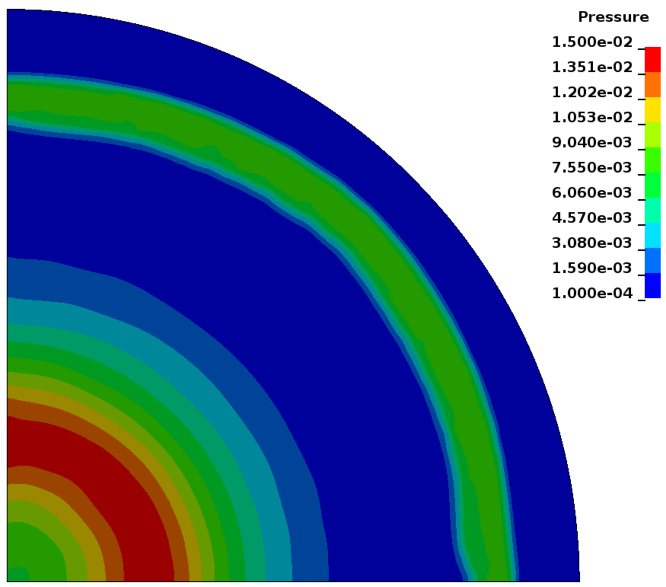




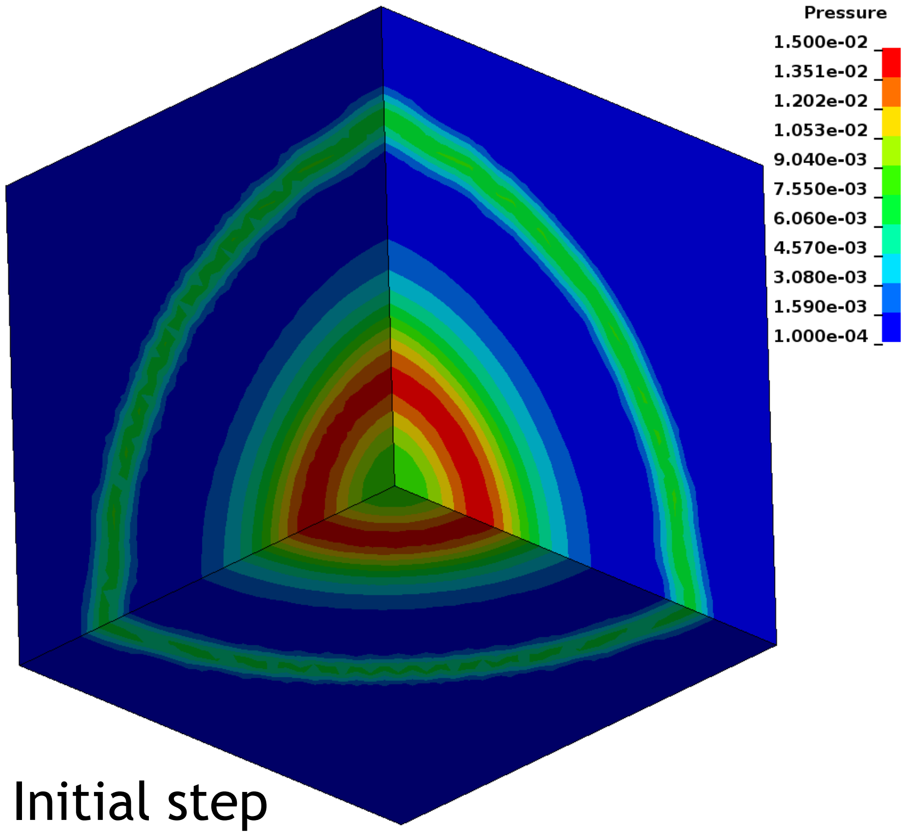


Application - Axisymmetric: Map 2D detonation to 3D

- 2D - fine mesh
  - ls-dyna i=main_2D.k map=2dto3d
- 3D - coarse mesh
  - ***INITIAL_ALE_MAPPING**
  - ls-dyna i=main_3D.k map=2dto3d



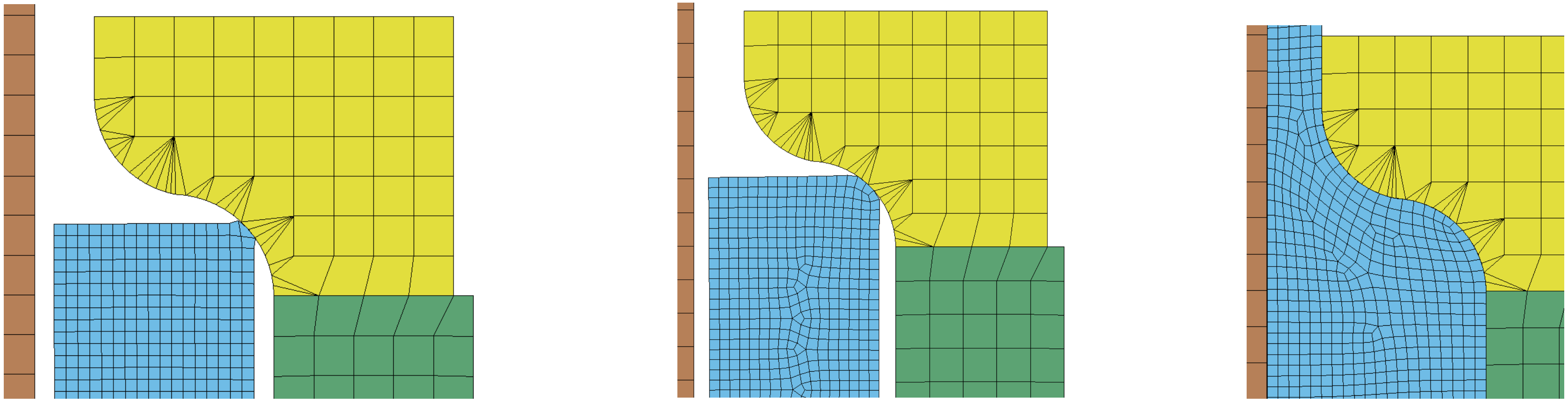
Final step



Initial step

Adaptivity in 2D

- Adaptivity is powerful for modeling large deformation problems to avoid mesh distorsion.
- Adaptivity in 2D is based on remeshing where a completely new mesh is generated and the results are mapped
- Remeshing is triggered by time increments
- Nodal constraints are lost.
  - Use **`*CONTRAINED_GLOBAL`** or **`*CONSTRAINED_LOCAL`** for constraints
  - Define movements by **`*PART`** not by **`*NODE_..`** or **`*SET_NODE`**



Adaptivity in 2D - *CONTROL_ADAPTIVE

```
*CONTROL_ADAPTIVE
$#  adpfreq    adptol    adpopt    maxlvl    tbirth    tdeath     lcadp    ioflag
       0.30       0.1         8         3
$#  adpsize    adpass    ireflg    adpene     adpth    memory    orient     maxel

$#  ladpn90    ladpgh    ncfred    ladpcl    adpctl    cbirth    cdeath     lclvl
                                        1
$#     cnla
```

- **adpfreq:** Time interval between remeshing
- **adptol:** Characteristic element size
- **adpopt:** 8 is r-adaptive remeshing for 2D shell elements.
  -8 self contacting material will not be merged.

Adaptivity in 2D – cont.

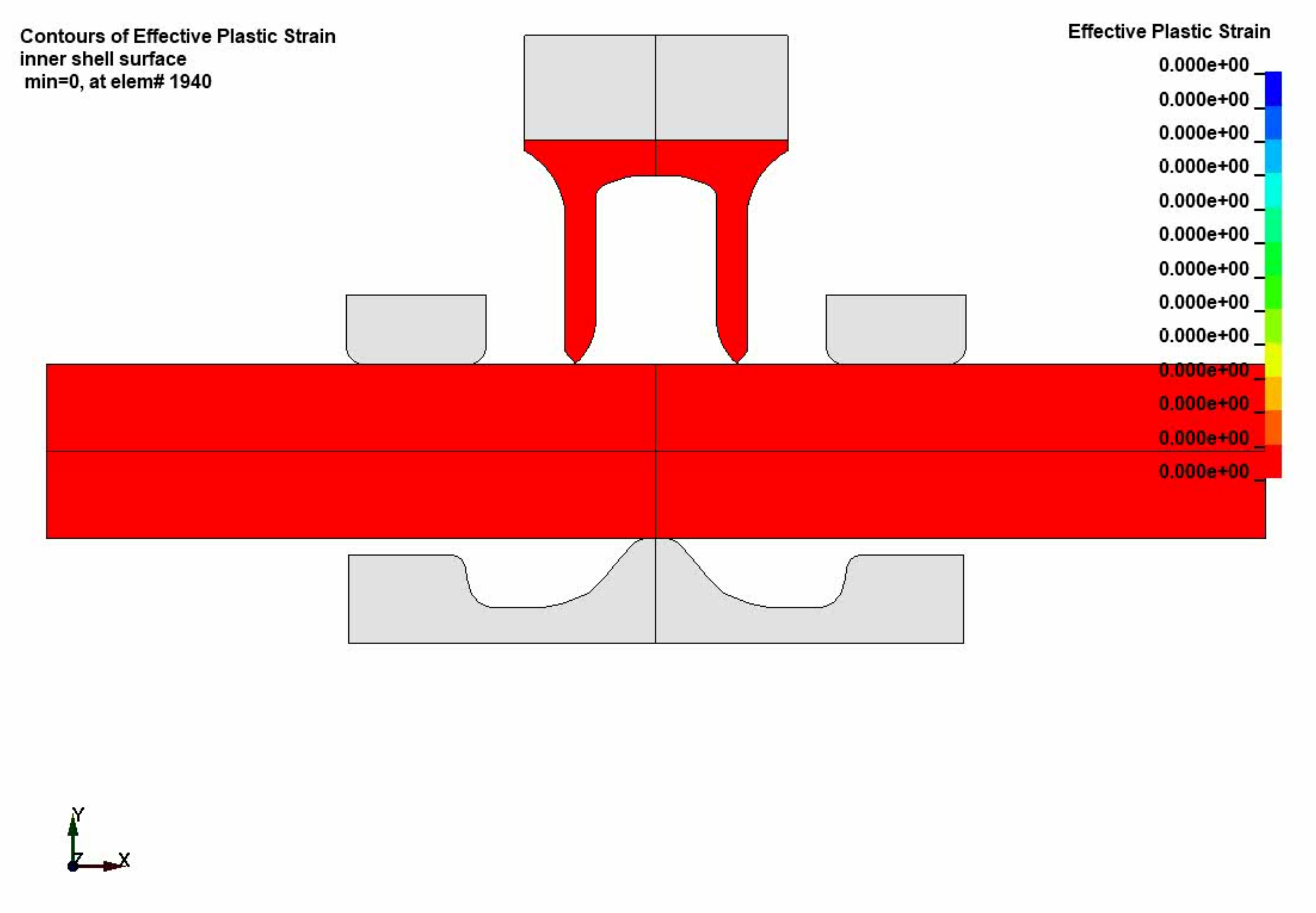
```
*PART
$# title
Steel Rivet
$#      pid      secid        mid      eosid       hgid       grav     adpopt       tmid
          1          1          3                                          2
```

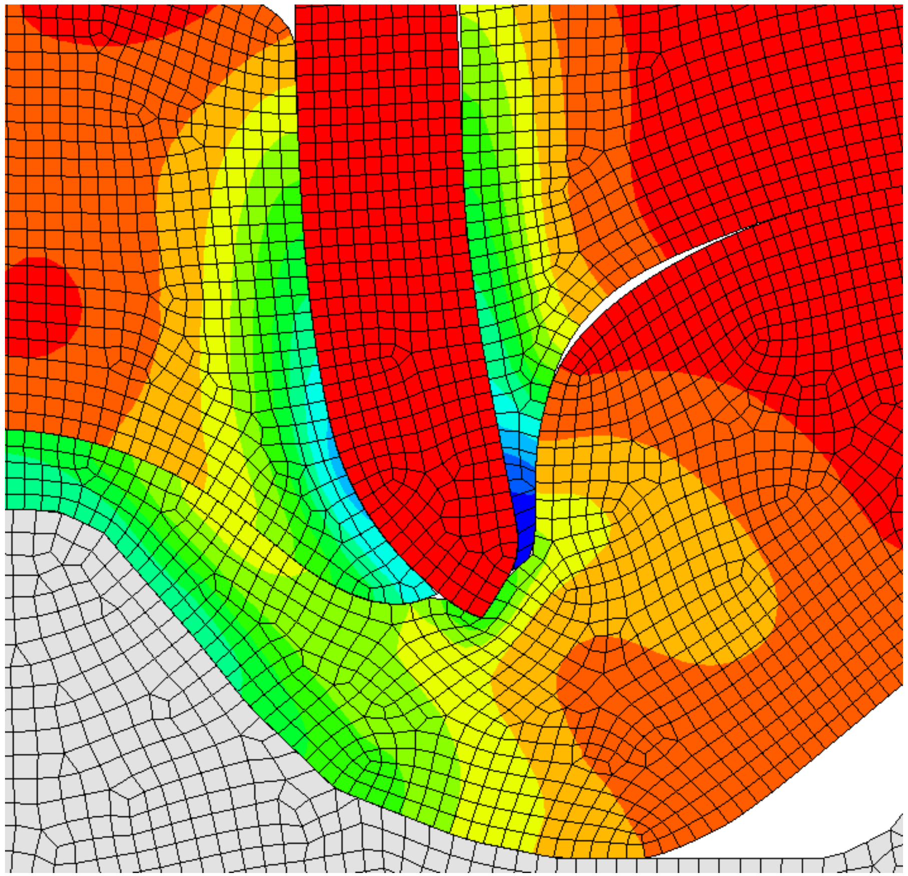
- **`adpopt:`**2 activates r-adaptivity for that part

```
*PART_ADAPTIVE_FAILURE
$#      pid          t
          4       0.10
```

- Allows for a part to split into two parts. Useful for modeling failure.
- **`pid:`**Part id to which is applies
- **`t:`**Minimum thickness before it is split into two parts. Should be in the order of the element size.

Application - Axisymmetric: Self-Piercing Rivet





Conclusion

- 2D simulations can be done using implicit/Explicit, mpp/smp, Lagrange/Euler/ALE and CFD
- The modeling is done in the x,y plane and in the axisymmetric case with the y-axis as the symmetry axis.
- 2D has its own contacts, otherwise use regular keywords and materials
- Input/Output of forces and pressures are treated different depending on the choice of element.
- It is possible to convert 2D results to 3D results either by using LS-PREPOST or functionality in LS-DYNA (ALE).
- 2D adaptivity is based on remeshing

Thank you!

Your LS-DYNA distributor and more