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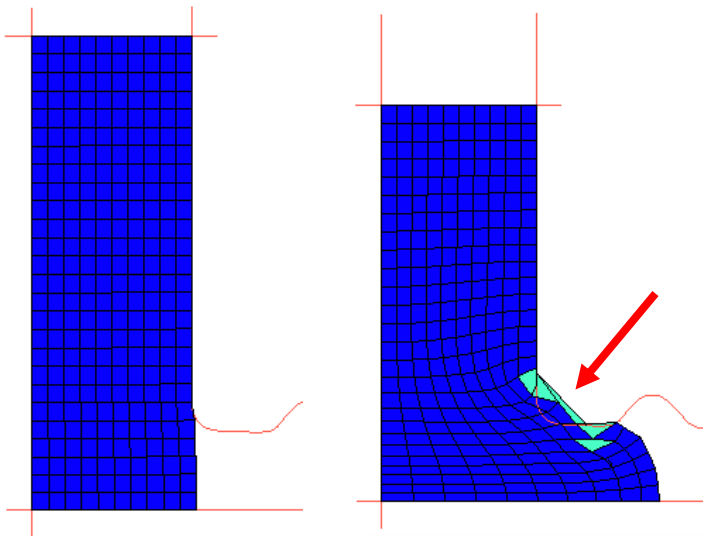
# Remeshing In Metal Forming and Rubber Seal Simulations with MSC.Marc and MSC.SuperForm

Gary Huang and Ted Wertheimer, MSC.Software Corp.  
Goang-Ding Shyu, Baker Oil Tools

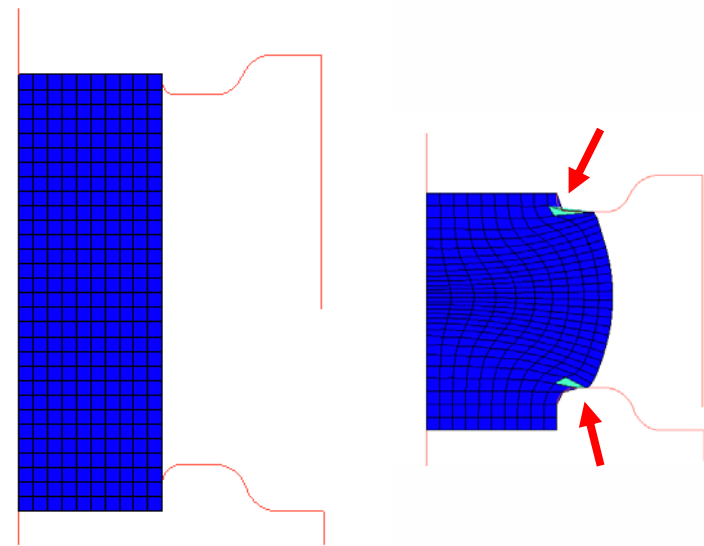


# Why Remeshing?

- Large deformation causes element distortion
- Large deformation causes incorrect boundary presentation



Rubber Seal Deformation  
without remeshing



Forging without remeshing



# Remeshing Steps – Automatic!

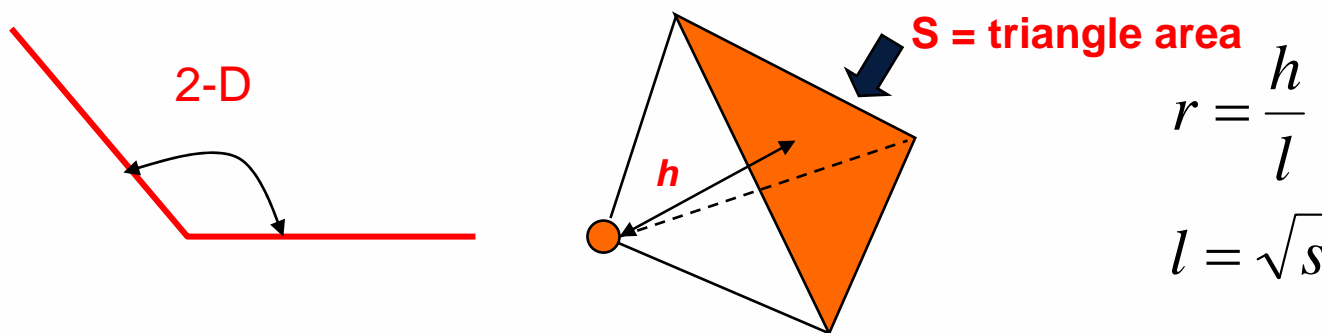


- Need remeshing? – Remeshing Criteria
- Prepare remeshing data – remeshing controls
- Call a mesh generator
- Replace mesh
- Transfer history data to new mesh
- Transfer boundary conditions to new mesh
- Resume analysis



# Remeshing Steps: Remeshing Criteria

- Increment frequency
  - Remesh after certain number of increments
- Strain change value
  - Remesh after an accumulated strain reaches a given limit
  - The accumulated strain is computed at element level
  - The accumulated strain is reset to zero after remeshing
- Element shape distortion
  - Default 2-D element inner angle:  $>175^\circ$  or  $<5^\circ$  or given angle
  - Default 3-D element volume ratio:  $r < 0.01$  or a given value



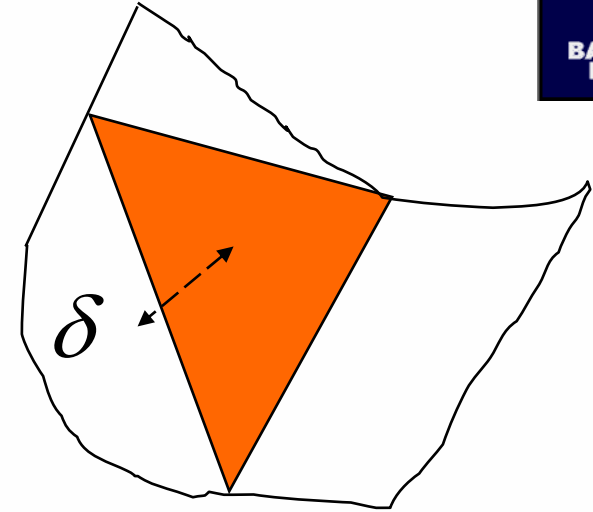
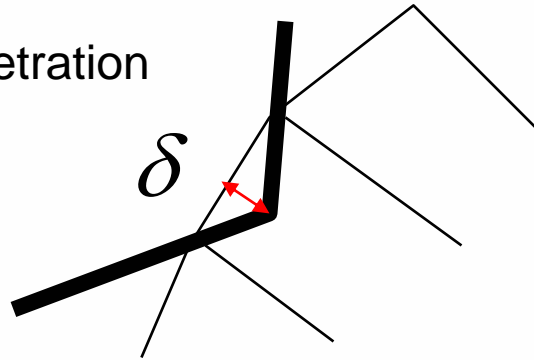


## Remeshing Steps: Remeshing Criteria

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- Contact penetration

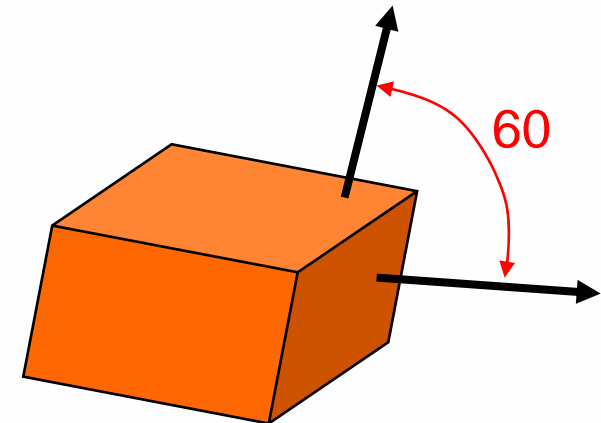
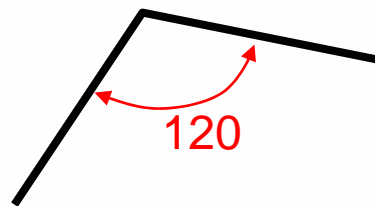


- Element angle deviation
  - For 2-D only - check inner angle change after remeshing
- Immediate (Forced remeshing)
  - Remesh before next analysis increment
  - Useful for element type change – from hex to tet element
- Cut-back (Internally forced remeshing)
  - This is used internally when there is an element distortion during analysis before time step cut-back



## Remeshing Steps: Remeshing Controls

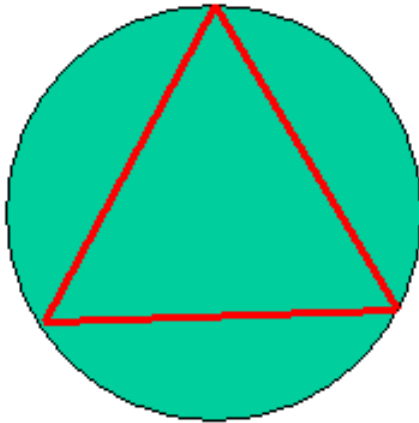
- New element size – controlling mesh size
  - Minimum element size – default  $0.33 * \text{element size}$
  - Maximum element size – default  $3 * \text{element size}$
- New number of elements
  - Approximate – new element size is computed based on area/volume
- Feature angles – controls what corners/edges to keep
  - Default 2-D: 120 degree and smaller
  - Default 3-D: 60 degree and larger



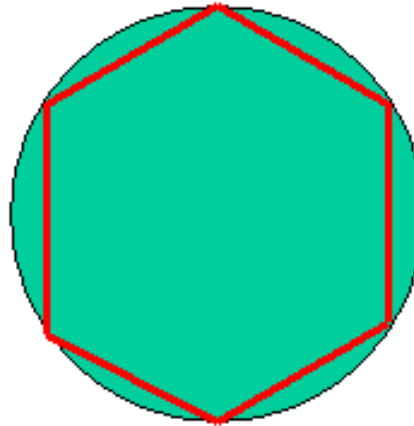


# Remeshing Steps: Remeshing Controls

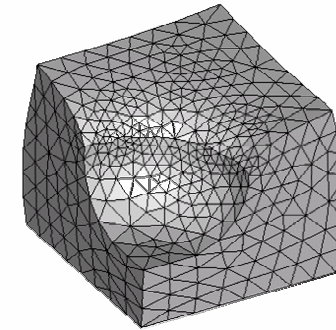
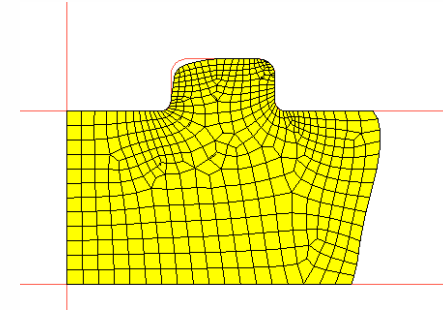
- Curvature dependency – divisions



Division = 3



Division = 6

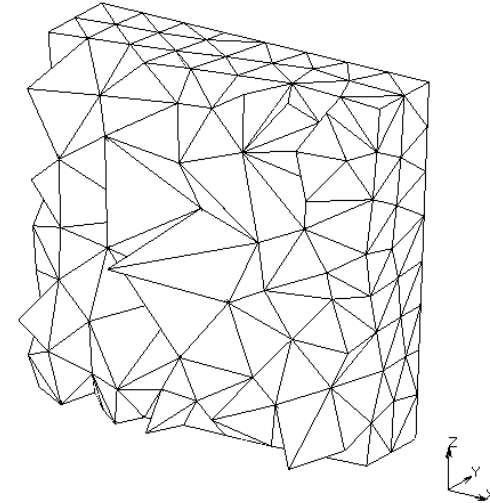
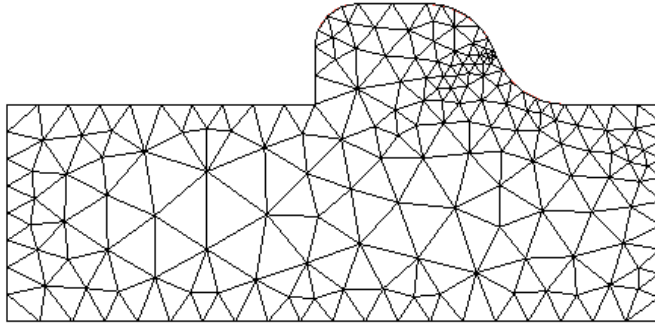


- With the same divisions, the greater the curvature the finer the mesh



# Remeshing Steps: Remeshing Controls

- Interior element coarsening



- Coarsening factor is used to enlarge interior elements
- Preserve good surface contact but reduce computational effort



## Remeshing Steps: Remeshing Controls

- Refinement boxes
  - Place small elements inside the refinement boxes
  - User subroutine for 2-D local refinement – `usizeout.f`
  - Refinement boxes can move with rigid bodies
- User subroutine for 2-D body split – `usplit.f`
  - Split a remeshing body when a thin section is reached
- Trimming – 2-D only
  - Used in metal forming to remove unwanted material part



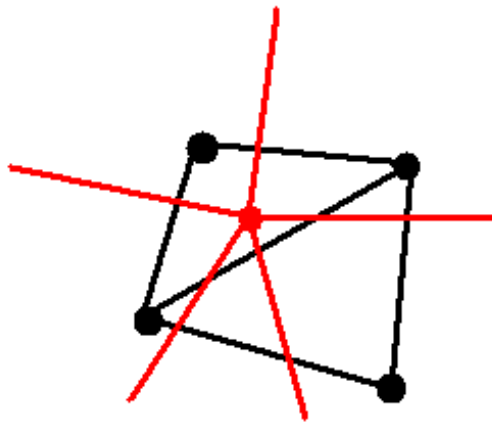
## Remeshing Steps: Mesh Generators

- 2-D Advancing front mesher – tri and quad element
- 2-D Delaunay mesher – triangle element
- 2-D Overlay mesher – quad element
- 3-D MSC.Patran (MOM and Hybrid) mesher – Tetrahedron element
- 3-D Overlay mesher - Hexahedron element



## Remeshing Steps: Data Mapping

- History data mapping
  - Extrapolate element data to nodal position in the old mesh
  - Average nodal data contribution from neighboring elements
  - Locate new nodal position within old mesh
  - Interpolation to obtain nodal data at the new nodes
  - Compute element data from nodal data in the new mesh
  - Analysis resume to achieve new equilibrium

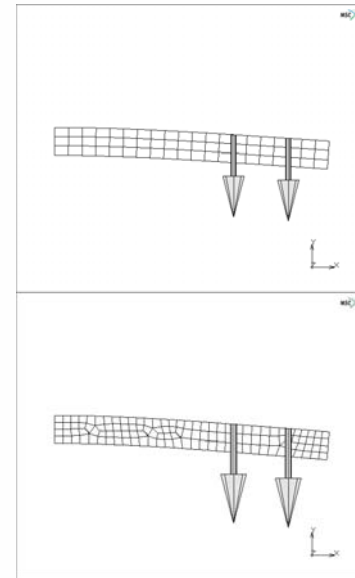


$$\mathbf{s}_{new} = \mathbf{N}\hat{\mathbf{s}}_{old}$$

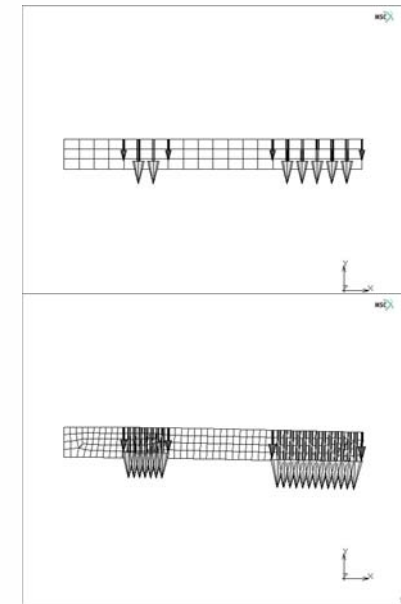


# Remeshing Steps: Data Mapping

- Boundary conditions (new for MSC.Marc 2005)
  - Apply boundary conditions to a 2-D mesh or geometry entities
  - Geometry entities are attached to mesh entities
  - Boundary conditions are grouped in SETS
  - Points and curves with boundary conditions are kept as “hard” points and “soft” edges during remeshing
  - Obtain the “hard” points and “soft” edges from the new mesh
  - Re-associate boundary conditions to the “hard” points and “soft” edges



Point loads



Edge loads

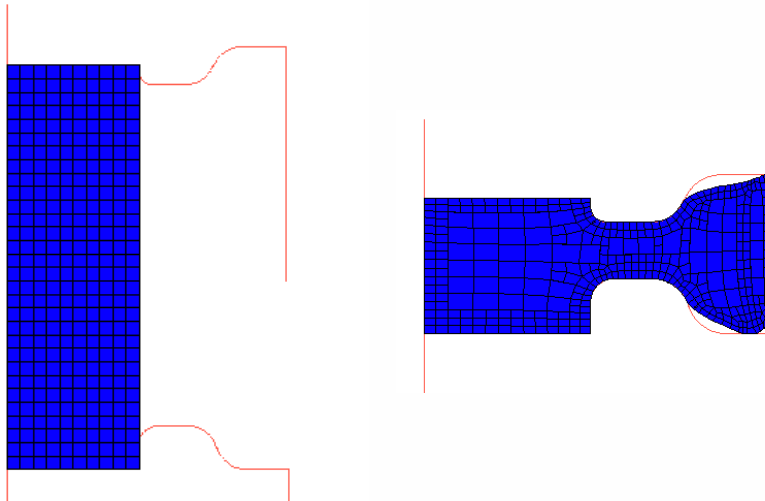




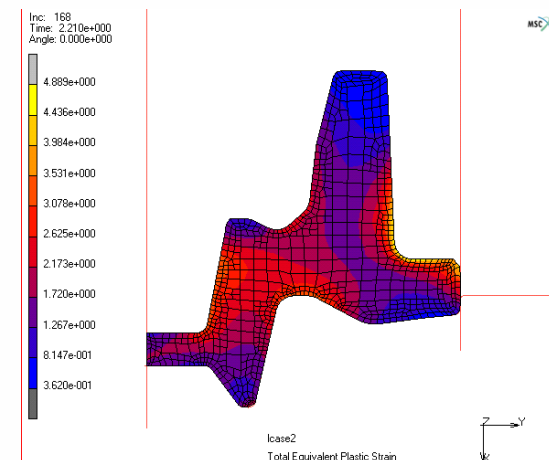
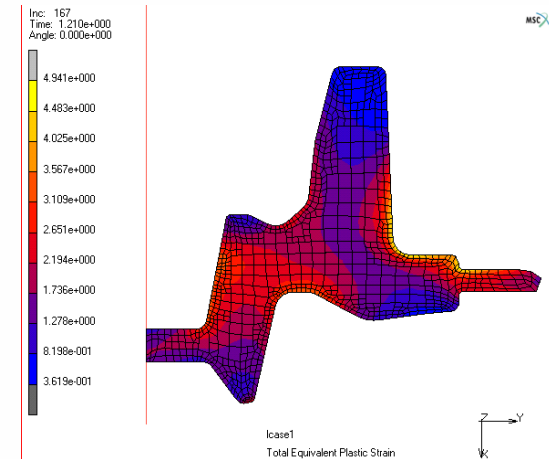
# Metal Forming: 2-D overlay mesher

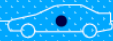
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- refinement and coarsening using tying
- 2-D Trimming

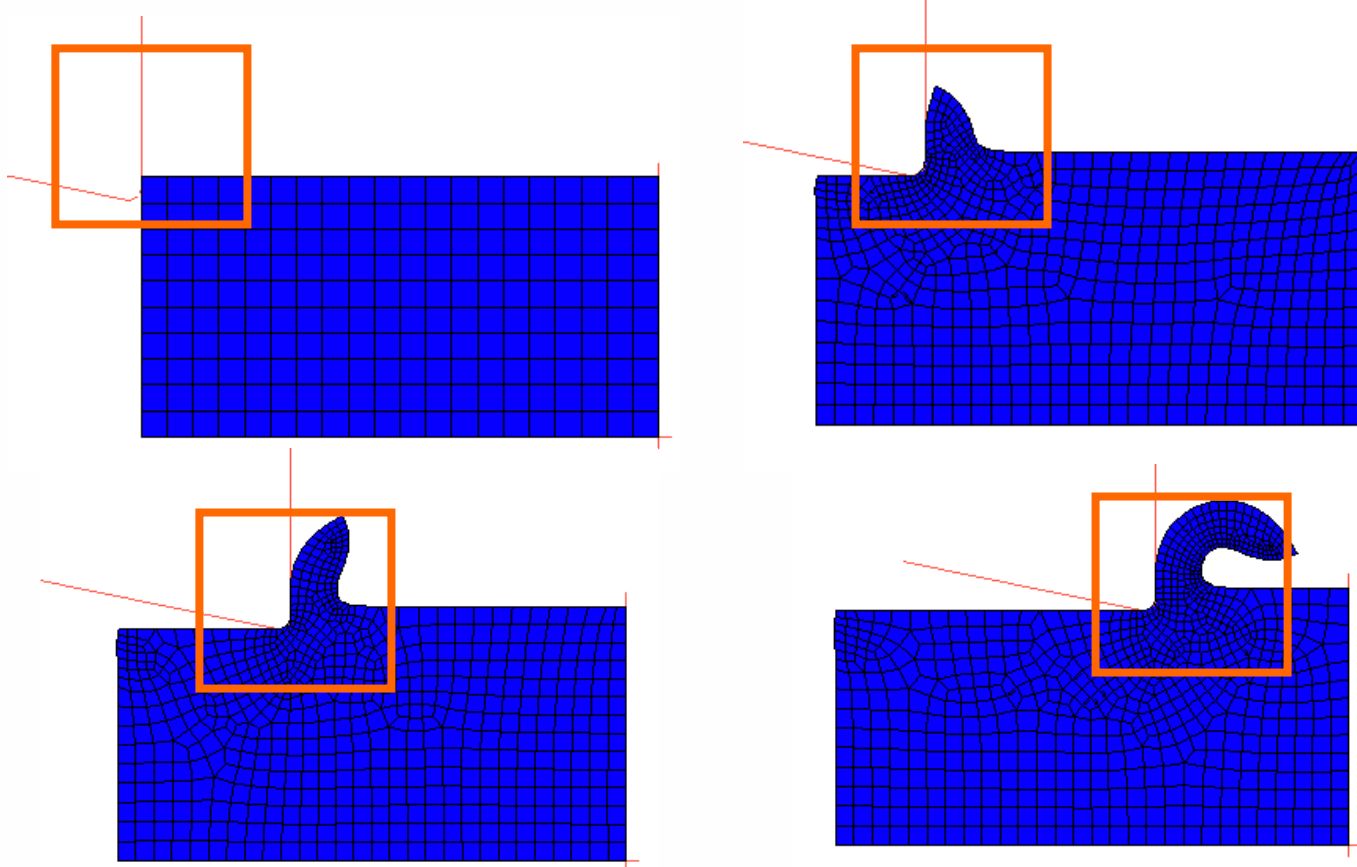




## Metal Forming: 2-D advancing front mesher

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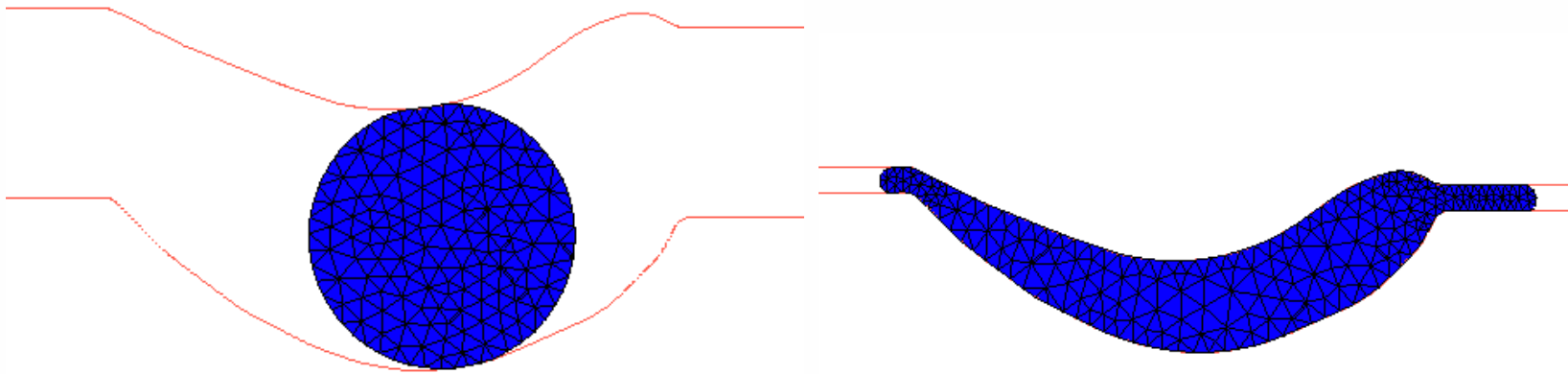
- moving local refinement box using `usizeout.f`



# Metal Forming: 2-D Delaunay mesher

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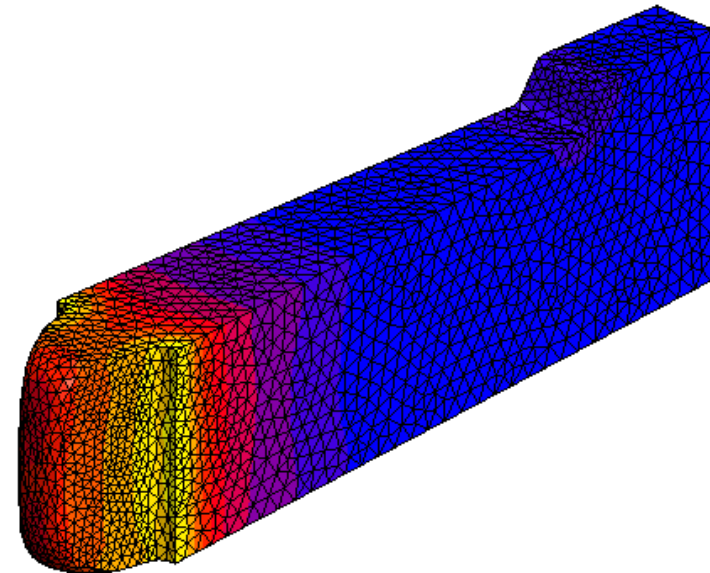
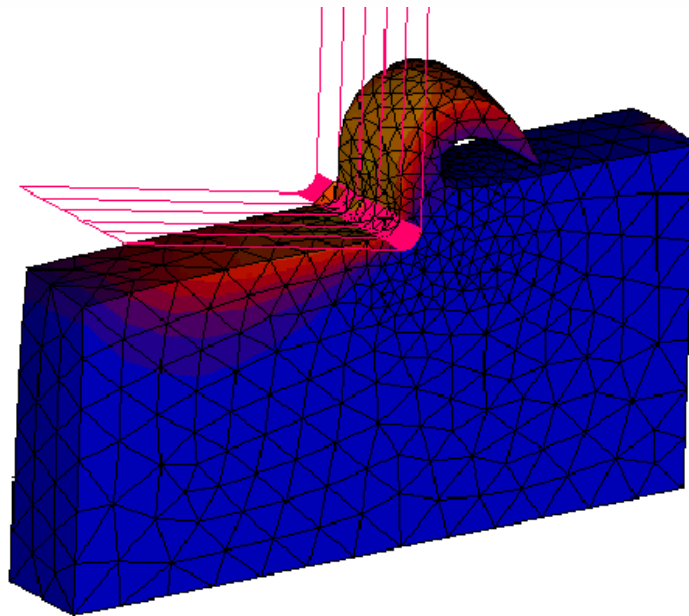
- local refinement based on curvature



# Metal Forming: 3-D MSC.Patran mesher

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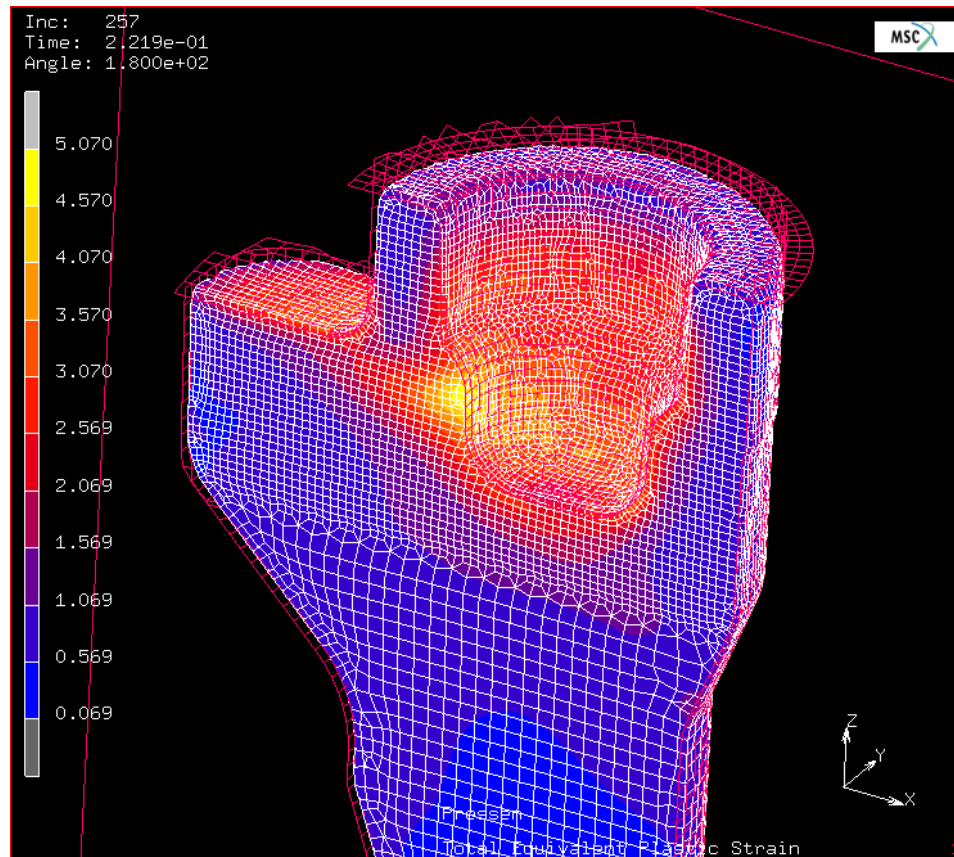
- local refinement based on curvature and refinement box



# Metal Forming: 3-D Hex mesher

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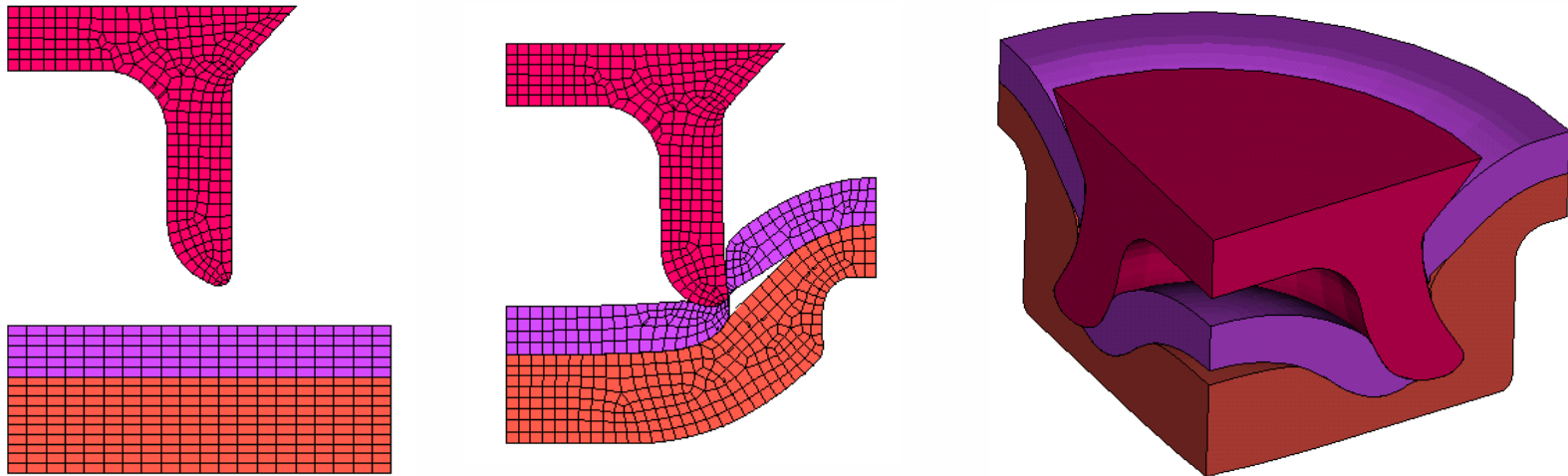
- local refinement based on refinement box



# Metal Forming: material split using USPLIT.F

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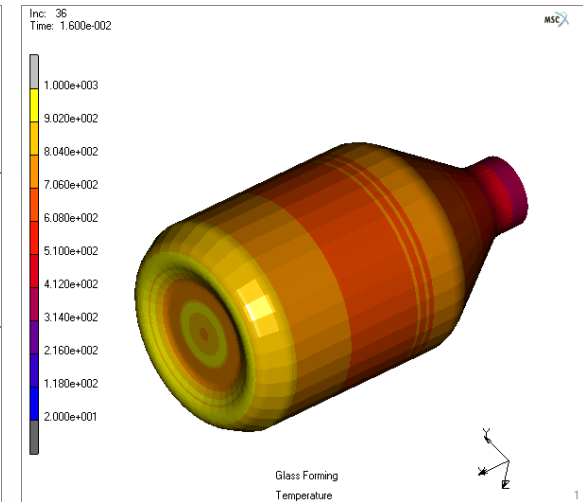
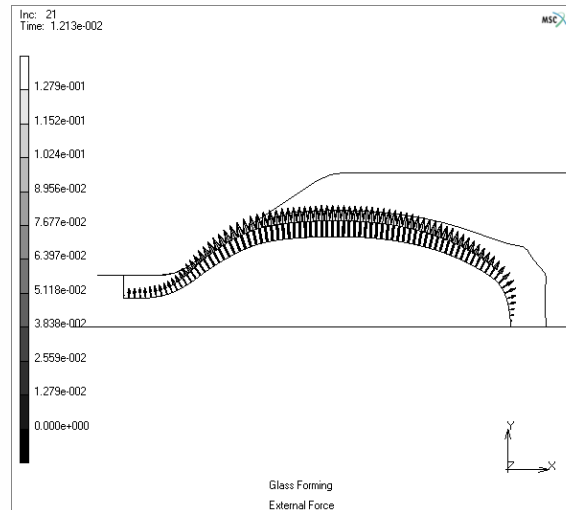
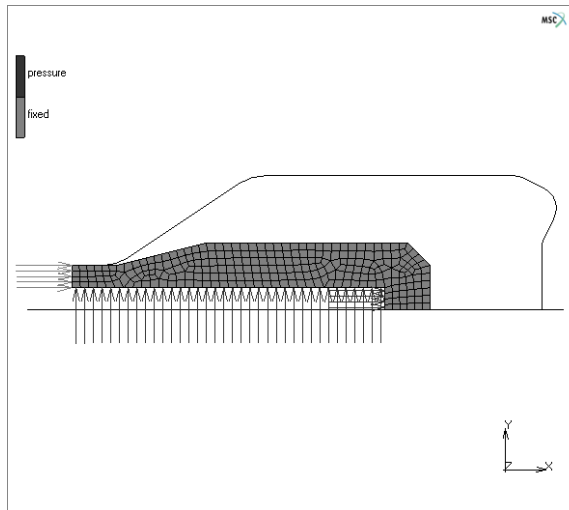
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- self rivet installation



# Glass Forming: Boundary Conditions



- Glass forming of a container with Internal Pressure



## Future Development in Remeshing

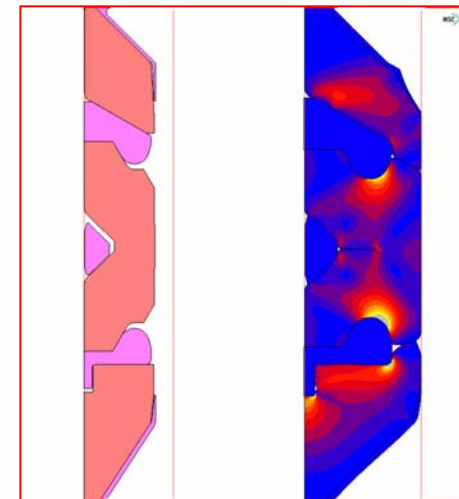
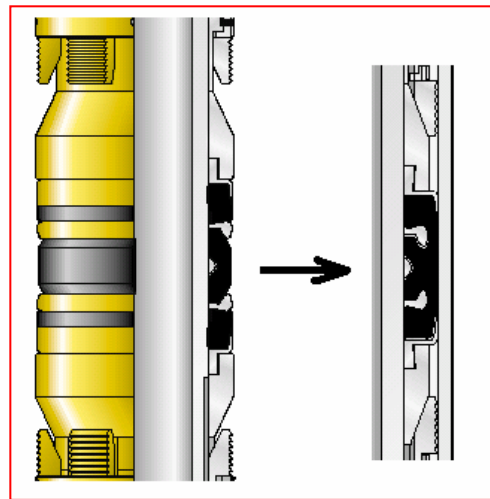
- Boundary Conditions mapping in 3-D remeshing
- Remeshing with DDM parallelization
- 3-D Surface Remeshing for Sheet metal forming
- 3-D Trimming



# Seal Analysis

## Design Considerations

- Pressure Differential
- Extrusion Gap
- Seal Geometry
- Backup System
- Temperature
- Duration of usage
- Chemical Environment



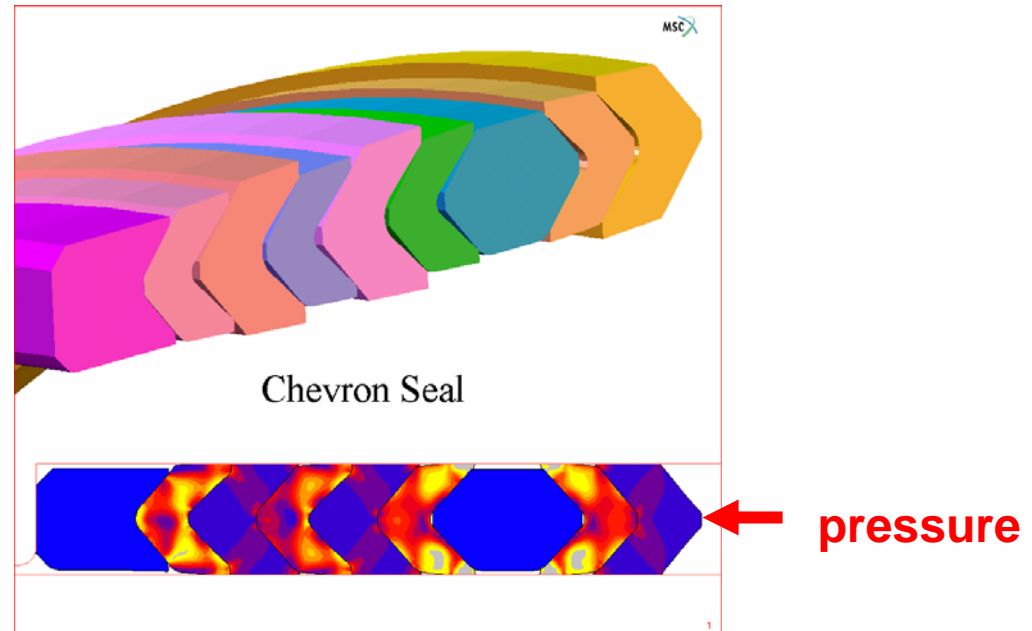
Packer



# Seal Analysis

Analysis Considerations:

- Which Material Model to Use ?
- Large Deformation
- Self-Contact ?
- Remeshing ?
- Will Local Damage Affect the Sealing Capability ?

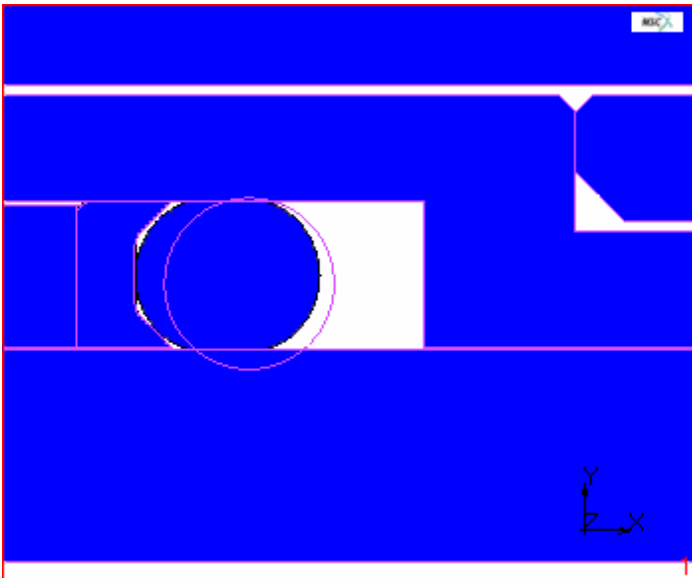




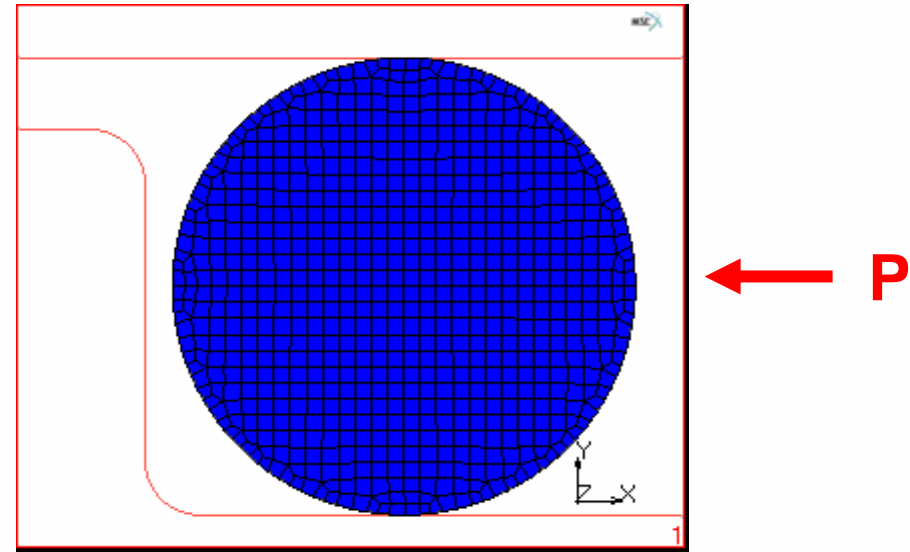
# Seal Analysis - Examples

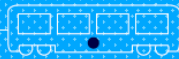
## O-Ring

With Backup

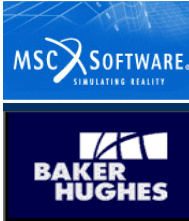


Without Backup



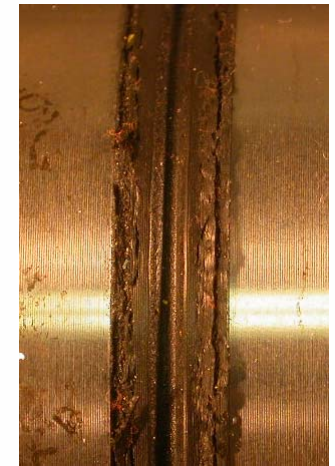
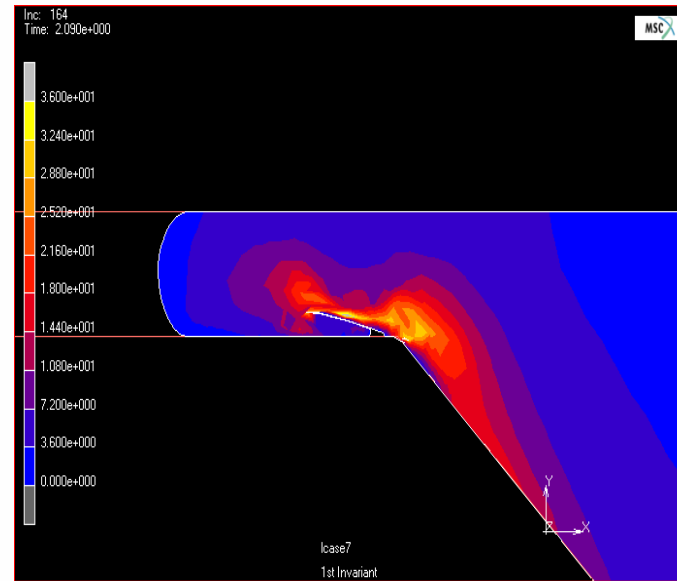
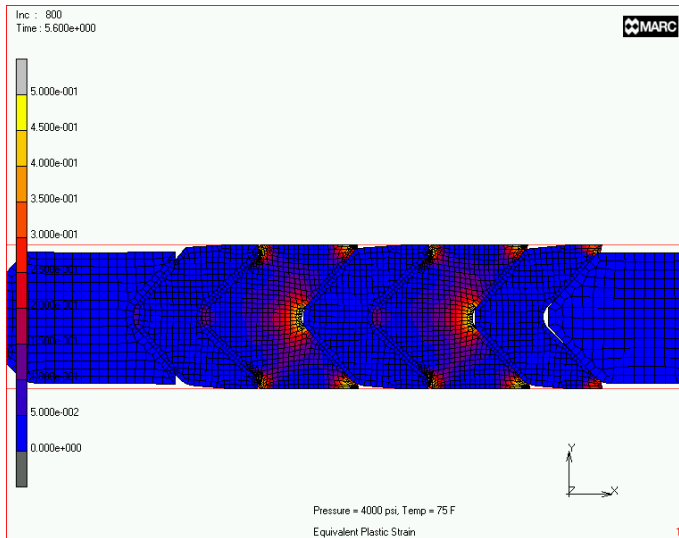


# Seal Analysis - Examples



## Chevron Seal

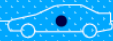
## Bonded Seal



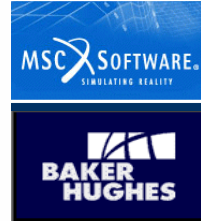
Passed the test at 6,000 psi

FEA: Fracture starts at 2,800 psi.

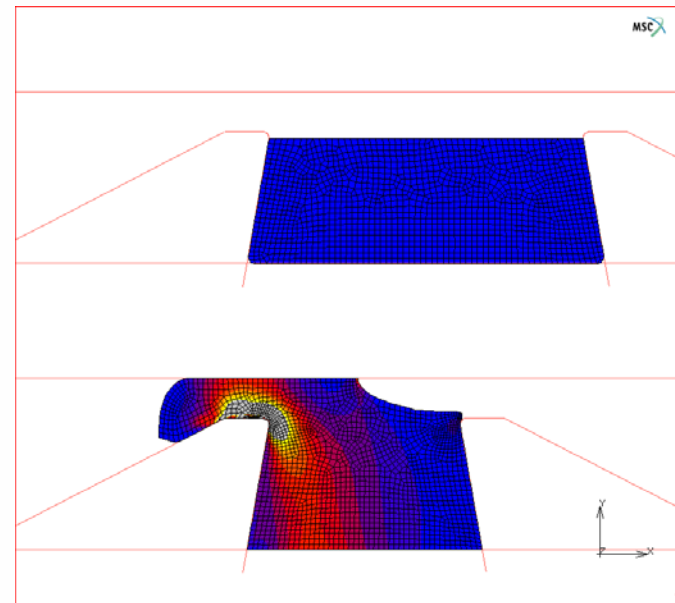
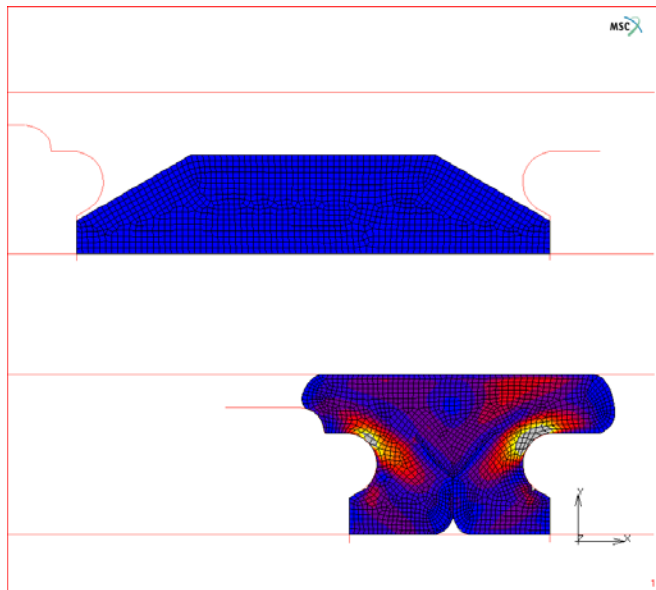
Test: At 6,000 psi, the seal still holds pressure in spite of heavy damage.



# Seal Analysis - Examples



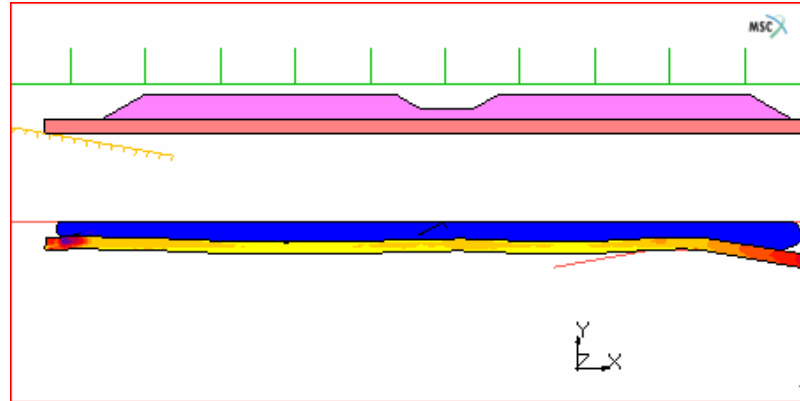
Retrievable and Permanent Packer



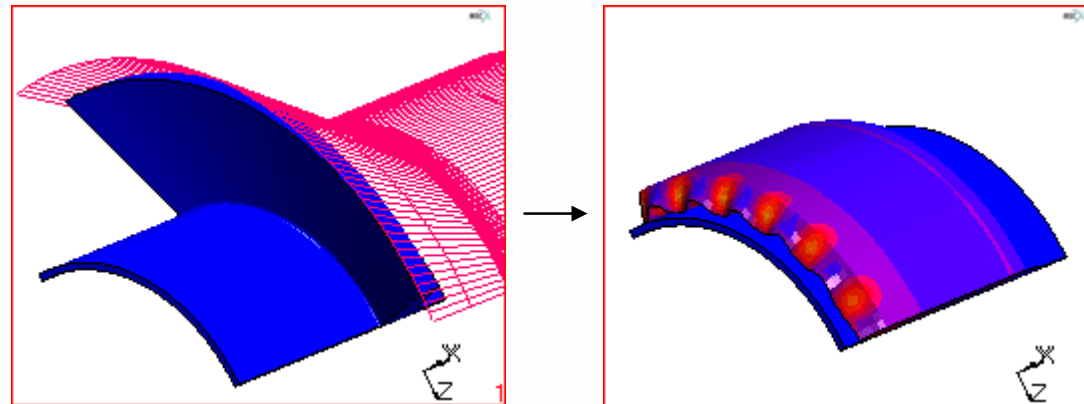


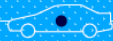
# Seal Analysis - Examples

Expandable Packer



Wiper Plug





# Conclusions

- Remeshing is indispensable in successful analysis of many rubber seal systems.
- Remeshing makes simulation of fracture initiation and propagation possible.
- Further improvement in self-contact and development in fracture initiation and propagation is desired.