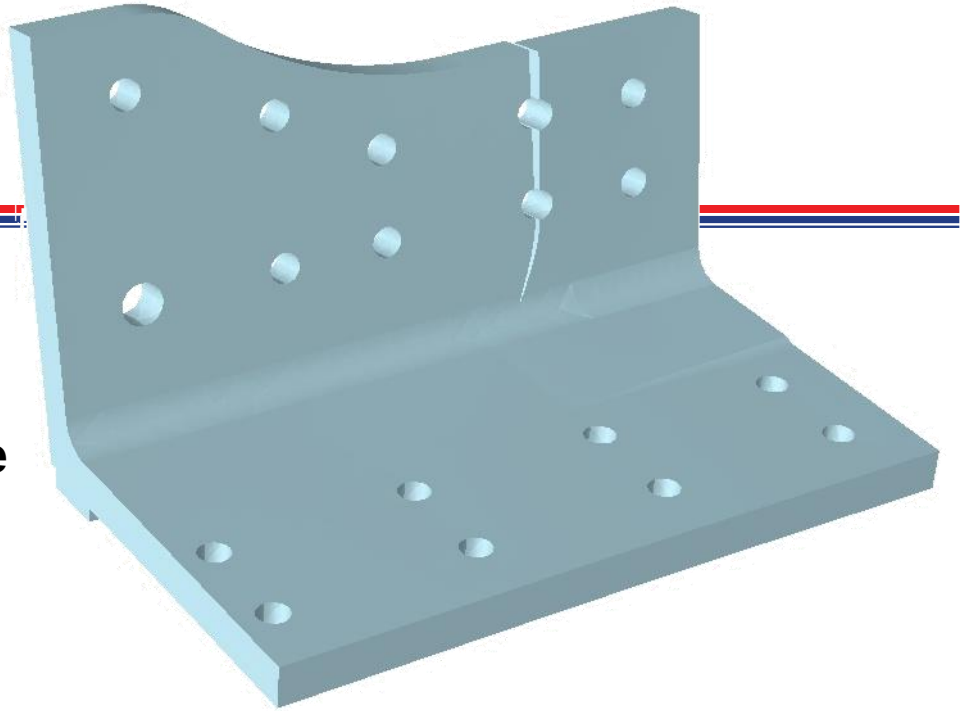


StressCheck

Prepared for the 2013 AFGROW User's Conference

Breakout Model Analysis of Organically-Shaped Cracks for

COMPUTATION OF STRESS INTENSITY FACTORS

Brent Lancaster
ESRD, Inc.

Overview

STRESSCHECK

- It has become very important to be able to quickly analyze detailed breakout models of structural airframe components
  - Global Loads -> 3D Local Detail
- Global-Local Methods in StressCheck?
  - TLAP Bearing/Traction
- Damage tolerance assessment (DTA) can easily be incorporated into a breakout analysis
  - Cracks can be any shape, as long as it can be represented by a surface (area)
  - Imported crack geometry

StressCheck Modeling Focus

STRESSCHECK

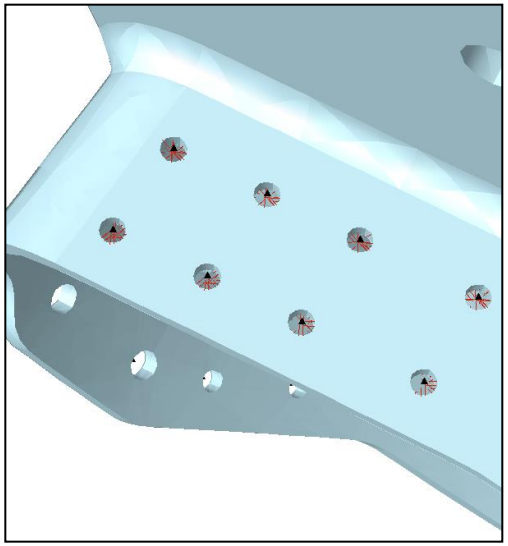
- High fidelity detail analysis at the component level.
- Multi-body contact expands role to sub-assemblies.
- Global-Local analysis capability bridges the gap between vehicle and high fidelity detail analysis.

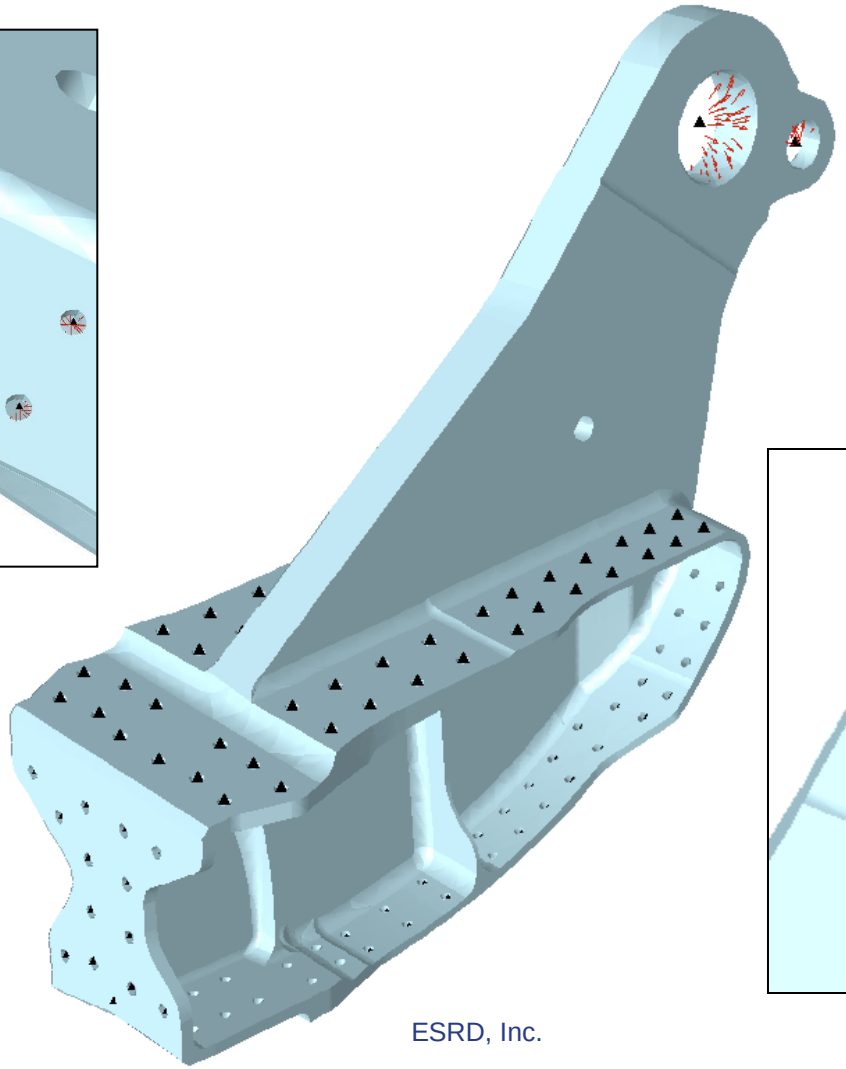
Goals	Model Size		
	Vehicle	Sub-Assemblies	Components
Design			
Certification			
Test Prediction			
Forensic			

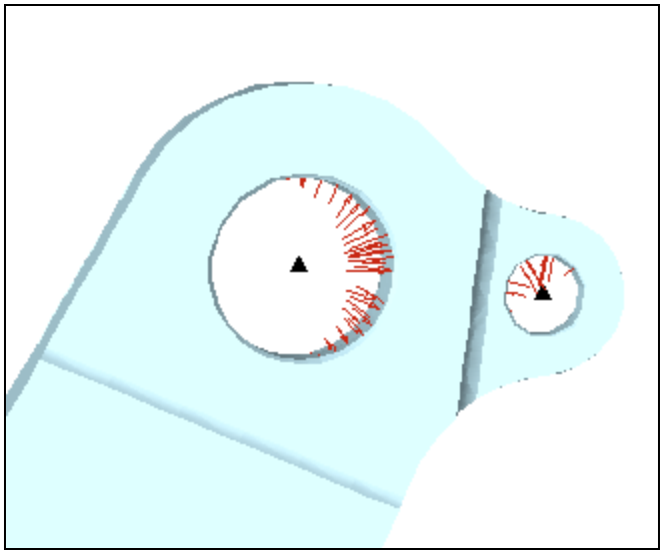
V9.2
> 25 million DOF
Enhanced Global-Local

Global-Local Analysis

Global-Local methods
Total Load at a Point (TLAP)

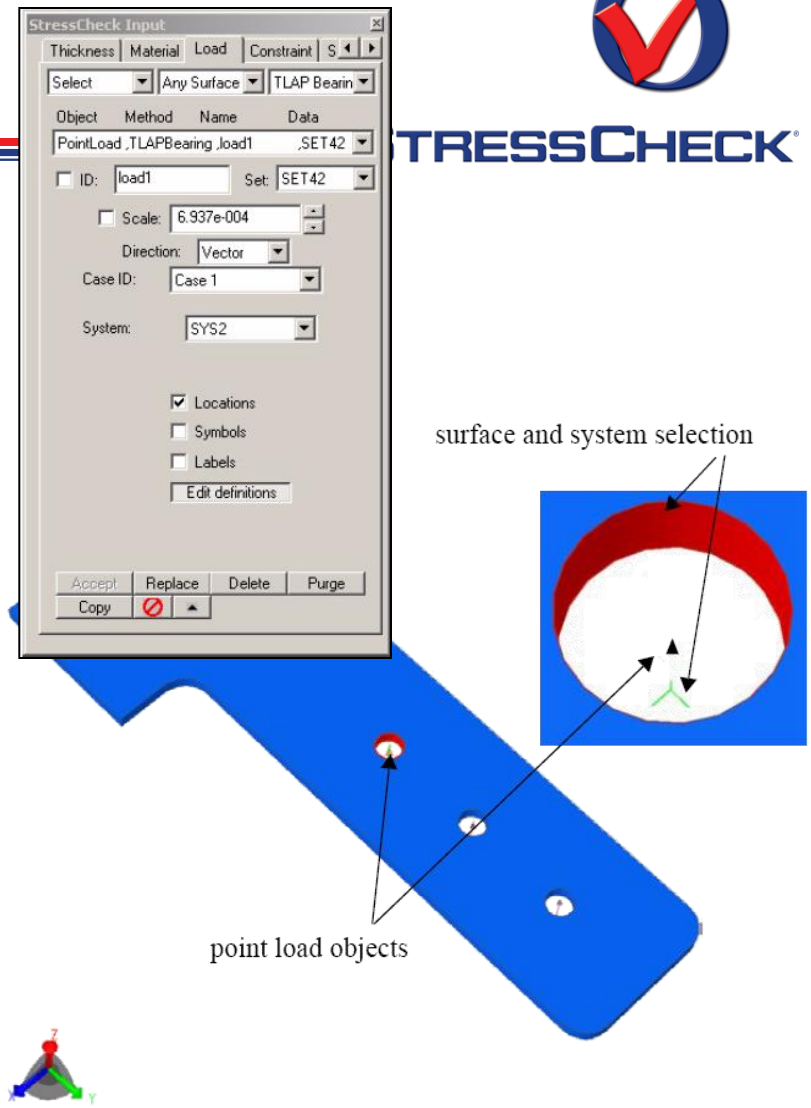






Global-Local methods
TLAP-Bearing

- To apply TLAP-Bearing loads
  - Select faces of elements or surface of hole.
  - Select local coordinate system with z-axis in the direction of the axis of the hole.
  - Select the point load object.
- StressCheck determines a traction distribution in the hole
  - Translates the force components to the center of the hole.
  - Rotates the forces and moments into the local system at the center of the hole.
  - Converts the resultant forces into tractions.



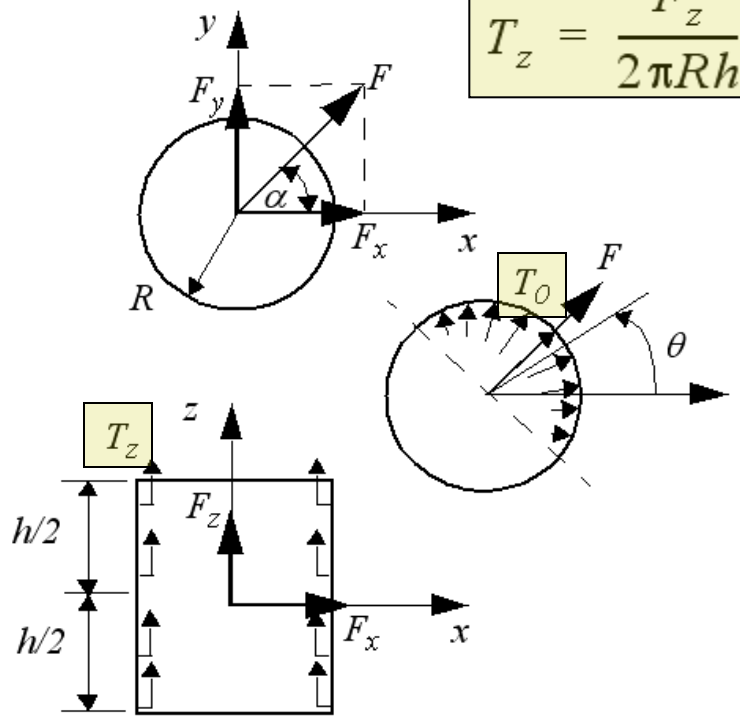
Global-Local methods
TLAP-Bearing

STRESSCHECK

Forces

$$T_0 = \frac{-2F}{\pi R h}\cos(\theta - \alpha)$$

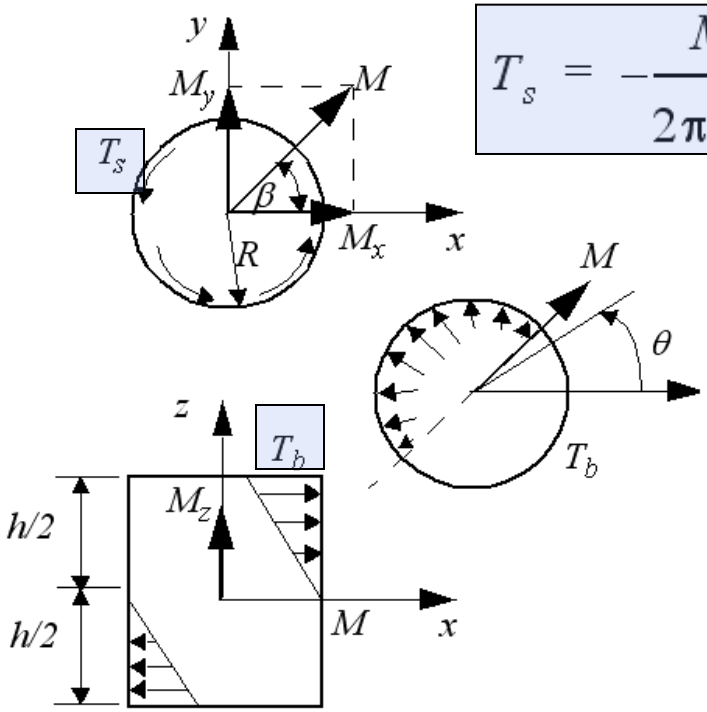
$$T_z = \frac{F_z}{2\pi R h}$$



Moments

$$T_b = \frac{24M}{\pi R h^3} Z \sin(\theta - \beta)$$

$$T_s = -\frac{M_z}{2\pi R^2 h}$$

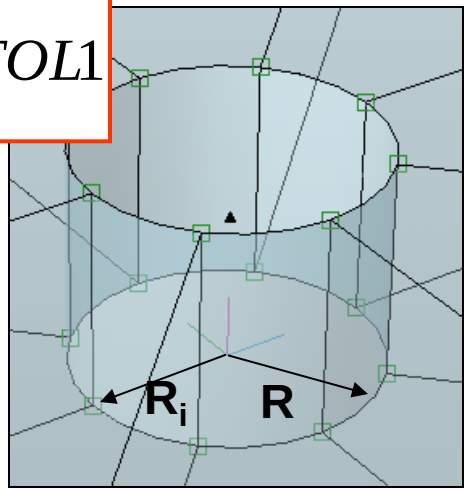


Global-Local methods
TLAP-Bearing controls

STRESSCHECK

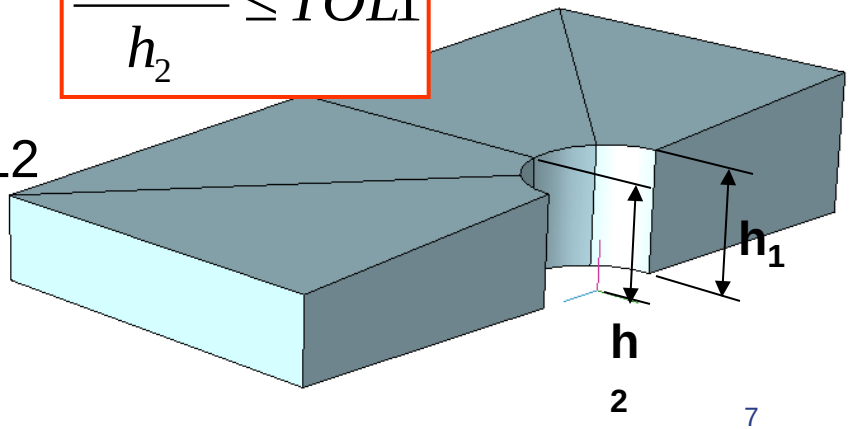
- Hole circularity
  - R = hole radius
  - R_i = distance from node to centerline
  - TOL1 = 0.001 (default)
  - Parameter _bearing_tol to control TOL1

$$\frac{R_i - R}{R} \le TOL1$$



- Plate taper
  - h_1 = max height of cylinder
  - h_2 = Average height of cylinder
  - TOL2 = 0.05
  - Parameter _taper_tol to control TOL2

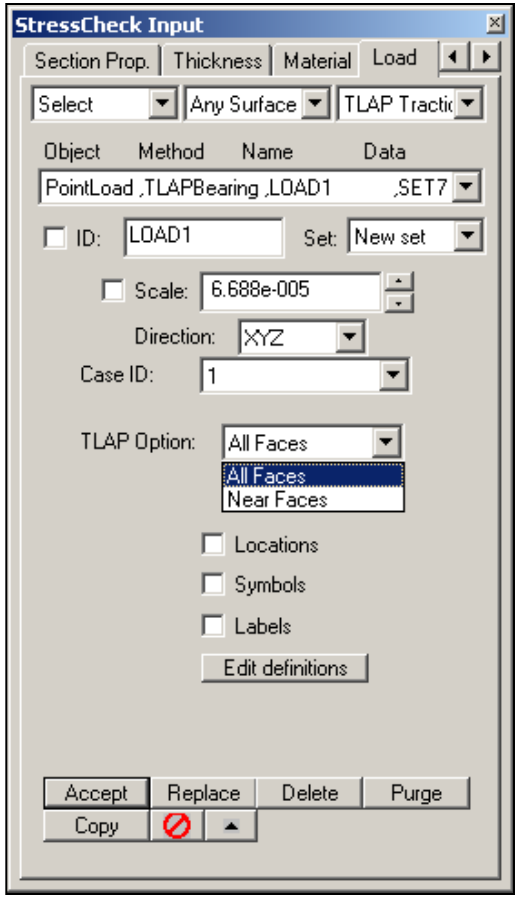
$$\frac{h_1 - h_2}{h_2} \le TOL1$$



Global-Local methods
TLAP-Traction

STRESSCHECK

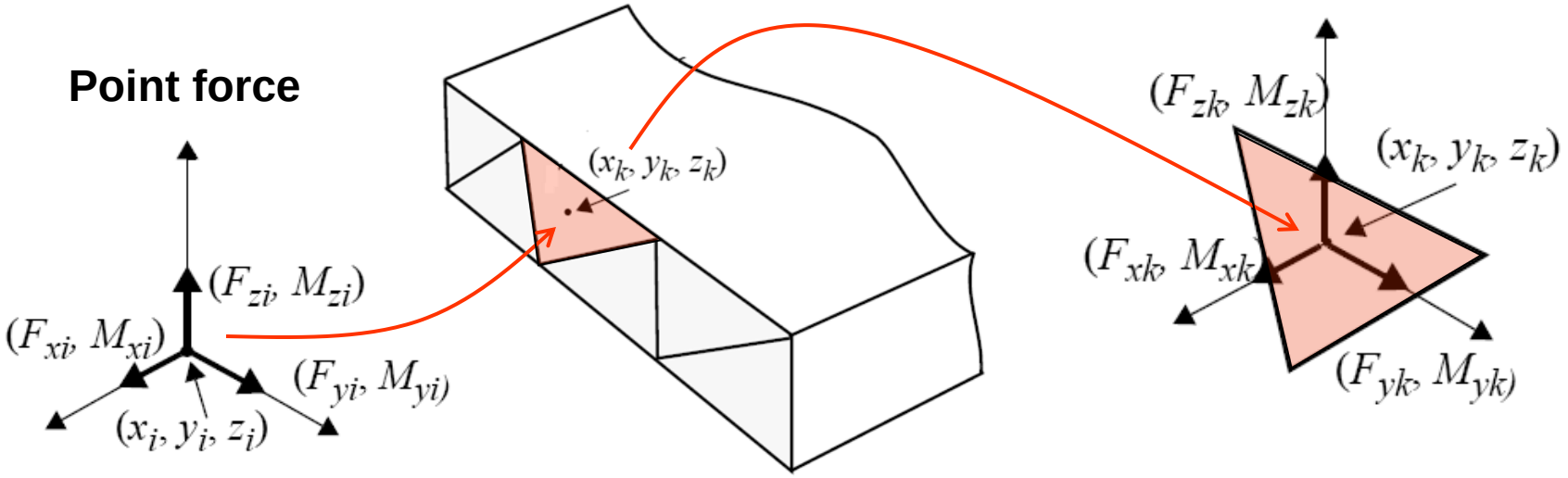
- Point loads obtained from a free-body extraction of a global model applied to faces or surfaces of a solid model.
- The point force/moment is converted into tractions distributed over the faces of the solid elements such that they are statically equivalent to the corresponding point load/moment.
  - Near faces option: Each point load applied to one face only (closest to point load).
  - All faces option: All selected point loads will be distributed to all selected faces.
- The load method identified as TLAP-Traction is available in the Load class of the input interface.
  - TLAP stands for Total Load At a Point.



Global-Local methods
TLAP-Traction

STRESSCHECK

Point force



$$T_x = (a_1 + a_2\xi + a_3\eta)\Phi(\xi,\eta)$$

$$T_x = (a_4 + a_5\xi + a_6\eta)\Phi(\xi,\eta)$$

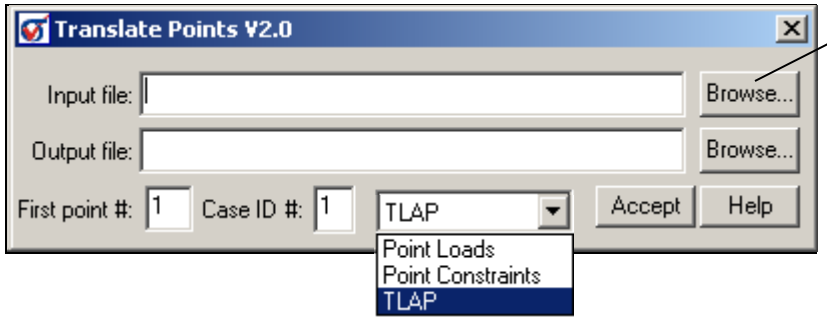
$$T_x = (a_7 + a_8\xi + a_9\eta)\Phi(\xi,\eta)$$

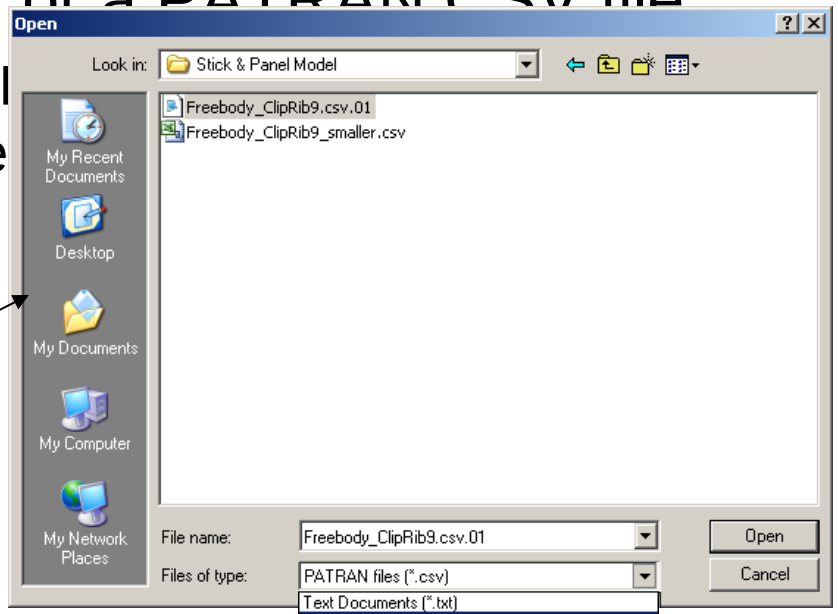
$$\begin{cases} (F_x)_k = \int_{A_k} T_x dA \\ (F_y)_k = \int_{A_k} T_y dA \\ (F_z)_k = \int_{A_k} T_z dA \end{cases} \qquad \begin{cases} (M_x)_k = \int_{A_k} [(y-y_k)T_z - (z-z_k)T_y] dA \\ (M_y)_k = \int_{A_k} [(z-z_k)T_x - (x-x_k)T_z] dA \\ (M_z)_k = \int_{A_k} [(x-x_k)T_y - (y-y_k)T_x] dA \end{cases}$$

Global-Local methods
Translation utility

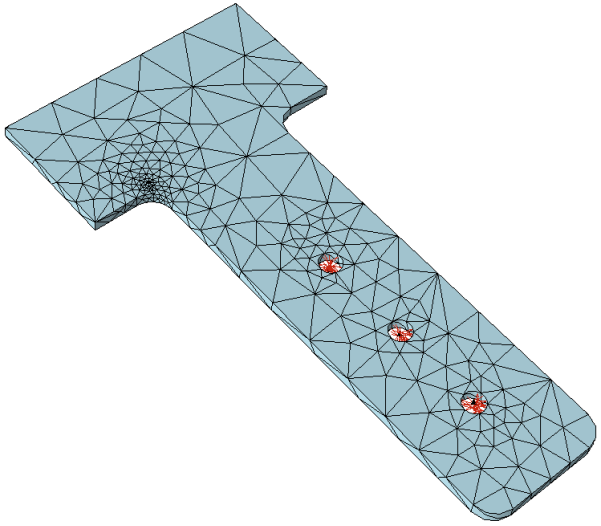
STRESSCHECK

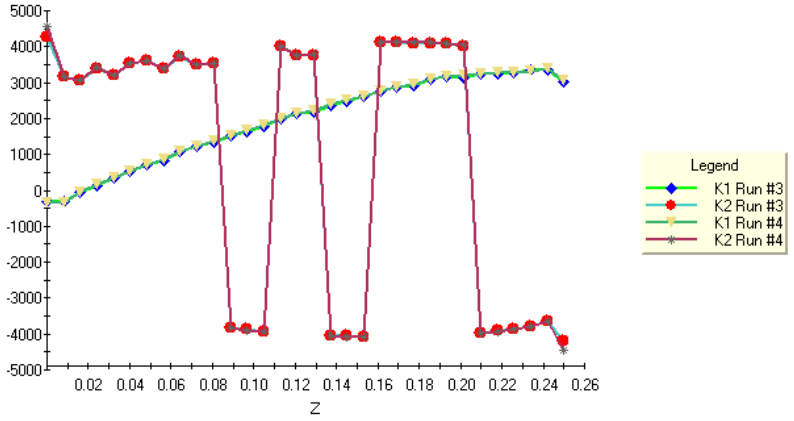
- Translator utility converts point load/constraint data obtained from a global shell model into StressCheck format for application to a local model.
- The input can be a space or comma delimited ASCII file with the point information or a PATRAN CSV file
  - When a CSV file is selected, TI
    option, and the Case ID is take
    load cases are accepted.





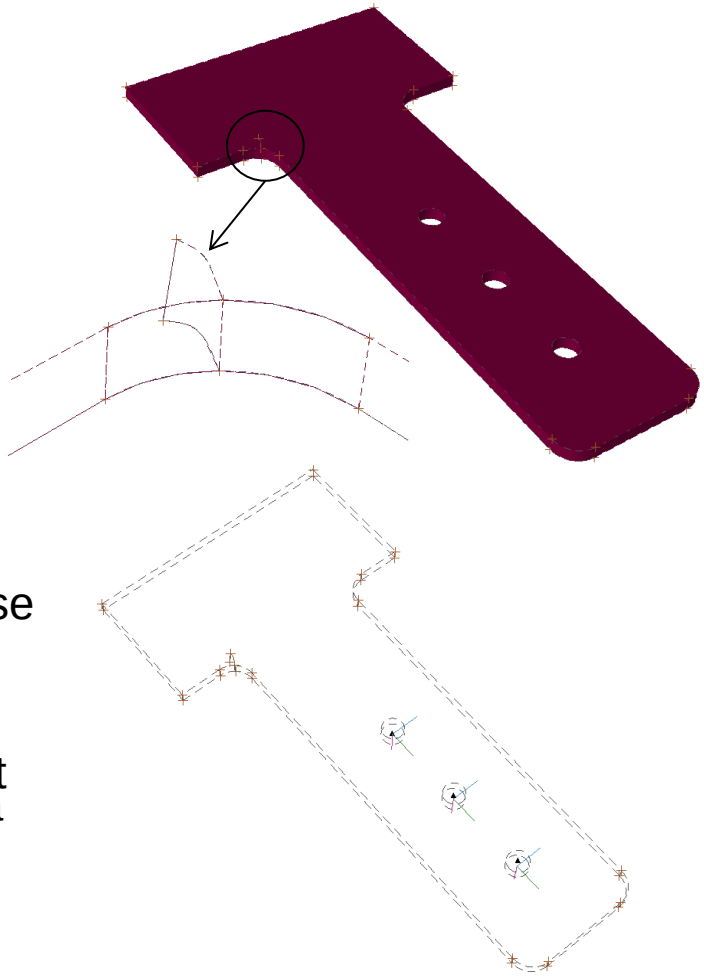
Demo 1:
TLAP Bearing Application





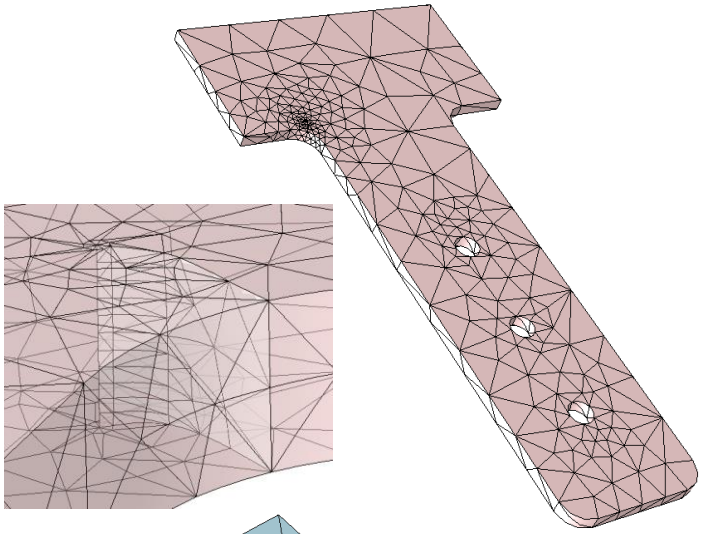
- Import solid geometry
- Import crack shape
- Union solid + crack
- Append .sci file containing point load information
- Create cylindrical coordinate systems for TLAP-Bearing assignment
- Automesh solid w/ crack
- Assign attributes
  - TLAP-Bearing in 3 holes
- Solve linear by p-extension
- Post-process SIF's

Demo 1:
TLAP Bearing Application

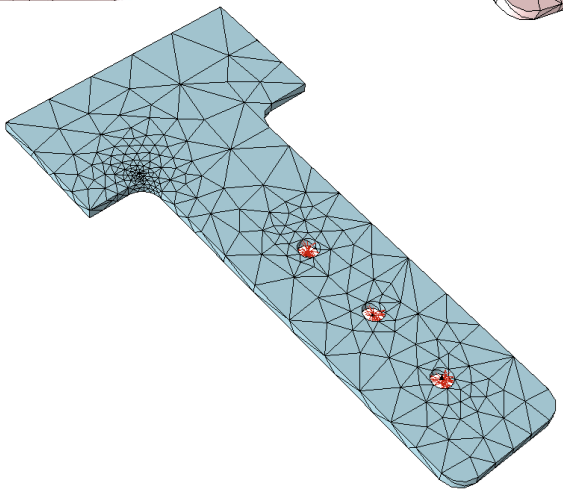


- Import solid model
  - File > Import
    - TLAP_Model_1.x_t
- Import crack surface
  - File > Import
    - CrackSurf.x_t
- SC Input > Geometry
  - Create > Body > Bool-Union
  - Select body, then surface, Accept
- Append load data
  - File > Append input
    - TLAP_Data.sci
- SC Input > Load
  - Enable the display of TLAP-Bearing: Locations and symbols.
  - Edit definitions: Review content of Case Definitions interface.
- SC Input > Geometry
  - Create > Circle > Sample > Screen
  - Turn off display of Surfaces and select bounding circles of cylinders to have a local system at center of each hole.

Demo 1:
TLAP Bearing Application



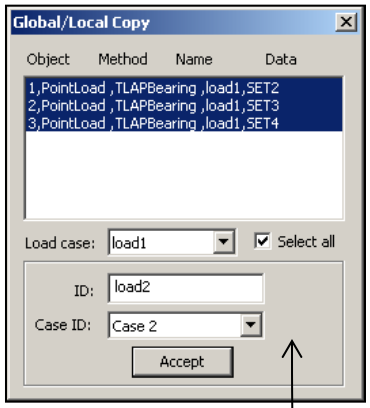
- Create mesh and assign attributes
  - SC Input > Mesh
    - Create > Mesh > Auto (use defaults)
    - Create > Mesh > Crack Face
      - Select surface representing crack, Accept
    - Create > Mesh > Bndry. Layer
      - Ratio=0.1, Layers=2, To=0.02, T-Total=0.1
      - Select curve representing crack front, Accept
  - SC Input > Material
    - Define and Assign material 7075-T6
- TLAP-Bearing loads
  - SC Input > Load
    - Select > Any Surface > TLAP-Bearing. ID: Load1, Case ID: Case 1, Locations On
    - Select one hole surface, select corresponding SYS from combo box and CTRL-SHIFT to select point load, then Accept.
    - Repeat for each hole.

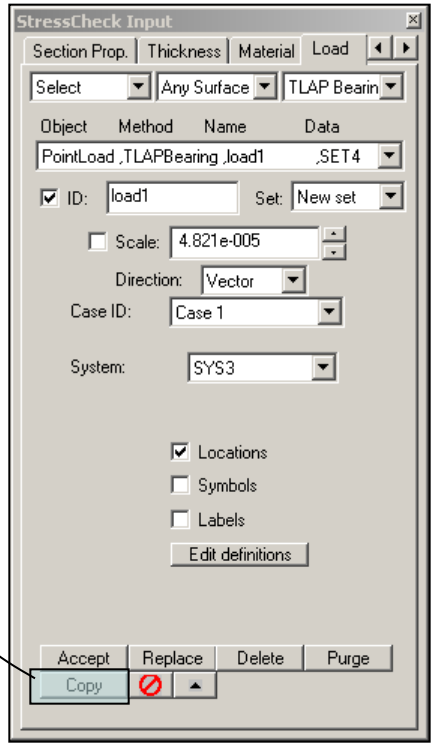


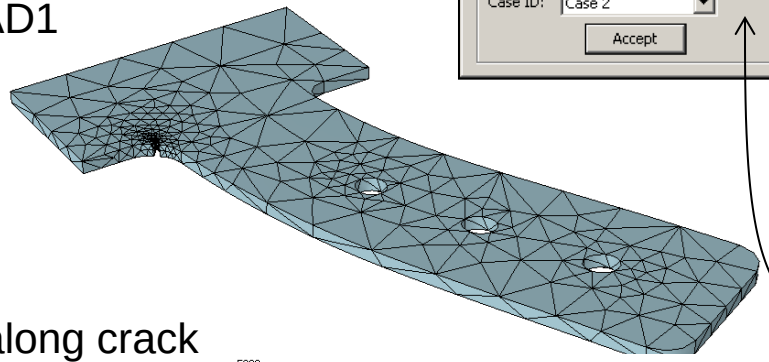
Demo 1:
TLAP Bearing Application

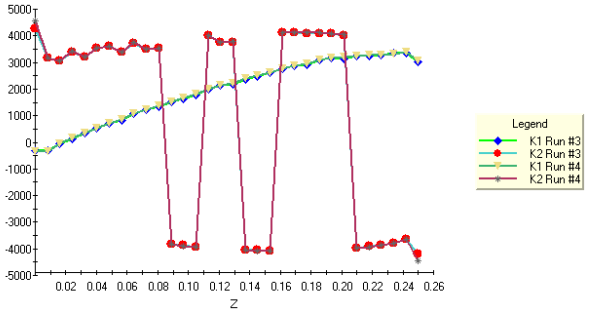
STRESSCHECK

- SC Input > Load
  - ID: Load 2: Copy from Load1 using Case2 data
- SC input > Constraint
  - Create built-in constraints on 3 sides
- SC Input > Solution ID
  - SOL > CONST > LOAD1
- SC Solver
  - Run p=2 to 5
  - Activate Batch Solve
- SC Results
  - Plot deformed shape
  - Convergence of SIF along crack front
  - Distribution of SIF's along crack front



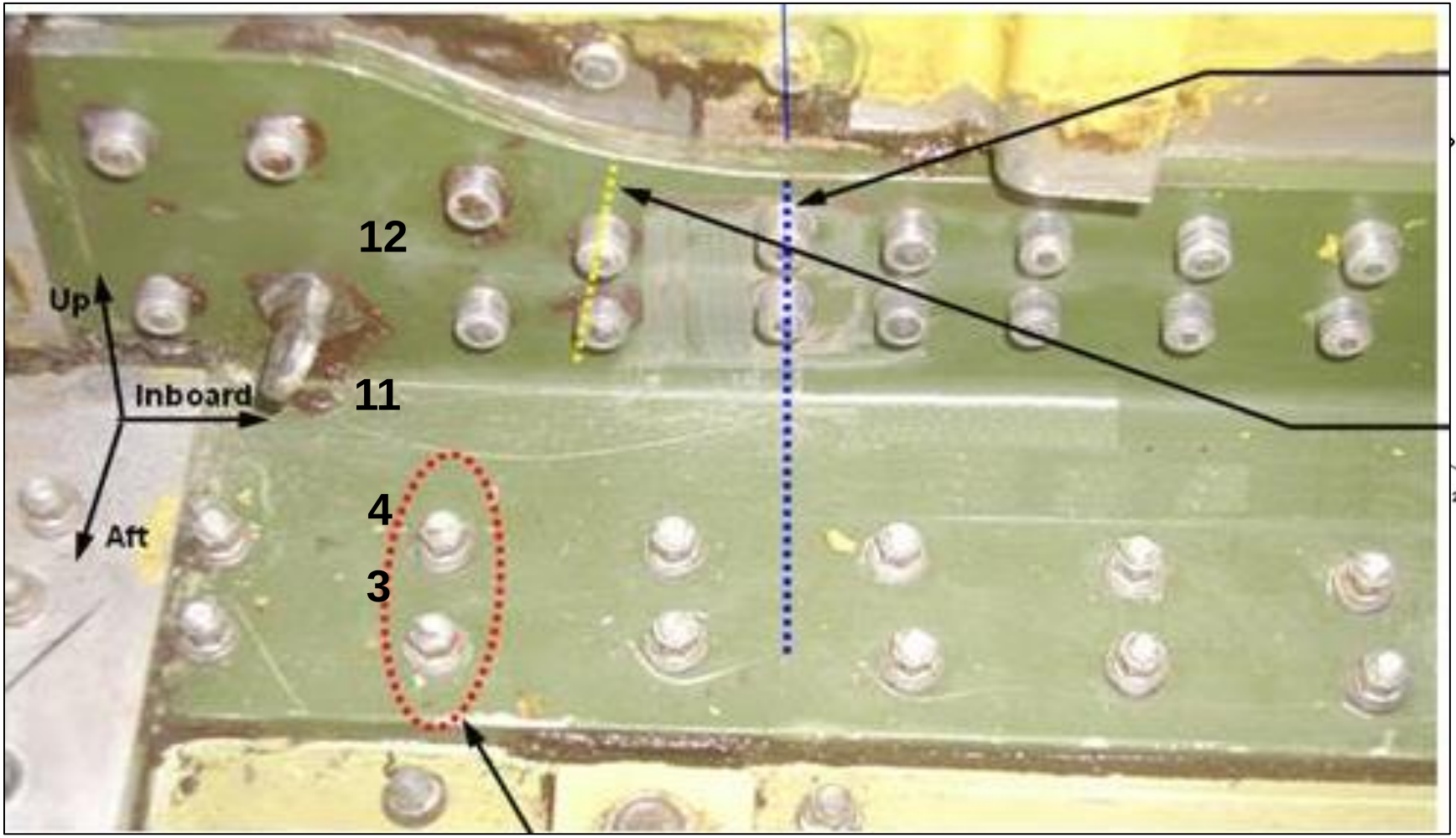




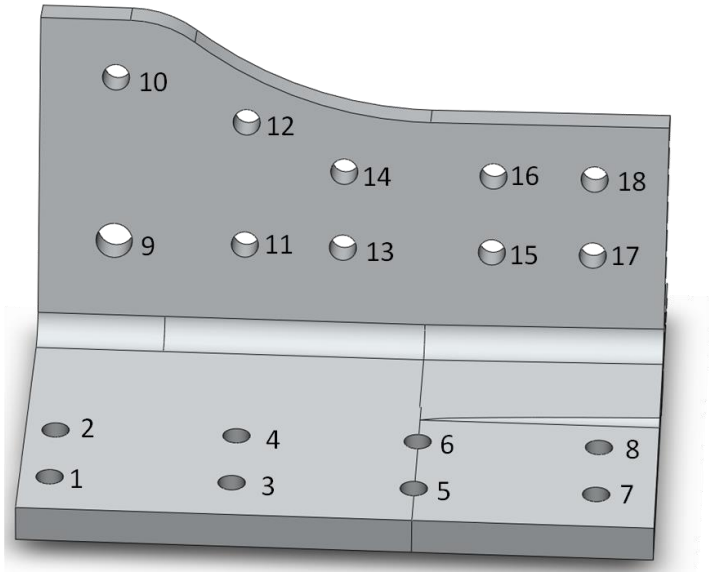


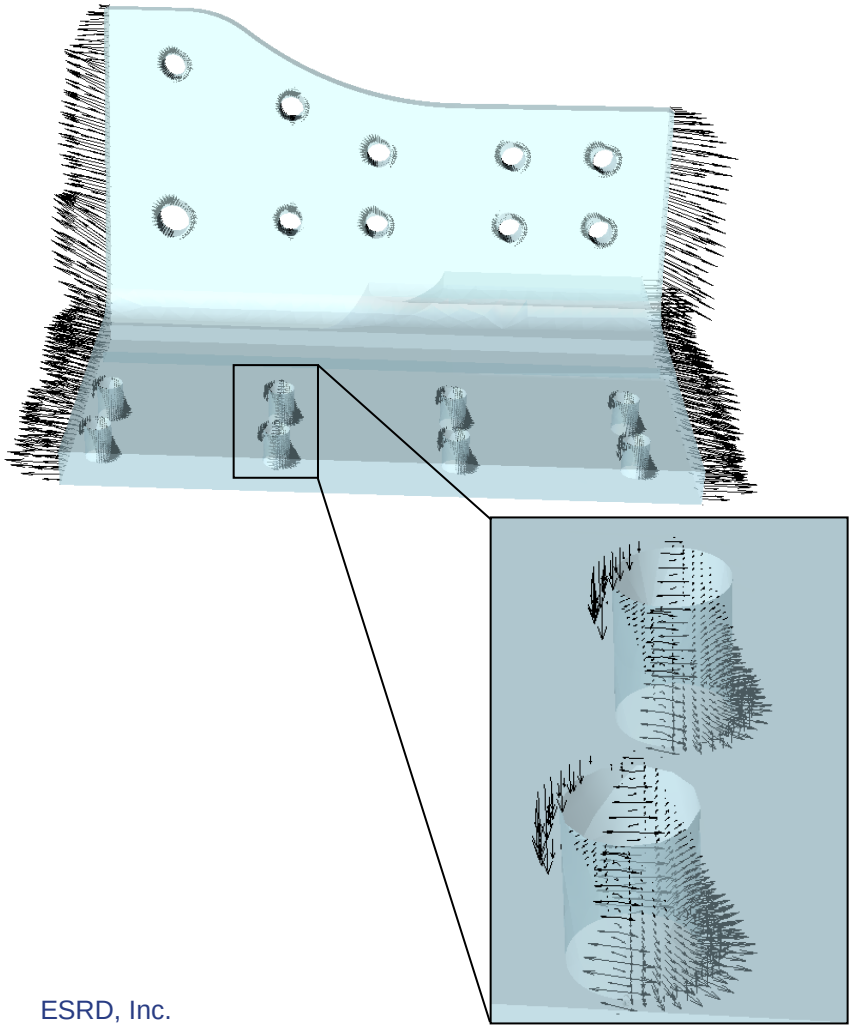
Detail of a Spar Cap
DaDT Analysis

STRESSCHECK

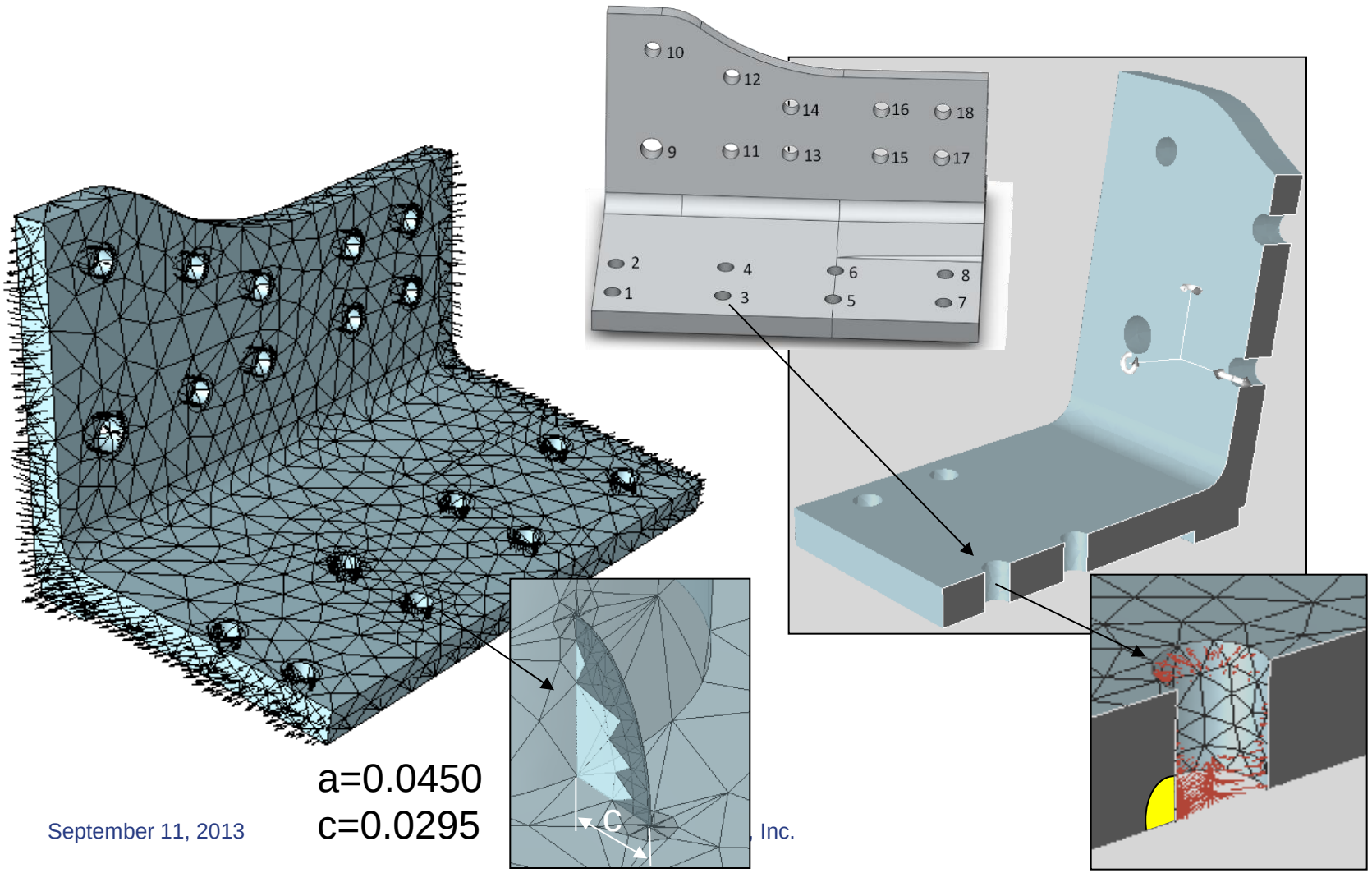


Spar Cap
FB-Loads from Global Model

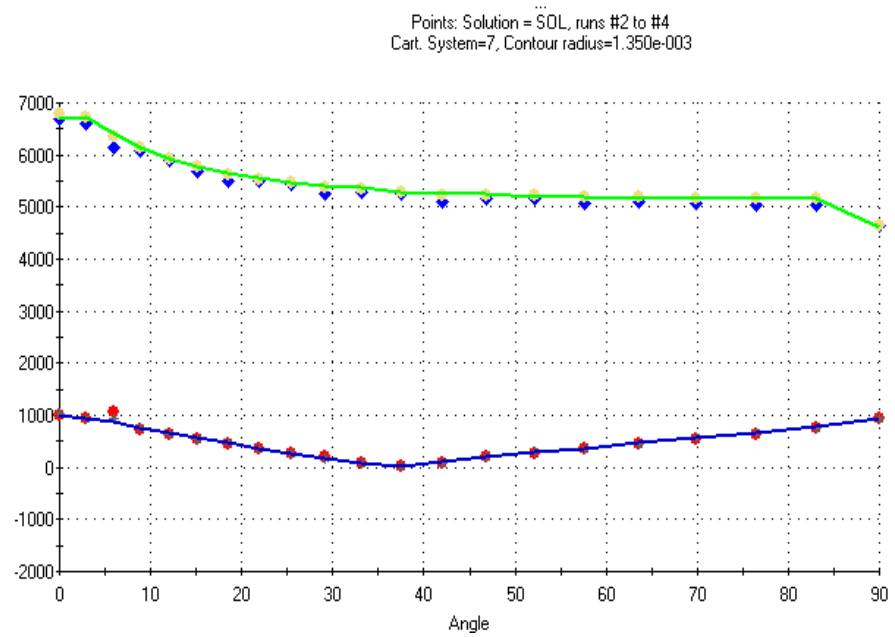


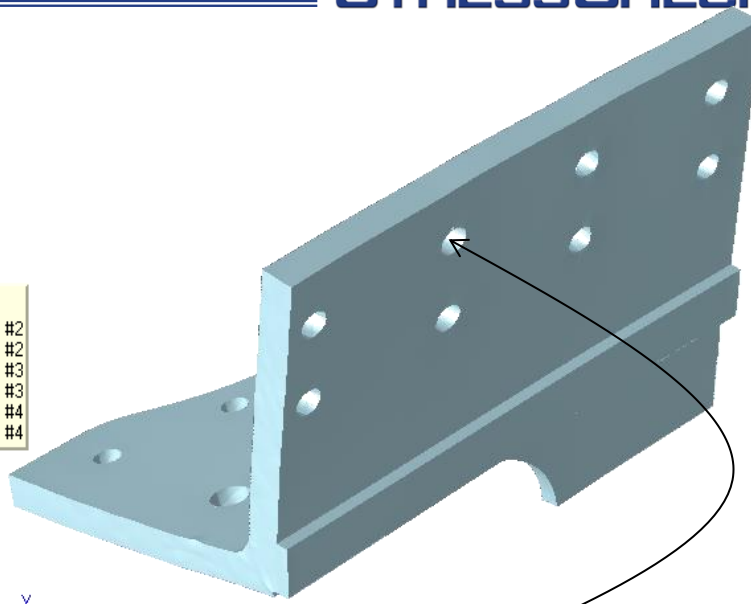


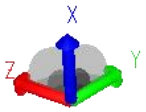
Spar Cap
FB-Loads from Global Model

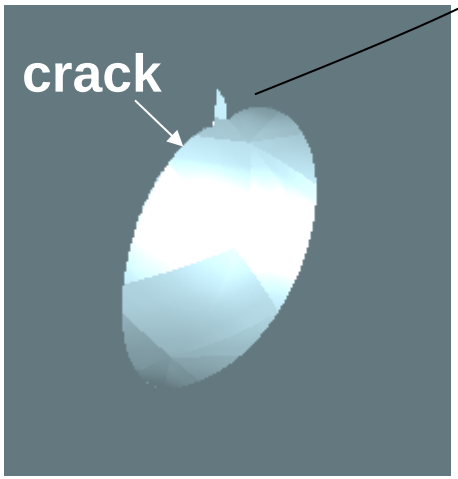


Spar Cap
K1 & K2 – Crack Front

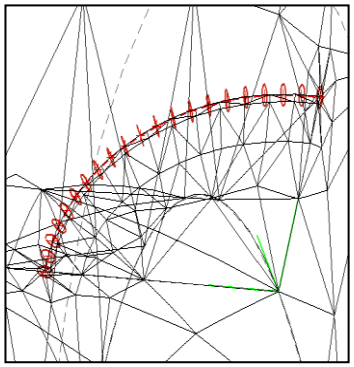






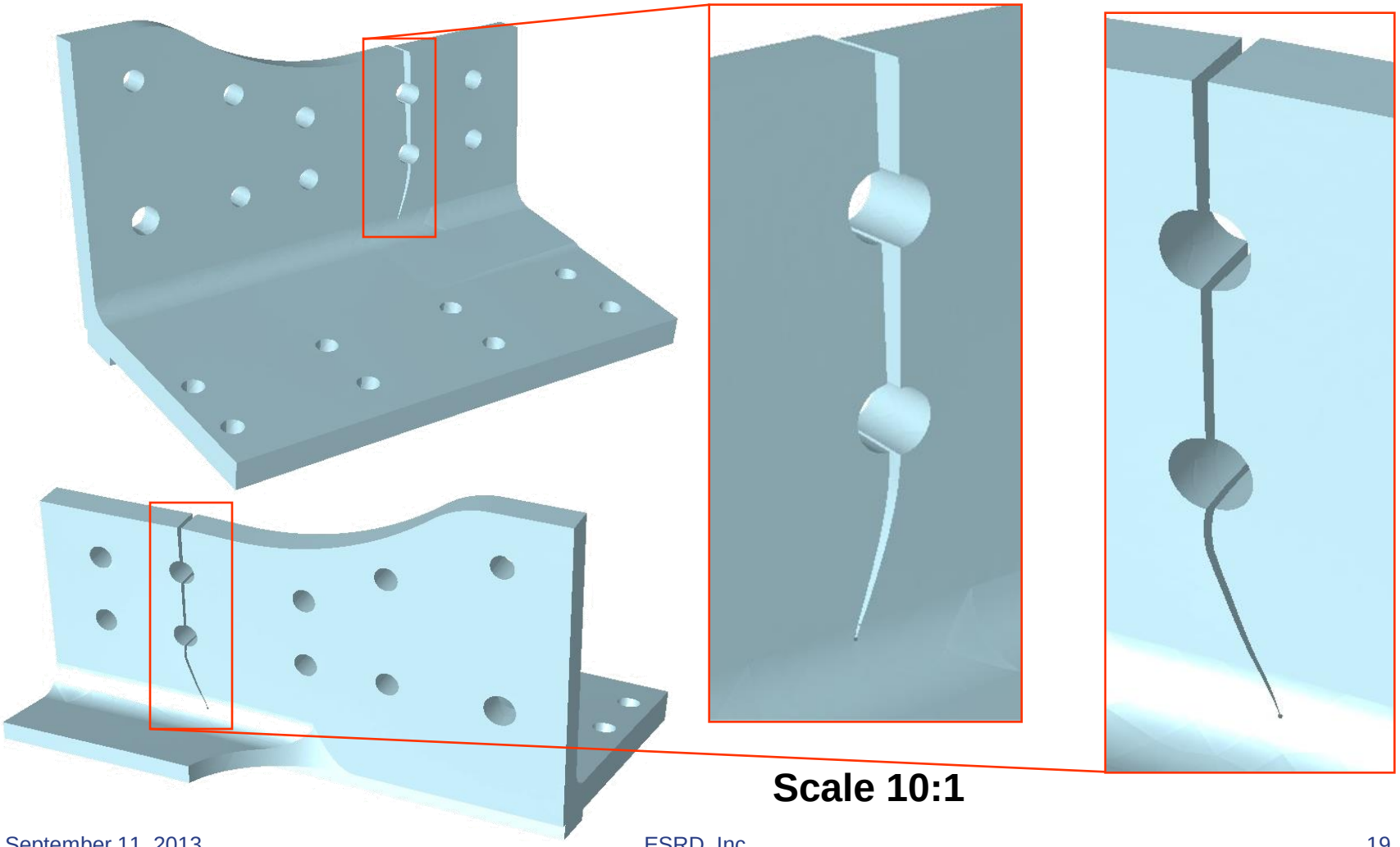


Angle = 0º



Angle = 90º

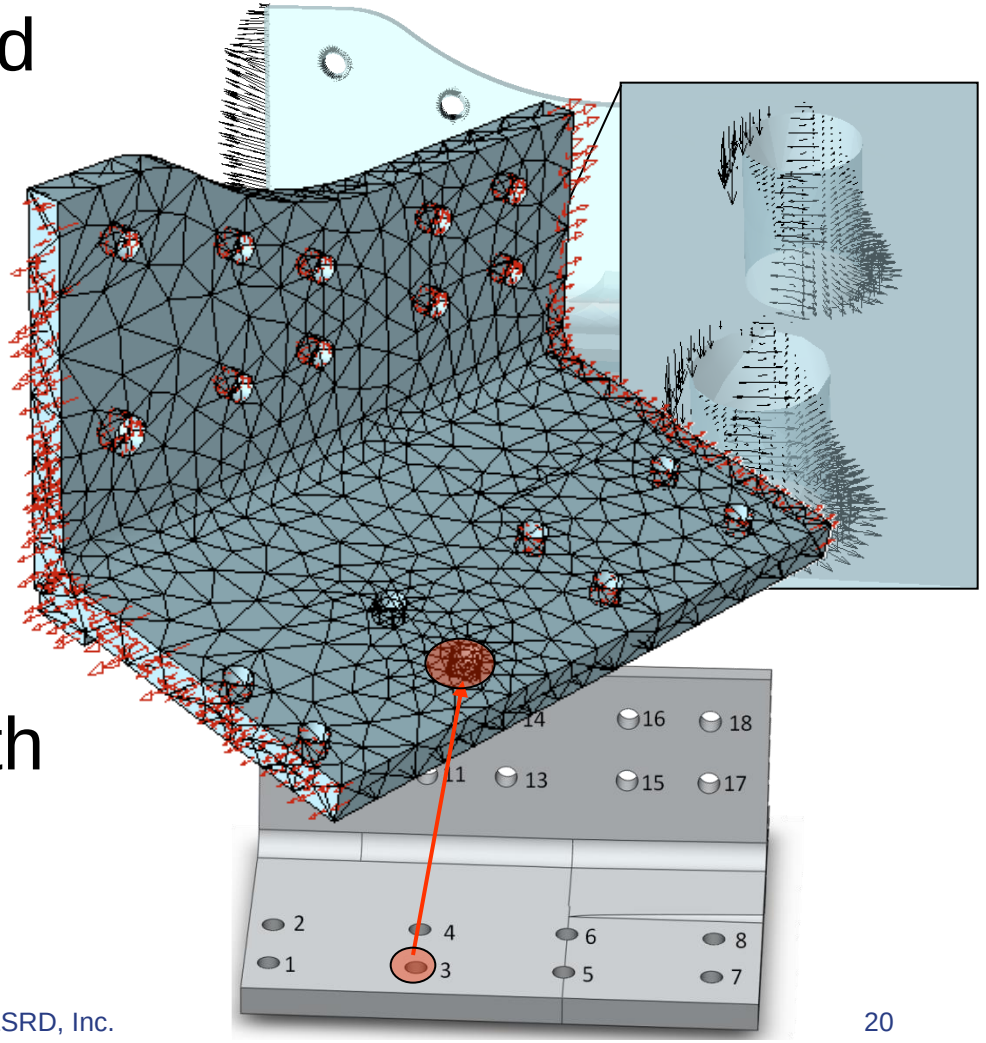
Spar Cap
Crack Turning



Scale 10:1

Demo 2
TLAP-Traction (BDF format)

- Import load data saved in NASTRAN BDF format.
- Append input file with 3D-model
- Apply as TLAP-Tractions
- Replace TLAP-Tractions of hole 3 with TLAP-Bearing



Demo 2
TLAP-Traction (BDF format)

STRESSCHECK

- Start StressCheck
  - File > Import: case5.bdf (set filter to NASTRAN files).
- SC Input > Mesh
  - Select > nodes: select all nodes and Delete.
- File > Append input
  - LocalModel.sci (solid and mesh)
- SC Input > Load
  - Select > Any Surface > TLAP-Traction
  - Select all surfaces where TLAP symbols are near
  - Ctrl-Shift to select all point loads
  - Set TLAP Option: Near Faces and Accept
  - Check > All elements: Verify the resultant of applied tractions are in equilibrium
- Replace TLAP-Tractions of hole 3 with TLAP-Bearing
  - Check > Any elements by marquee-pick around hole 3 (use SYS5 as center of moment)
  - Create a new point load (#6875) at the location of SYS5 with forces and moments determined from the load check.
  - Delete TLAP-Traction record
  - Create TLAP-Bearing record using SYS1