

AE 737 - MECHANICS OF DAMAGE TOLERANCE

LECTURE 25

Dr. Nicholas Smith

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Wichita State University, Department of Aerospace Engineering

SCHEDULE

- 3 May - Finite Elements, Damage in Composites
- 5 May - Repair
- 10 May - Final Project Due by 5:00 pm

SKUNK WORKS TALK

- Friday, May 6
- 12:00 - 1:00 pm
- Shocker Hall Multipurpose Room - Honors College
- Pizza (first-come first-served)



Figure 1: LASRE on top of SR-71 Blackbird

OUTLINE

1. finite elements
2. damage in composites

FINITE ELEMENTS

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 - Adds "phantom" cracks in all elements

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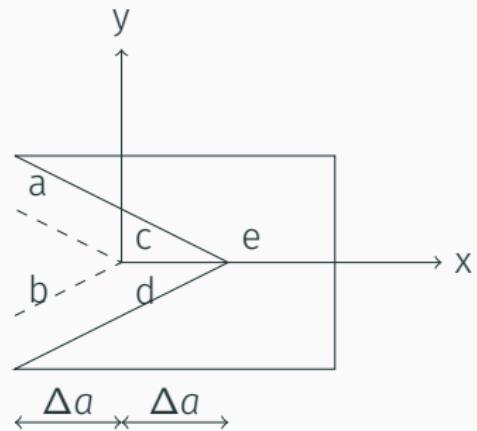
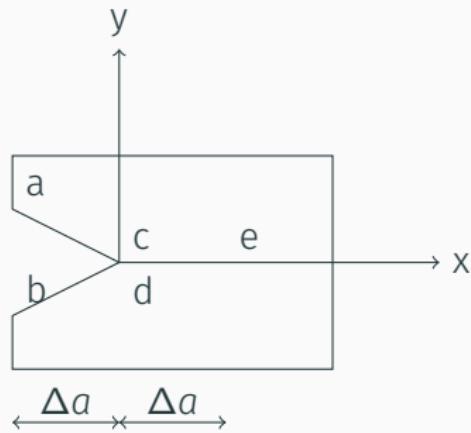
$$G_I = \frac{\kappa + 1}{8\nu} K_I^2 \quad (25.2)$$

where

$$\kappa = 3 - 4\nu \quad (\text{plane strain})$$

$$\kappa = \frac{3 - \nu}{1 + \nu} \quad (\text{plane stress})$$

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- $\Delta a/a \leq 0.05$

$$G_I = \frac{1}{2\Delta a} F_y^{(c)} \left(u_y^{(a)} - u_y^{(b)} \right) \quad (25.3)$$

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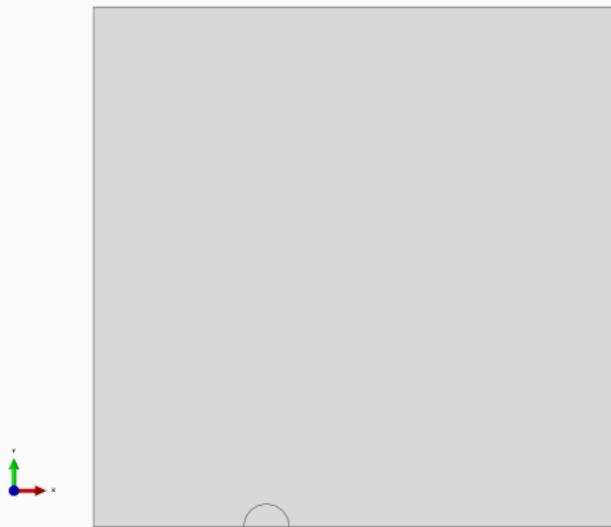
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- Partition the edge so that you can easily separate the crack tip from the plate

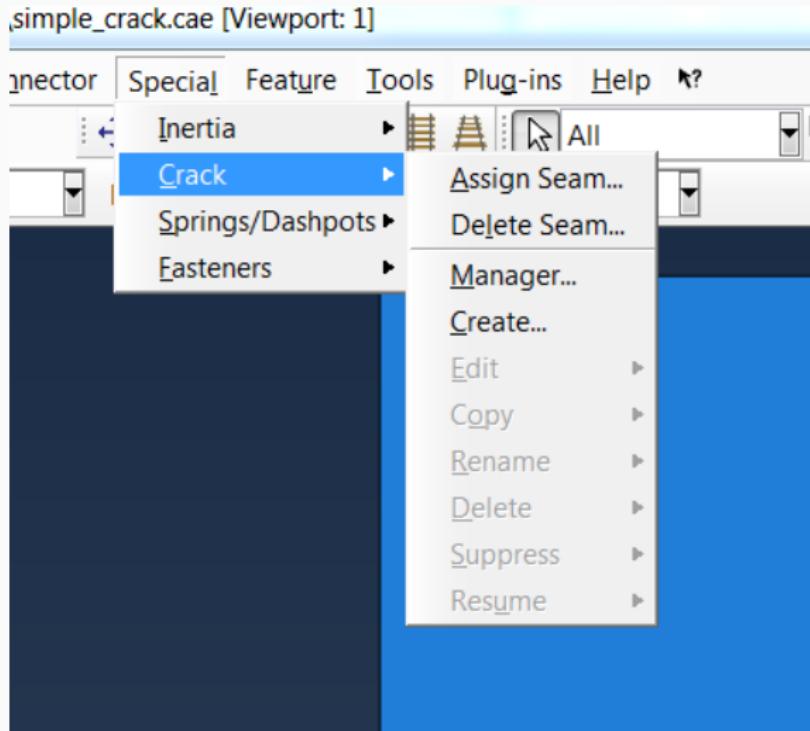
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- It is helpful to add some partitions now for meshing purposes later, a box or circle/semi-circle around the crack tip

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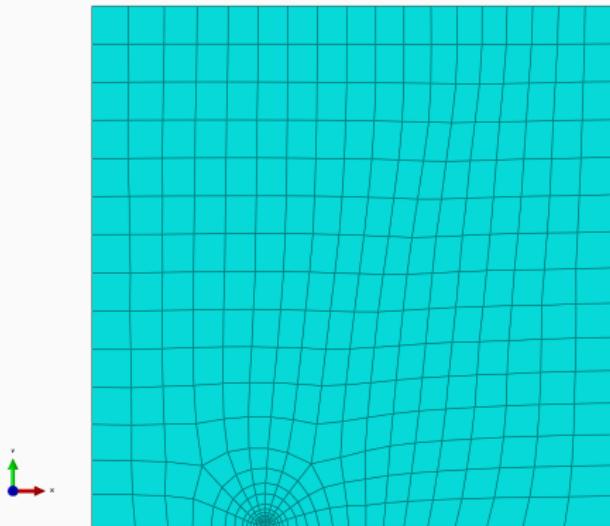
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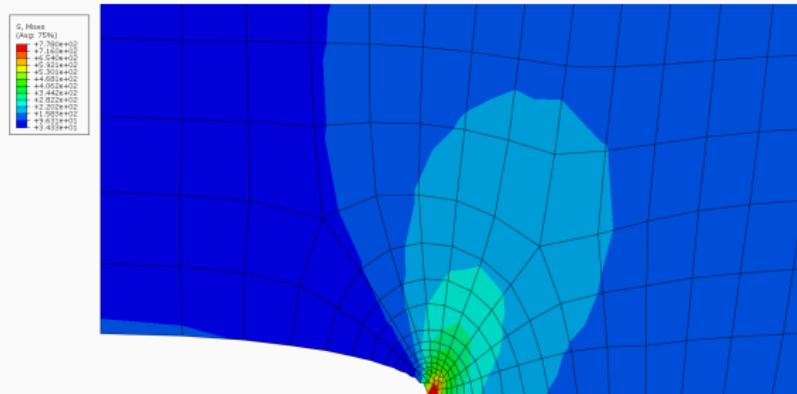
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- To mesh, be sure to seed the edges, this is where partitioning comes in handy

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- To get nodal values in ABAQUS, from the Visualization module we use Tools -> Query -> Node -> Probe Values
- The variable corresponding to F_y in ABAQUS is RF2
- We also probe the nodal value of displacement one node away, u_y in ABAQUS is U2

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- You can now paste this data into Excel for processing

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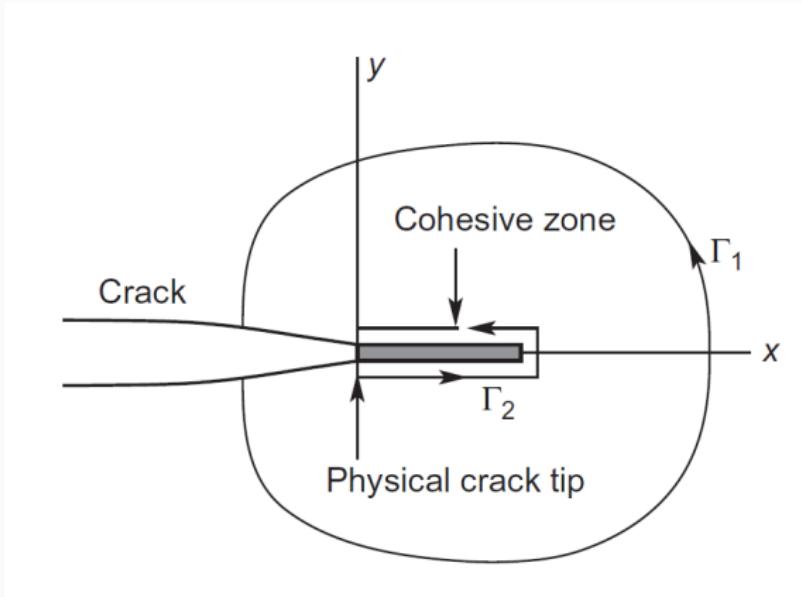
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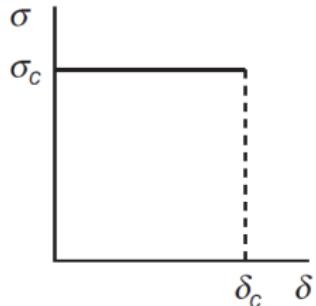
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- The stress required to separate the atoms changes as a function based on their Traction-Separation law, until the atomic bond is broken

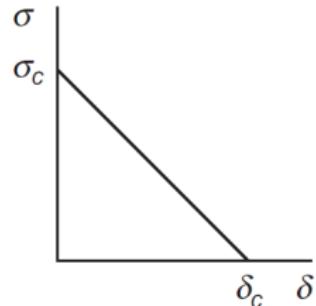
COHESIVE ZONE



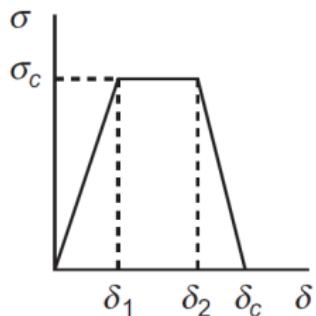
TRACTION SEPARATION



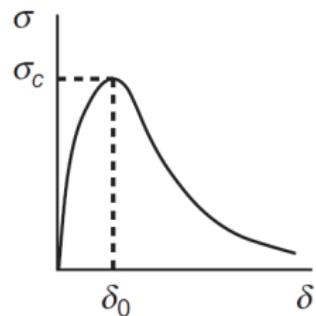
(a)



(b)



(c)



(d)

COHESIVE ZONE USES

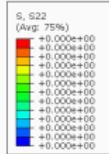
- In practice, the cohesive zone can be used to model crack growth

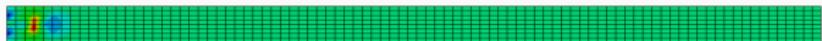
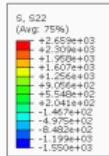
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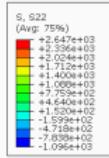
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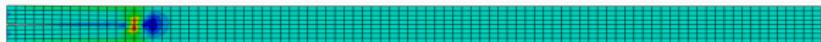
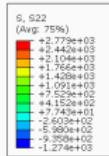
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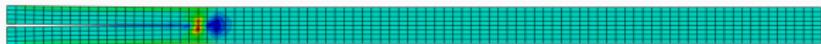
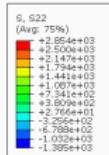
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- Also commonly used to model delamination in composites

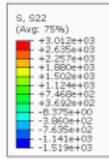


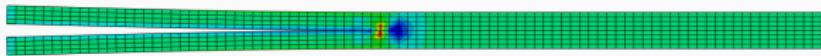
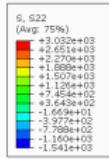


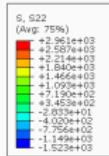


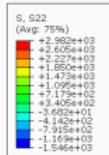












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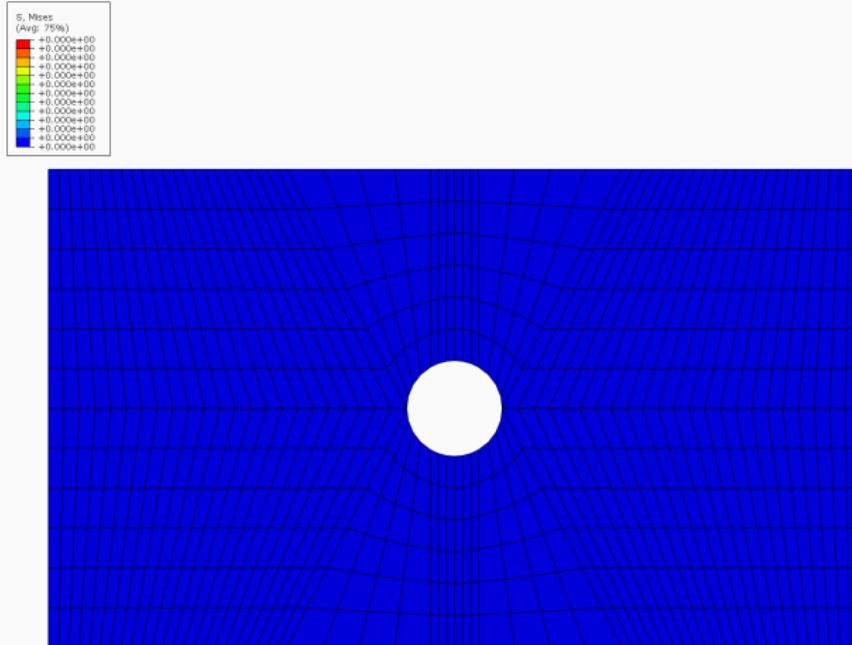
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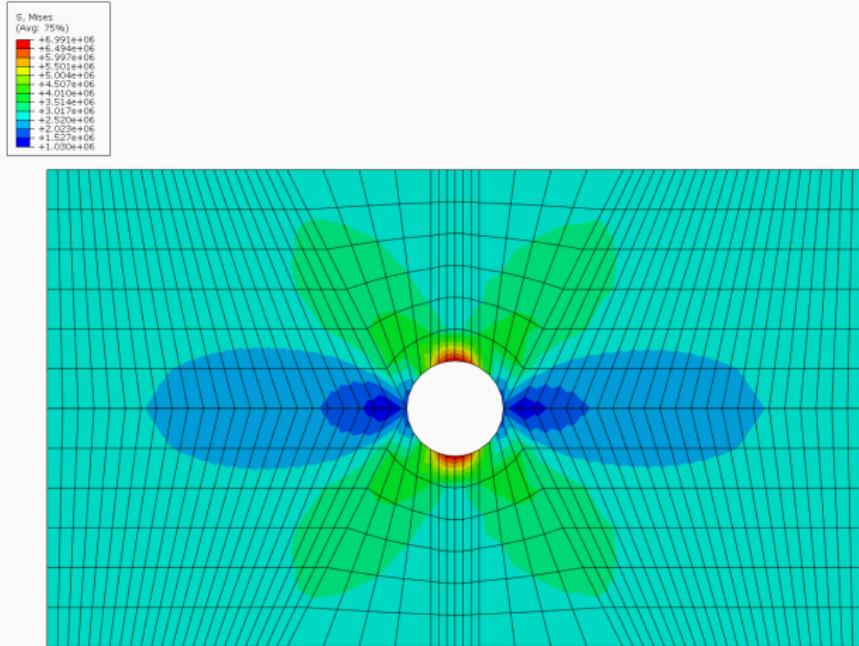
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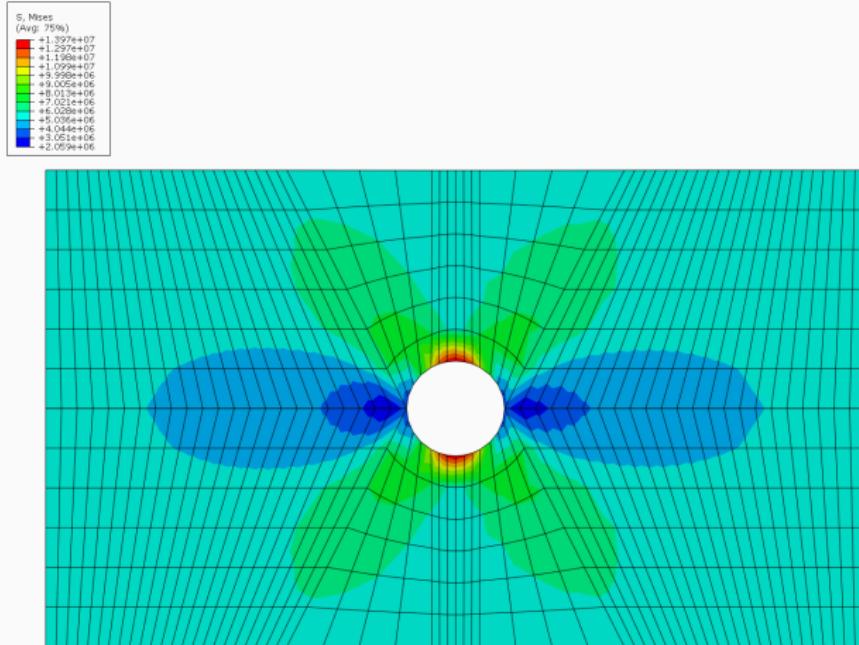
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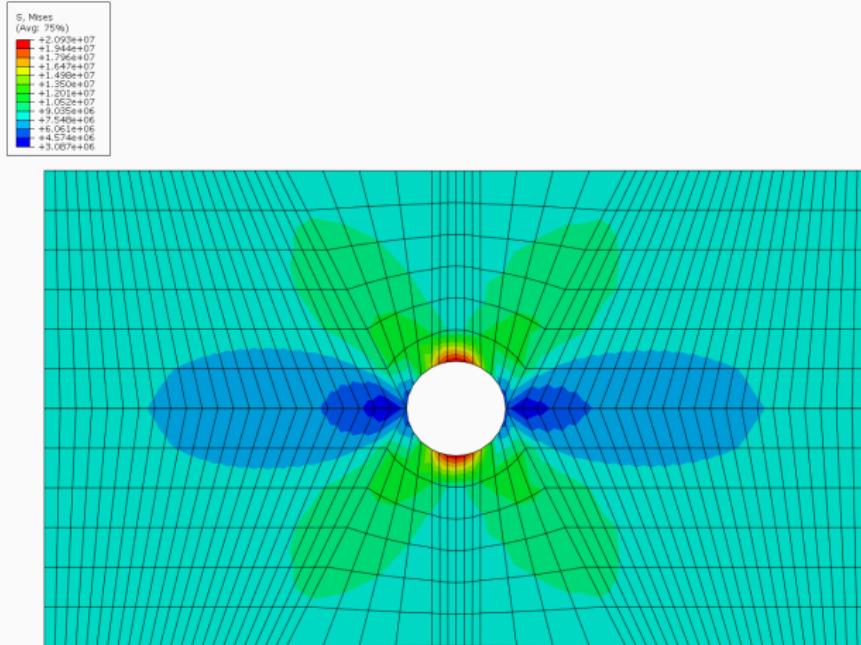
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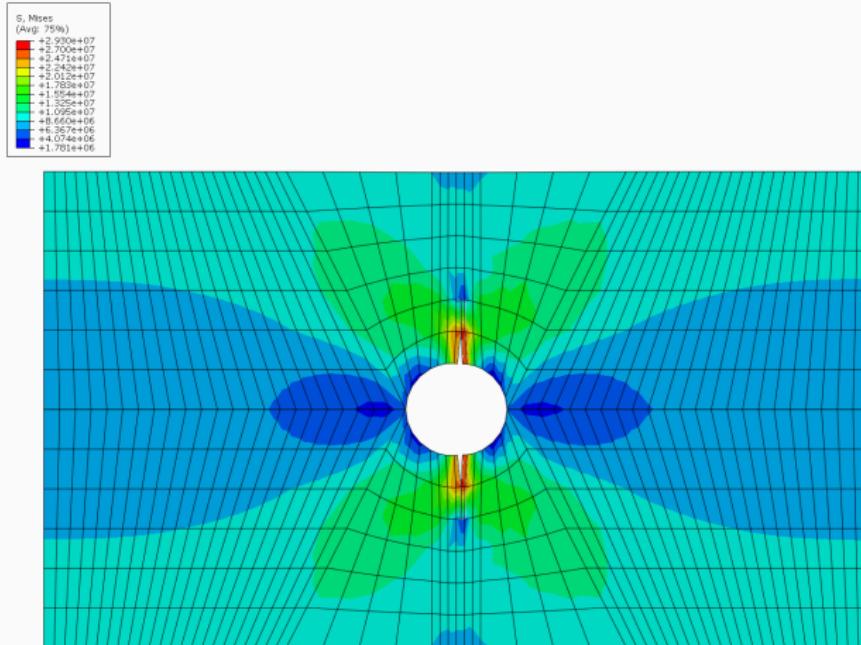
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- This is done using nodal enrichment functions, which model the singularity near the crack tip

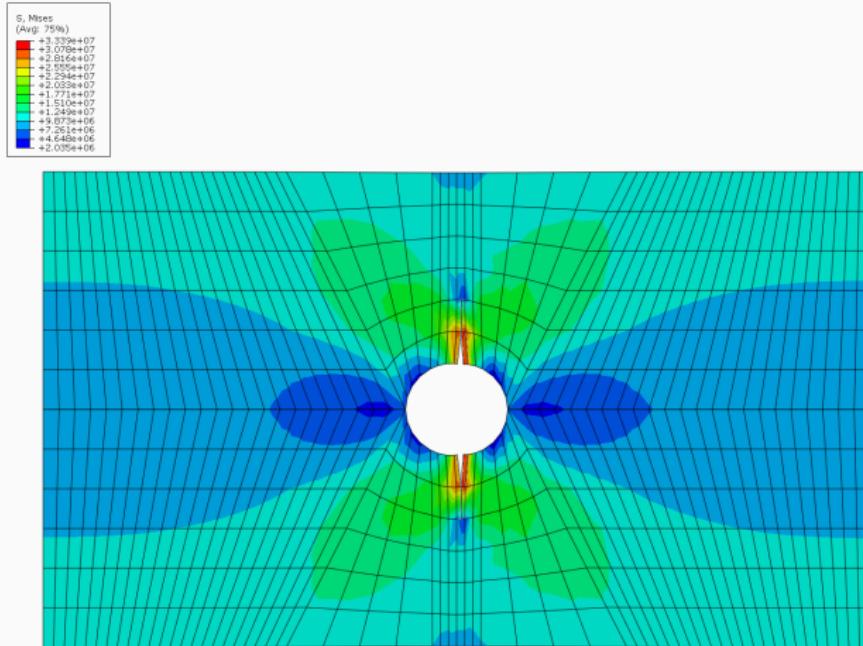


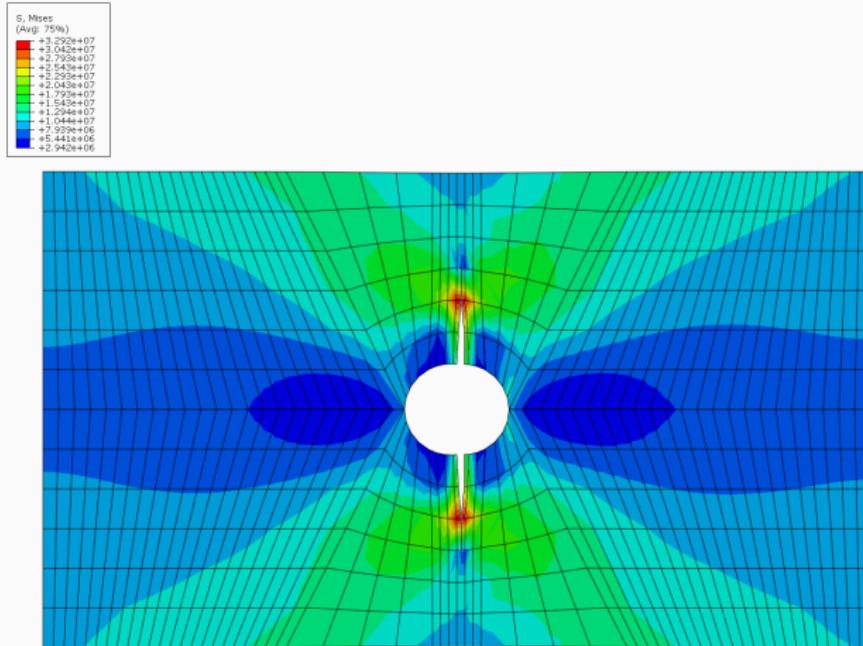


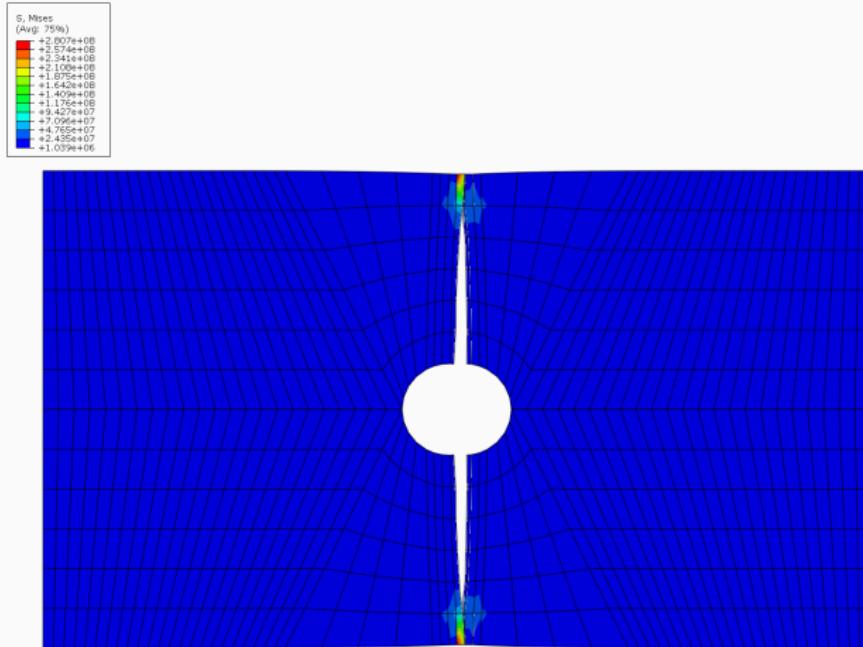












DAMAGE IN COMPOSITES

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- For intermediate loads, matrix cracking and crack growth can occur
- For low loads, crack propagation will not occur in a lamina
- Composite laminae have a relatively high fatigue limit, leading many to neglect fatigue in composites

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- In laminates, cracks can also develop (or propagate to) the boundary between layers
- Delamination can then occur, while individual laminae remain intact, the strength of the structure is compromised as the layers are no longer bound together

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- This is a good assumption away from the edges of a part, however this stress term sharply increases near the free edge
- This stress term can initiate cracks between layers at the edge
- In this region, the assumptions of a perfectly bonded laminate no longer hold, and unexpected damage propagation can occur

IMPACT DAMAGE

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- This leads to poor impact damage behavior, as an impact can generate significant out-of-plane damage

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- This leads to poor impact damage behavior, as an impact can generate significant out-of-plane damage
- This is another challenge for composites in aircraft

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- Work force is not trained in anisotropic/heterogeneous analysis

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- Adhesive joining (reduce holes, fastener count)