AE 737 - Mechanics of Damage Tolerance

Lecture 24

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schedule

- 26 Apr - Exam Solutions, Damage Tolerance
- 28 Apr - SPTE, Finite Elements
- 3 May - Damage in Composites
- 5 May - Repair, Final Project Due May 10

outline

1. exam
2. damage tolerance
3. inpsection cycle
4. finite elements

exam

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- Class average: 89.5
- Standard deviation: 11
- There is no curve for this exam

solutions

damage tolerance

definitions

- Safe Life

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  - Use crack growth or fatigue analysis to establish safe life, in which part will not fail
- Damage tolerant
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  - When cracks grow to a sufficient size, they are inpsectable
  - Inspection cycles are set such that we can be sure crack will not become critical during regular operation

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- **Operating load** stress spectrum (used for crack propagation/fatigue)

structural categories

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- Multiple load path - externally inspectable

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- Single load path - damage tolerant
- Multiple load path - externally inspectable
- Multiple load path - inspectable prior to failure

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- This often requires replacing parts pre-maturely

single load path - damage tolerant

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- When the detectable crack size is much less than the critical crack length, we can safely inspect a part so that it is only replaced when damage is detected
- Many times this damage can be repaired to avoid replacing the part entirely
- Ideal for large, expensive parts that are easy to access (inspection and repair)

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- A secondary structure is inspectable
- The secondary structure can support a certain number of cycles after failure of the primary structure
- Secondary structure can be inspected to observe damage in primary structure

multiple load path - inspectable prior to failure

- In this case the primary structure is inspectable

multiple load path - inspectable prior to failure

- In this case the primary structure is inspectable
- Otherwise same as externally inspectable structure

inpsection cycle

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- We have developed all the equations necessary to determine our own
  1. Determine loading cycle (or equivalent load cycle using Boeing method)
  2. Determine maximum crack length
  3. Determine initial assumed crack length (minimum detectable crack)
  4. Calculate number of cycles/flights until crack grows to maximum allowable size

load cycle

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$$\sum_i (z\sigma_{max})_i^p N_i = (S)^p \tag{24.1}$$

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- We also want to ensure that the crack propagation is still in Region II at this point
- Crack growth becomes unstable in Region III

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- Radiographic (X-Ray, nearly any material)

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- ΔN should be small enough to give converged solution

example

finite elements

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  - Adds ”phantom” cracks in all elements

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- This requires a very fine mesh (computationally expensive)
- Alternatively, many FE packages include ”singularity” elements which allow coarse(r) mesh

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- Use symmetry in your model to reduce node count

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modeling tips

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- Center-crack can be modeled using on 1/4 of the model
- Use biased node seeding (more nodes near tip)

symmetry

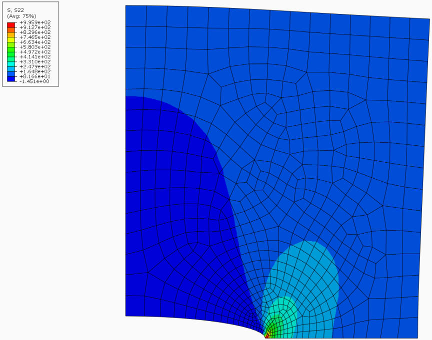

Figure 1:

symmetry

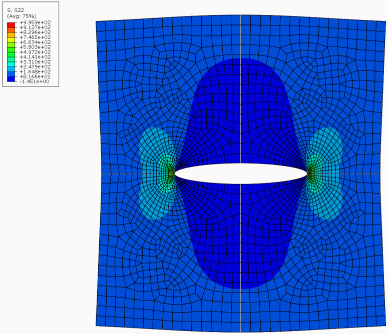

Figure 2:

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- It is also possible to consider the crack opening displacement

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- Where κ is to easily differentiate between plane stress and plane strain

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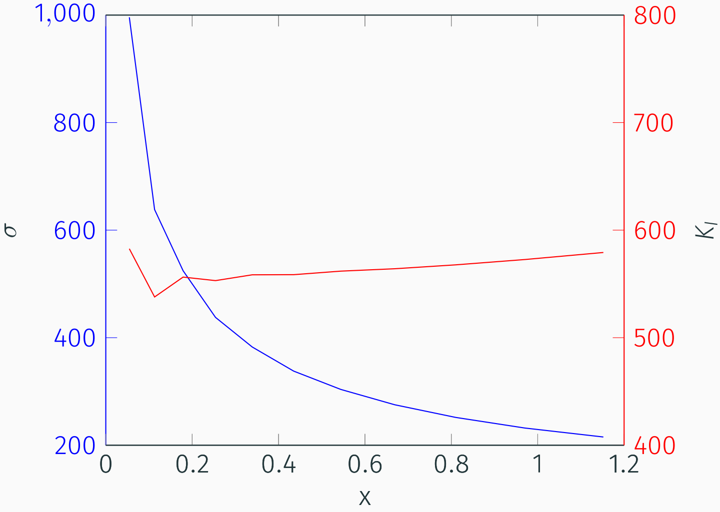
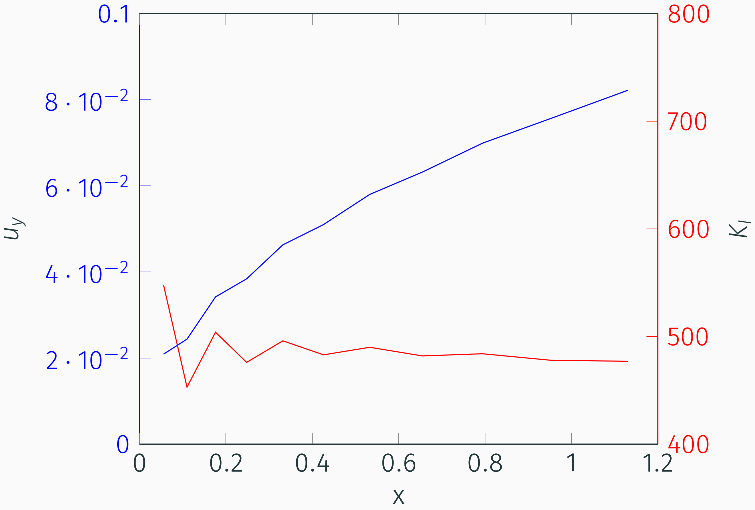
- The displacement method is generally more accurate in Finite Elements

stress results



displacement results



next class

- crack closure
- cohesive elements
- XFEM
- damage in composites