Short Course for American Society for Composites Technical Conference; Wed Afternoon Oct 8, 2025

Course Title: Best Practices and Lessons Learned for Applying Continuum Damage Mechanics to Aerospace Structures

Duration: 3 hours

Session 1:

Objective:

Introduce individuals who are new to continuum damage mechanics (CDM) or progressive damage and failure analysis (PDFA) to the terminology, approaches, and resources. Disseminate the broad knowledge related to the verification, validation, evaluation, and application of CDM and PDFA methods developed under United States government funded research programs.

Outline:

1. CDM and PDFA terminology (30 minutes) (**Frank and Brian**)
    a. Cohesive Zone Modeling (CZM)
    b. Fracture Process Zones
    c. Extended Finite Element Method (and variants)
    d. Continuum Damage Mechanics
    e. ABCD Framework
2. CDM and PDFA approaches and tools and how to access them (5 minutes) (**Brian**)
3. Verification and Validation (20 minutes) (**Brian**)
4. Related Government Programs and Projects (5 minutes) (**Brian**)

Q&A / Discussion / Break (10 minutes)

Session 2:

Objective:

Walk students through the process of building a finite element model for a continuum damage mechanics analysis, explaining the concepts and past studies that have led to our best practices. Finish with examples that demonstrate the importance of some of the best practices.

Outline:

1. Best Practices for building models (30 minutes) (**Frank**)
    a. Laminate discretization
        i. Ply-Tie-Cohesive-Ply-Tie
        ii. Zero-thickness versus finite-thickness cohesive elements
    b. Fiber-aligned meshing
    c. Matrix crack spacing
    d. Constitutive snap-back element size limits
    e. Fracture-based element size limits
    f. Element aspect ratio and skew with respect to material directions
    g. Fine regions, coarse regions, and transition regions

2. Running models (15 minutes) (**Frank**)
    a. Time- and mass-scaling
    b. Computational scalability
    c. Hourglass control, Distortion control, Element deletion
3. Best Practices for post-processing and interpreting model results (15 minutes) (**Frank**)
    a. Intentionally define "what is damage" according to the purpose of the analysis. What experimental data will be available for comparison?
    b. Determining the end of validity of an analysis, e.g., after a large load drop. Select meaningful output frames to visual damage state, not necessarily the last computed frame.
    c. Quantifying dissipated energies — model-wide, by interface, by ply, etc.
    d. Generating damage images for comparison with ultrasound and/or X-ray scan data
4. Example Problems (30 minutes)
    a. Differences between Abaqus input decks for analyses with and without CDM, using two or three single-element examples from the CompDam repository (**Frank**)
        i. User material definition
        ii. User state variables
        iii. Initial conditions
        iv. Output variables
    b. Center Notch (Mode I and Misaligned Mesh study) **(Brian)**
        i. Demonstrate constitutive snap-back and consequences.
        ii. Demonstrate fracture-based element sizing limits and consequences.
        iii. Mesh orientation and its effect on energy dissipation and crack propagation
    c. Open hole tension, seven-point bend, or low-velocity impact (**Frank**)
        i. Mass-scaling problems, e.g., non-physical oscillations after a load drop
        ii. Element-deletion problems, e.g., interpenetration
5. Highlight areas in need of additional research and development (10 minutes) (**Frank and Brian**)

Q&A and Group Discussion (10 minutes)