Modeling Fracture and Failure with Abaqus

2017
Course objectives
Upon completion of this course you will be able to:

- Use proper modeling techniques for capturing crack-tip singularities in fracture mechanics problems
- Use Abaqus/CAE to create meshes appropriate for fracture studies
- Calculate stress intensity factors and contour integrals around a crack tip
- Simulate material damage and failure
- Simulate crack growth using cohesive behavior, VCCT, and XFEM
- Simulate low-cycle fatigue crack growth

Targeted audience
Simulation Analysts

Prerequisites
This course is recommended for engineers with experience using Abaqus

3 days
Day 1

- Lecture 1  Basic Concepts of Fracture Mechanics
- Lecture 2  Modeling Cracks
- Lecture 3  Fracture Analysis
  - Workshop 1  Crack in a Three-point Bend Specimen
  - Workshop 2  Crack in a Helicopter Airframe Component
Day 2

- Lecture 4  Material Failure and Wear
- Lecture 5  Element-based Cohesive Behavior
  - Workshop 3  Crack Growth in a Three-point Bend Specimen using Cohesive Connections (Part 1)
  - Workshop 4  Crack Growth in a Helicopter Airframe Component using Cohesive Elements
- Lecture 6  Surface-based Cohesive Behavior
  - Workshop 3  Crack Growth in a Three-point Bend Specimen using Cohesive Connections (Part 2)
Day 3

- Lecture 7  Virtual Crack Closure Technology (VCCT)
  - Workshop 5  Crack Growth in a Three-point Bend Specimen using VCCT

- Lecture 8  Low-cycle Fatigue

- Lecture 9  Mesh-independent Fracture Modeling (XFEM)
  - Workshop 6  Crack Growth in a Three-point Bend Specimen using XFEM
  - Workshop 7  Modeling Crack Propagation in a Pressure Vessel with Abaqus using XFEM
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Portfolio of established, best-in-class products

- Abaqus
- Isight
- Tosca
- fe-safe
- Simpack

- Design Optimization. Tosca Structure *
  Simulation-driven design refinement to improve performance

- Durability Assessment. fe-safe *
  Accurate life estimation to achieve certification

- FEA Stress Analysis. Abaqus *
  Detailed stress analysis using extracted load history from MBS

- Multibody Simulation. Simpack
  System analysis to extract virtual load history of complete working cycle

- CAD Geometry. CATIA
  Fully parameterized 3D geometry; FEA model generation via associative interface

- Mesh Calibration. Isight *
  Automated mesh calibration, sufficient mesh quality for accurate results

* Included in extended licensing pool
# SIMULIA’s Power of the Portfolio

<table>
<thead>
<tr>
<th>Tool</th>
<th>Features</th>
<th>Use Cases</th>
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| Abaqus | - Routine and Advanced Simulation  
- Linear and Nonlinear, Static and Dynamic  
- Thermal, Electrical, Acoustics  
- Extended Physics through Co-simulation  
- Model Preparation and Visualization | - Realistic Human Simulation  
- High Speed Crash & Impact  
- Noise & Vibration |
| Isight | - Process Integration  
- Design Optimization  
- Parametric Optimization  
- Six Sigma and Design of Experiments | - Material Calibration  
- Workflow Automation  
- Design Exploration |
| Tosca | - Non-Parametric Optimization  
- Structural and Fluid Flow Optimization  
- Topology, Sizing, Shape, Bead Optimization | - Conceptual/Detailed Design  
- Weight, Stiffness, Stress  
- Pressure Loss Reduction |
| fe-safe | - Durability Simulation  
- Low Cycle and High Cycle Fatigue  
- Weld, High Temperature, Non-metallics | - Safety Factors  
- Creep-Fatigue Interaction  
- Weld Fatigue |
| Simpack | - 3D Multibody Dynamics Simulation  
- Mechanical or Mechatronic Systems  
- Detailed Transient Simulation (Offline and Realtime) | - Complete System Analyses  
- (Quasi-)Static, Dynamics, NVH  
- Flex Bodies, Advanced Contact |
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Lesson 1: Basic Concepts of Fracture Mechanics

Lesson content:

- Overview
- Introduction
- Fracture Mechanisms
- Linear Elastic Fracture Mechanics
- Small Scale Yielding
- Energy Considerations
- The J-integral
- Nonlinear Fracture Mechanics
- Mixed-Mode Fracture
- Interfacial Fracture
- Creep Fracture
- Fatigue

1.5 hours
Lesson 2: Modeling Cracks

Lesson content:

- Crack Modeling Overview
- Modeling Sharp Cracks in Two Dimensions
- Modeling Sharp Cracks in Three Dimensions
- Finite-Strain Analysis of Crack Tips
- Limitations Of 3D Swept Meshing For Fracture
- Modeling Cracks with Keyword Options

1.5 hours
Lesson 3: Fracture Analysis

Lesson content:

- Calculation of Contour Integrals
- Examples
  - Penny-shaped crack in an infinite space
  - Conical crack in a half-space
  - Compact Tension Specimen
- Nodal Normals in Contour Integral Calculations
- J-Integrals at Multiple Crack Tips
- Through Cracks in Shells
- Mixed-Mode Fracture
- Material Discontinuities
- Numerical Calculations with Elastic-Plastic Materials
- Residual Stresses
- Workshop Preliminaries
- Workshop 1: Crack in a Three-point Bend Specimen
- Workshop 2: Crack in a Helicopter Airframe Component

3 hours
Lesson content:

- Progressive Damage and Failure
- Damage Initiation Criteria for Ductile Metals
- Damage Evolution
- Element Removal
- Damage in Fiber-Reinforced Composite Materials
- Damage in Fasteners
- Material Wear and Ablation
Lesson 5: Element-based Cohesive Behavior

Lesson content:

- Overview
- Introduction
- Element Technology
- Constitutive Response
- Viscous Regularization
- Modeling Techniques
- Examples
- Workshop 3: Crack Growth in a Three-point Bend Specimen using Cohesive Connections (Part 1)
- Workshop 4: Crack Growth in a Helicopter Airframe Component using Cohesive Elements

3 hours
Lesson content:

- Surface-based Cohesive Behavior
- Element- vs. Surface-based Cohesive Behavior
- Workshop 3: Crack Growth in a Three-point Bend Specimen using Cohesive Connections (Part 2)
Lesson content:

- Introduction
- VCCT Criterion
- LEFM Example using Abaqus/Standard
- LEFM Example using Abaqus/Explicit
- Output
- Ductile Fracture with VCCT
- VCCT Plug-in
- Comparison with Cohesive Behavior
- Examples
- Workshop 5: Crack Growth in a Three-point Bend Specimen using VCCT
Lesson 8: Low-cycle Fatigue

Lesson content:

- Introduction
- Low-cycle Fatigue in Bulk Materials
- Low-cycle Fatigue at Material Interfaces
Lesson 9: Mesh-independent Fracture Modeling (XFEM)

Lesson content:

- Introduction
- Basic XFEM Concepts
- Contact Modeling with XFEM
- Damage Modeling
- Cohesive Damage Modeling
- LEFM-based Damage Modeling
- Creating an XFEM Fracture Model
- Example 1 – Crack Initiation and Propagation using Cohesive Damage
- Example 2 – Crack Initiation and Propagation using LEFM
- Example 3 – Low Cycle Fatigue
- Example 4 – Propagation of an Existing Crack
- Example 5 – Delamination and Through-thickness Crack Propagation
- Example 6 – Contour Integrals
- Example 7 – Pressure Penetration
- Modeling Tips
- Limitations
- Workshop 6: Crack Growth in a Three-point Bend Specimen using XFEM
- Workshop 7: Modeling Crack Propagation in a Pressure Vessel with Abaqus using XFEM

3 hours