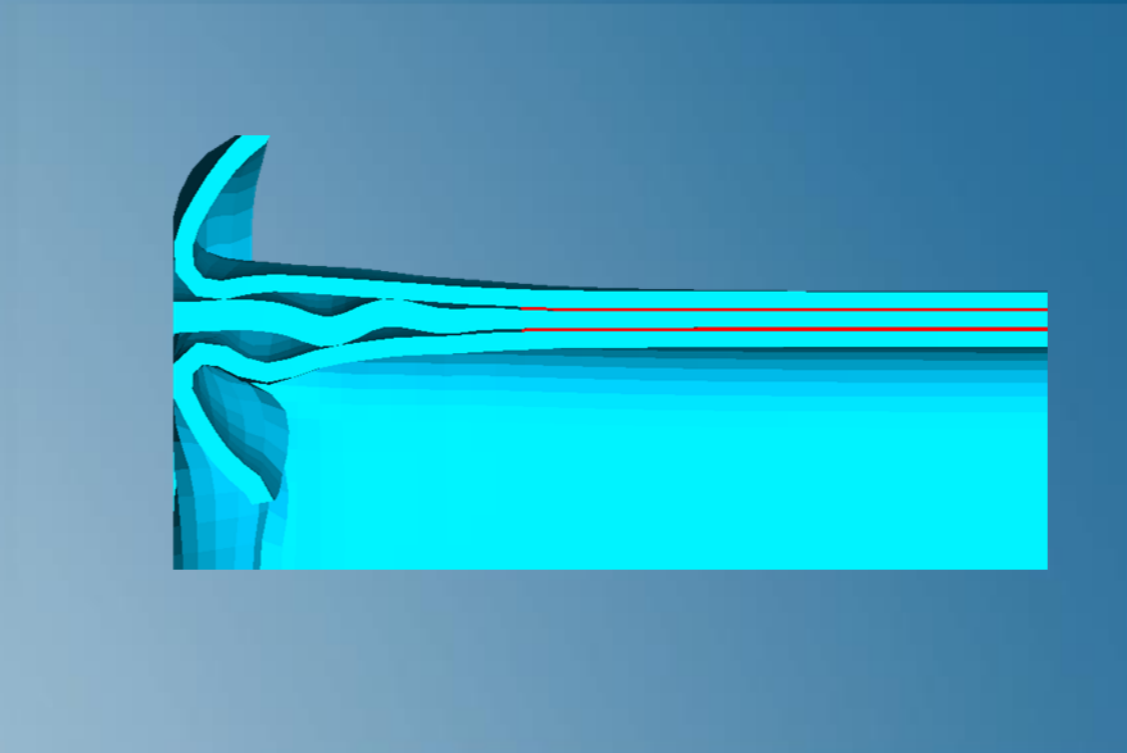


Analysis of Composite Materials with Abaqus

Abaqus 2022



3DEXPERIENCE[®]

About this Course

Course objectives

Upon completion of this course you will be able to:

- ▶ Define anisotropic elasticity for combining the fiber-matrix response
- ▶ Define composite layups
- ▶ Model progressive damage and failure in composites
- ▶ Model delamination and fatigue crack growth of composite structures
- ▶ Model sandwich composite structures and stiffened composite panels

Targeted audience

Simulation Analysts

Prerequisites

This course is recommended for engineers with experience using Abaqus



3 days

Day 1

- ▶ Lesson 1 Introduction
- ▶ Lesson 2 Macroscopic Modeling
- ▶ Lesson 3 Laminate Modeling
 - Workshop 1 The Pagano Plate Problem
- ▶ Lesson 4 Composite Modeling with Abaqus
 - Workshop 2a Buckling of a Laminate Panel
 - Workshop 2b Composite Wing Section
 - Workshop 3 Composite Yacht Hull (Optional)

Day 2

- ▶ Lesson 5 Modeling Damage and Failure in Composites

- ▶ Lesson 6 Cohesive Behavior
 - Workshop 4 Analysis of a DCB using Cohesive Behavior

- ▶ Lesson 7 Virtual Crack Closure Technique (VCCT)
 - Workshop 5 Analysis of a DCB using VCCT (Abaqus/Standard)

 - Workshop 6 Analysis of a DCB using VCCT (Abaqus/Explicit)

Day 3

- ▶ Lesson 8 Reinforcement Modeling

- ▶ Lesson 9 Modeling of Sandwich Composites
 - Workshop 7 Bending of a Sandwich Beam

- ▶ Lesson 10 Modeling of Stiffened Panels
 - Workshop 8 Bending of a Reinforced Flat Panel under Uniform Pressure

- ▶ Lesson 11 Fatigue Crack Growth at Material Interfaces
 - Workshop 9 Fatigue Crack Growth in a DCB Specimen

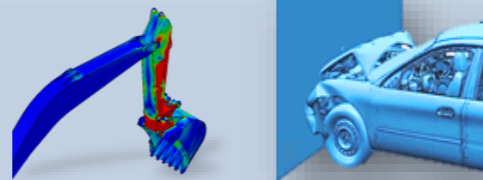
Additional Material

- ▶ Appendix 1 Debond Capability
- ▶ Appendix 2 Cohesive Element Modeling Techniques
- ▶ Appendix 3 More on Continuum Shell Elements
- ▶ Appendix 4 Alternative Modeling Techniques
- ▶ Appendix 5 Modeling Composite Material Impact
 - Workshop 10 Perforation of a Composite Plate
- ▶ Appendix 6 Material Orientation Examples
- ▶ Appendix 7 Multiscale Modeling

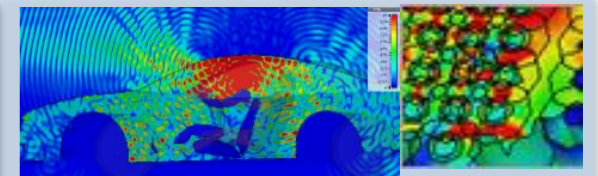
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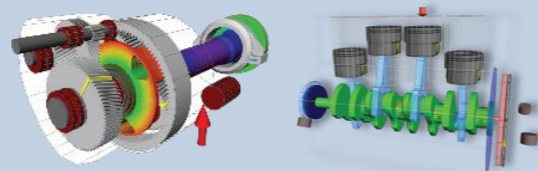
Structures



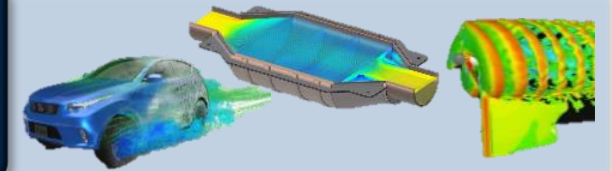
Electromagnetics



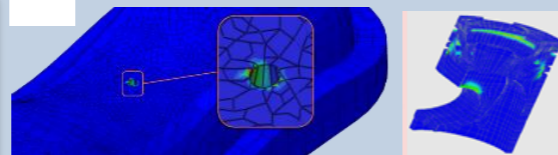
Multibody



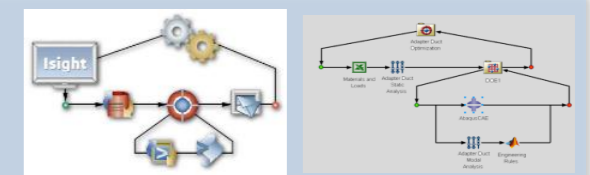
Fluids



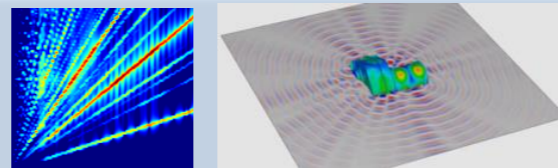
Durability



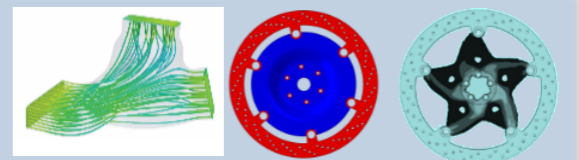
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Revision Status

Lesson 1	11/21	Updated for Abaqus 2022
Lesson 2	11/21	Updated for Abaqus 2022
Lesson 3	11/21	Updated for Abaqus 2022
Lesson 4	11/21	Updated for Abaqus 2022
Lesson 5	11/21	Updated for Abaqus 2022
Lesson 6	11/21	Updated for Abaqus 2022
Lesson 7	11/21	Updated for Abaqus 2022
Lesson 8	11/21	Updated for Abaqus 2022
Lesson 9	11/21	Updated for Abaqus 2022
Lesson 10	11/21	Updated for Abaqus 2022
Lesson 11	11/21	Updated for Abaqus 2022
Appendix 1	11/21	Updated for Abaqus 2022
Appendix 2	11/21	Updated for Abaqus 2022
Appendix 3	11/21	Updated for Abaqus 2022
Appendix 4	11/21	Updated for Abaqus 2022
Appendix 5	11/21	Updated for Abaqus 2022
Appendix 6	11/21	Updated for Abaqus 2022
Appendix 7	11/21	Updated for Abaqus 2022

Workshop 1	11/21	Updated for Abaqus 2022
Workshop 2a	11/21	Updated for Abaqus 2022
Workshop 2b	11/21	Updated for Abaqus 2022
Workshop 3	11/21	Updated for Abaqus 2022
Workshop 4	11/21	Updated for Abaqus 2022
Workshop 5	11/21	Updated for Abaqus 2022
Workshop 6	11/21	Updated for Abaqus 2022
Workshop 7	11/21	Updated for Abaqus 2022
Workshop 8	11/21	Updated for Abaqus 2022
Workshop 9	11/21	Updated for Abaqus 2022
Workshop 10	11/21	Updated for Abaqus 2022

Lesson 1: Introduction

Lesson content:

- ▶ Description of a Composite
- ▶ Some Typical Composites
- ▶ Finite Element Modeling of Composites



20 minutes

Lesson 2: Macroscopic Modeling

Lesson content:

- ▶ Introduction
- ▶ Anisotropic Elasticity
- ▶ Viscoelasticity
- ▶ Thermal Expansion
- ▶ Material Orientation
- ▶ Multiscale Modeling



45 minutes

Lesson 3: Laminate Modeling

Lesson content:

- ▶ Introduction
- ▶ Laminated Composite Shells
- ▶ Continuum Shell Elements
- ▶ Continuum Shell Meshing
- ▶ Continuum Solid Elements
- ▶ Continuum Solid Shell Elements
- ▶ Symmetry Conditions and Laminated Structures
- ▶ Workshop Preliminaries
- ▶ Workshop 1: The Pagano Plate Problem



3 hours

Lesson 4: Composite Modeling with Abaqus

Lesson content:

- ▶ Introduction
- ▶ Understanding Composite Layups
- ▶ Understanding Composite Layup Orientations
- ▶ Defining Composite Layup Output
- ▶ Viewing a Composite Layup
- ▶ Abaqus/CAE Demonstration: Three-ply composite
- ▶ Composites Modeler for Abaqus/CAE
- ▶ Workshop 2a: Buckling of a Laminate Panel
- ▶ Workshop 2b: Composite Wing Section
- ▶ Workshop 3: Composite Yacht Hull



3 hours

Lesson 5: Modeling Damage and Failure in Composites

Lesson content:

- ▶ Failure Criteria in Laminates
- ▶ Failure Theories
- ▶ Progressive Damage of Fiber-Reinforced Composites
- ▶ Example
- ▶ Import of Composite Damage Model



75 minutes

Lesson 6: Cohesive Behavior

Lesson content:

- ▶ Introduction
- ▶ Cohesive Element Technology
- ▶ Constitutive Response in Cohesive Elements
- ▶ Viscous Regularization for Cohesive Elements
- ▶ Cohesive Element Examples
- ▶ Surface-based Cohesive Behavior
- ▶ Element-based vs. Surface-based Cohesive Behavior
- ▶ Workshop 4: Analysis of a DCB using Cohesive Behavior



Note: Appendix 2 contains an in-depth discussion of modeling techniques for cohesive elements using both the interactive and keywords interfaces.



3 hours

Lesson 7: Virtual Crack Closure Technique (VCCT)

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
- ▶ Advanced Topics
 - Unstable crack growth
 - Smoothing crack tangential directions
- ▶ Workshop 5: Analysis of a DCB using VCCT (Abaqus/Standard)
- ▶ Workshop 6: Analysis of a DCB using VCCT (Abaqus/Explicit)



3 hours

Lesson 8: Reinforcement Modeling

Lesson content:

- ▶ Introduction
- ▶ Rebar Layers
- ▶ Embedded Elements



45 minutes

Lesson 9: Modeling of Sandwich Composites

Lesson content:

- ▶ Introduction to Sandwich Composites
- ▶ Abaqus Usage
- ▶ Modeling Skins with Abaqus/CAE
- ▶ Examples
 - Comparison to NAFEMS solution
 - Comparison of Conventional and Continuum Shells
 - Stacking Elements Through the Thickness
 - Tapered Sandwich Composite
- ▶ Workshop 7: Bending of a Sandwich Beam



1.5 hours

Lesson 10: Modeling of Stiffened Panels

Lesson content:

- ▶ Stiffened Composite Panels
- ▶ Abaqus Usage
- ▶ Example
- ▶ Workshop 8: Bending of a Reinforced Flat Panel under Uniform Pressure



2 hours

Lesson 11: Fatigue Crack Growth at Material Interfaces

Lesson content:

- ▶ Introduction
- ▶ Linear Elastic Fatigue Crack Growth Analysis Procedure
- ▶ Fatigue Crack Growth Criterion
- ▶ Example: Fatigue Crack Growth Prediction for a DCB
- ▶ Improving Crack Front Smoothness
- ▶ Workshop 9: Fatigue Crack Growth in a DCB Specimen



1 hour

Appendix 1: Debond Capability

Appendix content:

- ▶ Introduction
- ▶ Modeling Interface Behavior



30 minutes

Appendix 2: Cohesive Element Modeling Techniques

Appendix content:

- ▶ Viscous Regularization
- ▶ Modeling Techniques



1 hour

Appendix 3: More on Continuum Shell Elements

Appendix content:

- ▶ Defining the Thickness Direction for Continuum Shell Elements
- ▶ Shell Thickness
- ▶ Change in Thickness and Thickness Modulus



1 hour

Appendix 4: Alternative Modeling Techniques

Appendix content:

- ▶ Introduction
- ▶ Laminated Shell Section Definition
- ▶ Laminated Solid Section Definition
- ▶ Section Point-Based Postprocessing Technique



1 hour

Appendix 5: Modeling Composite Material Impact

Appendix content:

- ▶ Introduction
- ▶ Composite Damage Models in Abaqus/Explicit
- ▶ Unidirectional Fibers
 - Example – Composite Plate Impact
- ▶ Woven Fabrics
 - Example – Corrugated Beam Crushing
- ▶ Modeling Techniques
- ▶ Workshop 10: Perforation of a Composite Plate



1.5 hours

Appendix 6: Material Orientation Examples

Appendix content:

- ▶ Example 1: Layered Shell Elements
- ▶ Example 2: Solid Elements
- ▶ Example 3: Layered Solid Elements



Appendix 7: Multiscale Modeling

Appendix content:

- ▶ Introduction
- ▶ Linear vs. Nonlinear Short-fiber Reinforced Composites
- ▶ Mean-field Homogenization
- ▶ Mean-field Homogenization for Linear Elastic Composites
- ▶ Specifying the Microstructure of the Composite
- ▶ Validation: Unit Cube with Spherical Inclusion
- ▶ Validation: Matrix with Cylindrical Inclusion
- ▶ Fiber Orientation
- ▶ Example: Unidirectional stiffened panel subjected to axial compression
- ▶ Validation: Short Fiber Composites
- ▶ Multi-step Homogenization
- ▶ Example: Multiple Inclusion Model
- ▶ Composites with Thermal Expansion
- ▶ Incremental Mean-field Homogenization for Nonlinear Composites
- ▶ Output
- ▶ Examples
- ▶ Micromechanics Plug-in
- ▶ Upscaling
- ▶ Downscaling

