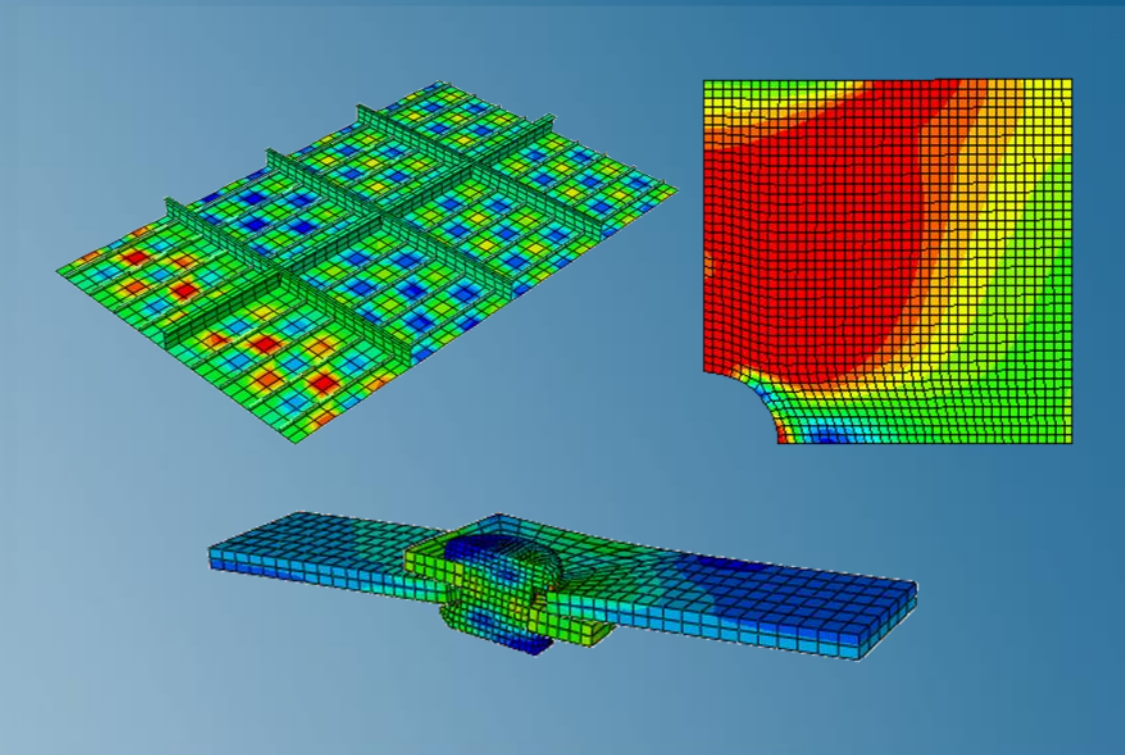


Modeling Contact and Resolving Convergence Issues with Abaqus

Abaqus 2022



About this Course

Course objectives

Upon completion of this course you will be able to:

- ▶ Define general contact and contact pairs
- ▶ Define appropriate surfaces (rigid or deformable)
- ▶ Model frictional contact
- ▶ Model large sliding between deformable bodies
- ▶ Resolve overclosures in interference fit problems
- ▶ Understand how nonlinear problems are solved in Abaqus
- ▶ Develop Abaqus models that will converge
- ▶ Identify modeling errors that cause models to experience convergence difficulties
- ▶ Recognize when a problem is too difficult or too ill-posed to be solved effectively

Targeted audience

Simulation Analysts

Prerequisites

This course is recommended for engineers with experience using Abaqus



3 days

Day 1

- ▶ Lesson 1 Introduction to Nonlinear FEA
- ▶ Lesson 2 Contact Workflow
 - Workshop 1 Compression of a Rubber Seal
- ▶ Lesson 3 Nonlinear FEA with Abaqus/Standard
 - Workshop 2 Bolted Flange Analysis
- ▶ Lesson 4 Why Abaqus Fails to Converge
 - Workshop 3 Crimp Forming Analysis (Part 1)

Day 2

- ▶ Lesson 5 Surface based contact

- ▶ Lesson 6 Solution of Unstable Problems
 - Workshop 3 Crimp Forming Analysis (Part 2)

 - Workshop 4 Reinforced Plate Under Compressive Loads

- ▶ Lesson 7 Contact Properties
 - Workshop 5 Disk Forging Analysis

- ▶ Lesson 8 Convergence Problems: Element Behavior
 - Workshop 6 Element selection

Day 3

- ▶ Lesson 9 Convergence Problems: Materials
 - Workshop 7 Limit Load Analysis
 - Workshop 8 Ball Impact (optional)

- ▶ Lesson 10 Interference Fits
 - Workshop 9 Interference Fit Analysis

- ▶ Lesson 11 Convergence Problems: Constraints and Loading

- ▶ Lesson 12 Modeling Tips
 - Workshop 10 Snap Fit Analysis
 - Workshop 11 Analysis of a Radial Shaft Seal (optional)

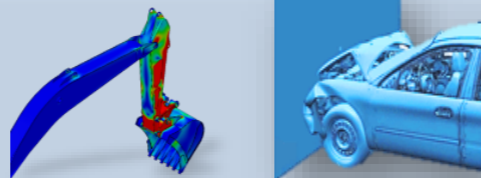
Additional Material

- ▶ Appendix 1 Node-to-Surface Formulation
- ▶ Appendix 2 Contact Elements
- ▶ Appendix 3 Dynamic Contact using Implicit Integration
- ▶ Appendix 4 Contact Logic and Diagnostics Tools
- ▶ Appendix 5 Additional Contact Features
- ▶ Appendix 6 Additional Contact Output
- ▶ Appendix 7 Advanced Friction Models
- ▶ Appendix 8 Contact Clearance
- ▶ Appendix 9 Geometric Smoothing
- ▶ Appendix 10 Resolving Overconstraints

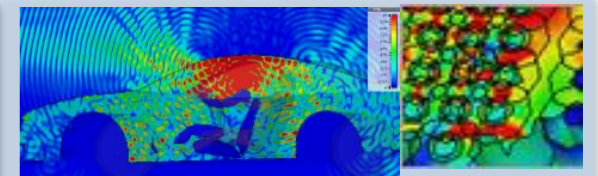
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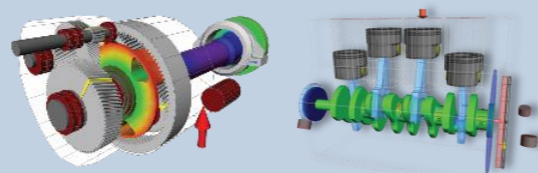
Structures



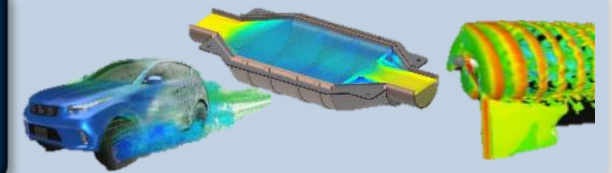
Electromagnetics



Multibody



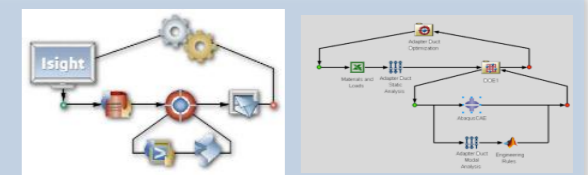
Fluids



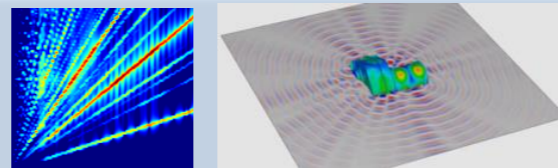
Durability



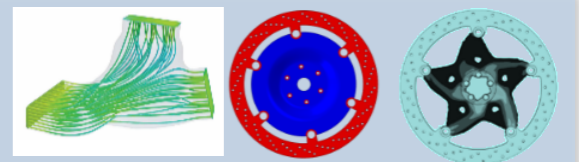
Automation



Vibro-acoustics



Optimization



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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
Lesson 12	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
Appendix 8	11/21	Updated for Abaqus 2022
Appendix 9	11/21	Updated for Abaqus 2022
Appendix 10	11/21	Updated for Abaqus 2022

Workshop 1	11/21	Updated for Abaqus 2022
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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
Workshop 11	11/21	Updated for Abaqus 2022

Lesson 1: Introduction to Nonlinear FEA

Lesson content:

- ▶ What is Convergence?
- ▶ When is a Problem Nonlinear?
- ▶ Properties of Linear Problems in Mechanics
- ▶ Properties of Nonlinear Problems in Mechanics
- ▶ Numerical Techniques for Solving Nonlinear Problems



1 hour

Lesson 2: Contact Workflow

Lesson content:

- ▶ Defining General Contact
- ▶ Defining Contact Pairs
- ▶ Defining Surfaces
- ▶ Workshop Preliminaries
- ▶ Workshop 1: Compression of a Rubber Seal (IA)
- ▶ Workshop 1: Compression of a Rubber Seal (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



1.5 hours

Lesson 3: Nonlinear FEA with Abaqus/Standard

Lesson content:

- ▶ Nonlinear Solution Methods
- ▶ Abaqus/Standard Convergence Criteria: An Overview
- ▶ Automatic Time Incrementation
- ▶ Contact Convergence
- ▶ Workshop 2: Bolted Flange Analysis (IA)
- ▶ Workshop 2: Bolted Flange Analysis (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



1.5 hours

Lesson 4: Why Abaqus Fails to Converge

Lesson content:

- ▶ The Basic Problems
- ▶ Understanding the Warning Messages
- ▶ Helping Abaqus Find a Converged Solution
- ▶ Workshop 3 (Part 1): Crimp Forming Analysis (IA)
- ▶ Workshop 3 (Part 1): Crimp Forming Analysis (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



2 hours

Lesson 5: Surface-based Contact

Lesson content:

- ▶ Contact Formulations
- ▶ Contact Discretization
- ▶ Contact Enforcement Methods
- ▶ Relative Sliding Between Bodies
- ▶ Contact Output
- ▶ Summary



2 hours

Lesson 6: Solution of Unstable Problems

Lesson content:

- ▶ Unstable Quasi-Static Problems
- ▶ Globally Unstable Problems
- ▶ Stabilization of Local Instabilities
- ▶ Symptoms of Local Instability
- ▶ Automated Viscous Damping
- ▶ Implicit Dynamics
- ▶ Examples
- ▶ Stabilization of Initial Rigid Body Motion
- ▶ Workshop 3 (Part 2): Crimp Forming Analysis (IA)
- ▶ Workshop 3 (Part 2): Crimp Forming Analysis (KW)
- ▶ Workshop 4: Reinforced Plate Under Compressive Loads (IA)
- ▶ Workshop 4: Reinforced Plate Under Compressive Loads (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



2.5 hours

Lesson 7: Contact Properties

Lesson content:

- ▶ Pressure-Overclosure Models
- ▶ Friction Models
- ▶ Friction Enforcement
- ▶ Workshop 5: Disk Forging Analysis (IA)
- ▶ Workshop 5: Disk Forging Analysis (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



2 hours

Lesson 8: Convergence Problems: Element Behavior

Lesson content:

- ▶ Hourglassing in Reduced-Integration Elements
- ▶ Checkerboarding
- ▶ Ill-Conditioning
- ▶ Workshop 6: Element Selection (IA)
- ▶ Workshop 6: Element Selection (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



1.5 hours

Lesson 9: Convergence Problems: Materials

Lesson content:

- ▶ Large Strains and Linear Elasticity
- ▶ Unstable Material Behavior
- ▶ Example: Plate with a Hole
- ▶ Unsymmetric Material Stiffness
- ▶ Example: Concrete Slump Test
- ▶ Workshop 7: Limit Load Analysis (IA)
- ▶ Workshop 7: Limit Load Analysis (KW)
- ▶ Workshop 8: Ball Impact (IA)
- ▶ Workshop 8: Ball Impact (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



1.5 hours

Lesson 10: Interference Fits

Lesson content:

- ▶ Initial Overclosure
- ▶ Strain-free Adjustments
- ▶ Interference Fit Problems
- ▶ Interference Fit Techniques for General Contact
- ▶ Interference Fit Techniques for Contact Pairs
- ▶ Interference Fit Example
- ▶ Geometric Smoothing for Curved Surfaces
- ▶ Workshop 9: Interference Fit Analysis (IA)
- ▶ Workshop 9: Interference Fit Analysis (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



3 hours

Lesson 11: Convergence Problems: Constraints & Loading

Lesson content:

- ▶ General Remarks
- ▶ Overconstraints Detected during Model Processing
- ▶ Overconstraints Detected during Analysis Execution
- ▶ Controlling the Overconstraint Checks
- ▶ Nonconservative Loads



1.5 hours

Lesson 12: Modeling Tips

Lesson content:

- ▶ Initial Rigid Body Motion
- ▶ Overconstraint
- ▶ Contact with Quadratic Elements
- ▶ Unsymmetric Matrices in Finite-Sliding Problems
- ▶ Dynamic Instabilities
- ▶ Modeling Corners and Edges
- ▶ Contact and Convergence Guidelines
- ▶ Workshop 10: Snap Fit Analysis (IA)
- ▶ Workshop 10: Snap Fit Analysis (KW)
- ▶ Workshop 11: Analysis of a Radial Shaft Seal (IA)
- ▶ Workshop 11: Analysis of a Radial Shaft Seal (KW)



Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.



2 hours

Appendix 1: Node-to-Surface Formulation

Appendix content:

- ▶ Discretization
- ▶ Finite Sliding: Surface Considerations
- ▶ Small Sliding Characteristics
- ▶ Small Sliding: Local Contact Plane
- ▶ Small Sliding: Surface Considerations



1.5 hours

Appendix 2: Contact Elements

Appendix content:

- ▶ Surface-Based vs. Contact Element Approach
- ▶ Contact Elements
- ▶ Contact Element Output
- ▶ Contact Element Visualization



1 hour

Appendix 3: Dynamic Contact using Implicit Integration

Appendix content:

- ▶ Time Integration Issues
- ▶ Implicit Dynamics
- ▶ Damping
- ▶ Impact Problems



1 hour

Appendix 4: Contact Logic and Diagnostics Tools

Appendix content:

- ▶ Newton Method
- ▶ The Contact Algorithm
- ▶ Contact Diagnostics: Visual
- ▶ Contact Diagnostics: Text



2 hours

Appendix 5: Additional Features

Appendix content:

- ▶ Beam Contact
- ▶ Tie Constraints
- ▶ Rigid Bodies and Contact
- ▶ Analytical Rigid Surfaces
- ▶ Pre-Tensioning of Cross-Sections
- ▶ Pressure Penetration
- ▶ Contact in Linear Perturbation Procedures
- ▶ Initial Stresses for Contact



2 hours

Appendix 6: Additional Contact Output

Appendix content:

- ▶ Additional Field Output
- ▶ Main and Secondary Surfaces
- ▶ Error Indicators
- ▶ Contact Area and Units
- ▶ Contact Opening
- ▶ Self Contact
- ▶ Nodal Contact Output Requests
- ▶ Whole Surface Output
- ▶ Whole Model Output



2 hours

Appendix 7: Advanced Friction Models

Appendix content:

- ▶ Anisotropic Friction
- ▶ Surface Slip Directions
- ▶ Nonlinear Friction Coefficients
- ▶ Kinetic Friction Model
- ▶ User Subroutine FRIC_COEF



2 hours

Appendix 8: Contact Clearance

Appendix content:

- ▶ Precise Specification of Clearances
- ▶ Initial Clearance with General Contact
- ▶ Initial Clearance with Contact Pairs



2 hours

Appendix 9: Geometric Smoothing

Appendix content:

- ▶ Geometric Smoothing for Curved Surfaces
- ▶ Applicability
- ▶ Examples
- ▶ General Contact
- ▶ Contact Pairs



2 hours

Appendix 10: Resolving Overconstraints

Appendix content:

- ▶ Four Bar Linkage Example
- ▶ Constraint Chains
- ▶ Removing Overconstraints



2 hours