Modeling Contact and Resolving Convergence Issues with Abaqus

Abaqus 2019
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
Day 1

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

- Lecture 5  Surface based contact
- Lecture 6  Solution of Unstable Problems
  - Workshop 3  Crimp Forming Analysis (Part 2)
  - Workshop 4  Reinforced Plate Under Compressive Loads
- Lecture 7  Contact Properties
  - Workshop 5  Disk Forging Analysis
- Lecture 8  Convergence Problems: Element Behavior
  - Workshop 6  Element selection
Day 3

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

- Lecture 10  Interference Fits
  - Workshop 9  Interference Fit Analysis

- Lecture 11  Convergence Problems: Constraints and Loading

- Lecture 12  Modeling Tips
  - Workshop 10  Snap Fit Analysis
  - Workshop 11  Analysis of a Radial Shaft Seal (optional)
Additional Material - Appendices

- 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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- Portfolio of established, best-in-class products
  - Abaqus, Isight, Tosca, fe-safe, Simpack

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<table>
<thead>
<tr>
<th>Software</th>
<th>Features</th>
<th>Applications</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 |
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- Mechanical or Mechatronic Systems  
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- Flex Bodies, Advanced Contact |
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## Revision Status

| Lecture 1 | 11/18 | Updated for Abaqus 2019 |
| Lecture 2 | 11/18 | Updated for Abaqus 2019 |
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| Lecture 4 | 11/18 | Updated for Abaqus 2019 |
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| Lecture 6 | 11/18 | Updated for Abaqus 2019 |
| Lecture 7 | 11/18 | Updated for Abaqus 2019 |
| Lecture 8 | 11/18 | Updated for Abaqus 2019 |
| Lecture 9 | 11/18 | Updated for Abaqus 2019 |
| Lecture 10 | 11/18 | Updated for Abaqus 2019 |
| Lecture 11 | 11/18 | Updated for Abaqus 2019 |
| Lecture 12 | 11/18 | Updated for Abaqus 2019 |
| Appendix 1 | 11/18 | Updated for Abaqus 2019 |
| Appendix 2 | 11/18 | Updated for Abaqus 2019 |
| Appendix 3 | 11/18 | Updated for Abaqus 2019 |
| Appendix 4 | 11/18 | Updated for Abaqus 2019 |
| Appendix 5 | 11/18 | Updated for Abaqus 2019 |
| Appendix 6 | 11/18 | Updated for Abaqus 2019 |
| Appendix 7 | 11/18 | Updated for Abaqus 2019 |
| Appendix 8 | 11/18 | Updated for Abaqus 2019 |
| Appendix 9 | 11/18 | Updated for Abaqus 2019 |
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| Workshop 4 | 11/18 | Updated for Abaqus 2019 |
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| Workshop 9 | 11/18 | Updated for Abaqus 2019 |
| Workshop 10 | 11/18 | Updated for Abaqus 2019 |
| Workshop 11 | 11/18 | Updated for Abaqus 2019 |
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 content:

- Defining General Contact
- Defining Contact Pairs
- Defining Surfaces for Contact Pairs
- 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

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
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.
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.
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
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.
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
Appendix 2: Contact Elements

Appendix content:

- Surface-Based vs. Contact Element Approach
- Contact Elements
- Contact Element Output
- Contact Element Visualization
Appendix 3: Dynamic Contact using Implicit Integration

Appendix content:

- Time Integration Issues
- Implicit Dynamics
- Damping
- Impact Problems
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
Appendix 6: Additional Contact Output

Appendix content:

- Additional Field Output
- Master and Slave 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
Appendix 8: Contact Clearance

Appendix content:

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