Heat Transfer and Thermal-Stress Analysis with Abaqus

Abaqus 2019
Course objectives
Upon completion of this course you will be able to:

- Perform steady-state and transient heat transfer simulations
- Solve cavity radiation problems
- Model latent heat effects
- Perform adiabatic, sequentially-coupled, and fully-coupled thermal-stress analyses
- Model contact in heat transfer problems

Targeted audience
Simulation Analysts

Prerequisites
This course is recommended for engineers with experience using Abaqus
Day 1

- **Lecture 1**  Introduction to Heat Transfer
- **Lecture 2**  Heat Transfer Basics
  - Demo 1:  Heat Conduction through a Multilayered System
- **Lecture 3**  Geometry, Material Properties, and Elements
  - Demo 2:  Heat Transfer Analysis using Composite Layups
  - Workshop 1  Reactor Pressure Vessel: Properties and Elements
- **Lecture 4**  Solver Procedures and Convergence
  - Workshop 2  Reactor Pressure Vessel: Analysis Procedures
- **Lecture 5**  Boundary Conditions and Loads
  - Workshop 3  Reactor Pressure Vessel: Loads and Boundary Conditions
- **Lecture 6**  Thermal Interfaces
  - Demo 3:  Thermal Radiation
- **Lecture 7**  Thermal Output and Postprocessing
  - Workshop 4  Reactor Pressure Vessel: Thermal Contact and Analysis
Day 2

- Lecture 8  
  Thermal-Stress Analysis

- Lecture 9  
  Sequentially-Coupled Thermal-Stress Analysis

  - Demo 4:  
    Thermally Insulated Bolted Joint
  - Workshop 5  
    Reactor Pressure Vessel: Stress Response

- Lecture 10  
  Fully-Coupled Thermal-Stress Analysis

  - Workshop 6  
    Fully Coupled Thermal-stress Analysis of a Disc Brake

- Lecture 11  
  Adiabatic Analysis
Additional Material

- Appendix 1  Heat Transfer Theory
- Appendix 2  Forced Convection
  - Workshop 7  Continuous Casting
- Appendix 3  Cavity Radiation
  - Workshop 8  Radiation in a Finned Surface
- Appendix 4  Thermal Fatigue
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Portfolio of established, best-in-class products
- Abaqus, Isight, Tosca, fe-safe, Simpack

* Included in extended licensing pool
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<table>
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<tr>
<th>Tool</th>
<th>Features</th>
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<tr>
<td>Abaqus</td>
<td>• Routine and Advanced Simulation&lt;br&gt;• Linear and Nonlinear, Static and Dynamic&lt;br&gt;• Thermal, Electrical, Acoustics&lt;br&gt;• Extended Physics through Co-simulation&lt;br&gt;• Model Preparation and Visualization</td>
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<td>Isight</td>
<td>• Process Integration&lt;br&gt;• Design Optimization&lt;br&gt;• Parametric Optimization&lt;br&gt;• Six Sigma and Design of Experiments</td>
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<td>Tosca</td>
<td>• Non-Parametric Optimization&lt;br&gt;• Structural and Fluid Flow Optimization&lt;br&gt;• Topology, Sizing, Shape, Bead Optimization</td>
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<td>fe-safe</td>
<td>• Durability Simulation&lt;br&gt;• Low Cycle and High Cycle Fatigue&lt;br&gt;• Weld, High Temperature, Non-metallics</td>
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<td>Simpack</td>
<td>• 3D Multibody Dynamics Simulation&lt;br&gt;• Mechanical or Mechatronic Systems&lt;br&gt;• Detailed Transient Simulation (Offline and Realtime)</td>
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**Realistic Human Simulation**<br>High Speed Crash & Impact Noise & Vibration

**Material Calibration**<br>Workflow Automation Design Exploration

**Conceptual/Detailed Design**<br>Weight, Stiffness, Stress Pressure Loss Reduction

**Safety Factors**<br>Creep-Fatigue Interaction Weld Fatigue

**Complete System Analyses**<br>(Quasi-)Static, Dynamics, NVH Flex Bodies, Advanced Contact
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Lesson 1: Heat Transfer and Stress Analysis Overview

Lesson content:

- Motivation
- Abaqus Capabilities
- Thermal Stress Examples
- Course Overview
Lesson Content:

- Heat Transfer Definition
- Heat Transfer Modes
  - Conduction
  - Convection
  - Radiation
  - Combined
- Elements for Heat Transfer Analysis
- Demonstration 1: Heat Conduction through a Multilayered System
Lesson 3: Geometry, Material Properties, and Elements

Lesson content:

- Thermal Material Properties
  - Main Thermal Material Properties (conductivity, specific heat, density)
  - Temperature-dependent Properties
  - Field-dependent Variables
  - Advanced Thermal Material Properties
  - Material-related Properties (thermal radiation, composites, skins)
- Demonstration 2: Heat Transfer Analysis using Composite Layups
- Geometry Considerations
- Element Technology
  - Element types
  - Element topology
  - Restrictions
- Workshop Preliminaries
- Workshop 1: Reactor Pressure Vessel: Properties and Elements (IA)
- Workshop 1: Reactor Pressure Vessel: Properties and Elements (KW)

1 hour

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
Lesson 4: Analysis Procedures and Convergence

Lesson content:

- Overview
- Procedures
- Automatic Time Incrementation
- Reference Temperature Considerations
- Steady State Termination in Transient Analyses
- Convergence Difficulties
- Element Selection for Highly Nonlinear Problems
- Time Integration Accuracy
- Workshop 2: Reactor Pressure Vessel: Analysis Procedures (IA)
- Workshop 2: Reactor Pressure Vessel: Analysis Procedures (KW)

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
Lesson 5: Boundary Conditions and Loads

**Lesson content:**
- Overview
- Initial Conditions
- Prescribed Temperatures
- Prescribed Fluxes
- Prescribed Boundary Conditions and Loads
- Symmetry
- Film Conditions
- Radiation to the Ambient
- User Subroutines associated with Boundary Conditions
- Workshop 3: Reactor Pressure Vessel: Loads and Boundary Conditions (IA)
- Workshop 3: Reactor Pressure Vessel: Loads and Boundary Conditions (KW)

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
Lesson 6: Thermal Interfaces

Lesson content:

- Heat Transfer across Interfaces
- Bonded Interfaces
- Thermal Contact
- Gap Conductance
- Gap Radiation
- Cavity Radiation
- Demonstration 3: Thermal Radiation
Lesson 7: Thermal Output and Postprocessing

Lesson content:

- Field and History Output Overview
- Output Variables
- Output Requests
- Postprocessing Examples
- Workshop 4: Reactor Pressure Vessel: Thermal Contact and Analysis (IA)
- Workshop 4: Reactor Pressure Vessel: Thermal Contact and Analysis (KW)

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

- Thermal Stress Analysis Overview
- Thermal-Stress Procedures
- Element Selection

20 minutes
Lesson 9: Sequentially-Coupled Thermal-Stress Analysis

Lesson content:

- Sequentially-Coupled Analysis
- Thermal-Stress Modeling Considerations
- Methods for Assigning Temperature Data
- Temperature Application for Solid Elements
- Temperature Application for Shell Elements
- Temperature Application for Beam Elements
- Contact
- Summary
- Demonstration 4: Thermally Insulated Bolted Joint
- Workshop 5: Reactor Pressure Vessel: Stress Response (IA)
- Workshop 5: Reactor Pressure Vessel: Stress Response (KW)

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

2 hours
Lesson 10: Fully-Coupled Thermal-Stress Analysis

Lesson content:

- Full Temperature-Displacement Coupling
- Element Selection
- Contact Interaction
- Examples of Fully Coupled Analyses
- Rigid Bodies in Thermal-Stress Analysis
- Heat Transfer Analysis with Abaqus/Explicit
- Workshop 6: Fully Coupled Thermal-stress Analysis of a Disc Brake (IA)
- Workshop 6: Fully Coupled Thermal-stress Analysis of a Disc Brake (KW)

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

2 hours
Lesson 11: Adiabatic Analysis

Lesson content:

- Adiabatic Analysis
- Adiabatic Analysis Examples
Appendix 1: Heat Transfer Theory

Appendix content:

- Summary of Governing Equations for Conduction
- Constitutive Relation—Fourier's Law
- Thermal Energy Balance—Differential Form
- Thermal Energy Balance—Equivalent Variational Form
- Finite Element Approximation
- Transient Analysis
- Eulerian Formulation for Convection
- Thermal Radiation Formulation
- Adiabatic Thermal-Stress Analysis
- Nonlinear Solution Scheme
Appendix 2: Forced Convection

Appendix content:

- Example: 1-D Convective Heat Transfer
- Stabilization
- Convective/Diffusive Element Library
- Abaqus Usage
- Workshop 7: Continuous Casting (IA)
- Workshop 7: Continuous Casting (KW)

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
Appendix 3: Cavity Radiation

**Appendix content:**

- Thermal Radiation
- Cavity Radiation
- Fully Implicit Cavity Radiation Approach
- Open vs. Closed Cavities
- Cavity Radiation and Viewfactor Calculations
- Radiation Symmetry
- Radiation Motion
- Cavity Radiation Output
- Approximate Cavity Radiation Approach
- Workshop 8: Radiation in a Finned Surface (IA)
- Workshop 8: Radiation in a Finned Surface (KW)

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
Appendix 4: Thermal Fatigue

Appendix content:

- Thermal Fatigue
- Example