Heat Transfer and Thermal-Stress Analysis with Abaqus

Abaqus 2020
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

- **Lesson 1**  
  Introduction to Heat Transfer

- **Lesson 2**  
  Heat Transfer Basics
  
  - Demo 1:  
    Heat Conduction through a Multilayered System

- **Lesson 3**  
  Geometry, Material Properties, and Elements
  
  - Demo 2:  
    Heat Transfer Analysis using Composite Layups
  
  - Workshop 1:  
    Reactor: Properties and Elements

- **Lesson 4**  
  Solver Procedures and Convergence
  
  - Workshop 2:  
    Reactor: Analysis Procedures

- **Lesson 5**  
  Boundary Conditions and Loads
  
  - Workshop 3:  
    Reactor: Loads and Boundary Conditions

- **Lesson 6**  
  Thermal Interfaces
  
  - Demo 3:  
    Thermal Radiation

- **Lesson 7**  
  Thermal Output and Postprocessing
  
  - Workshop 4:  
    Reactor: Thermal contact and Analysis
Day 2

- Lesson 8  Thermal-Stress Analysis
- Lesson 9  Sequentially-Coupled Thermal-Stress Analysis
  - Demo 4:  Thermally Insulated Bolted Joint
  - Workshop 5  Reactor: Stress Response
- Lesson 10  Fully-Coupled Thermal-Stress Analysis
- Workshop 6  Disc Brake Analysis
- Lesson 11  Adiabatic Analysis
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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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- 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

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

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

- Mesh Calibration, Isight *
  - Automated mesh calibration, sufficient mesh quality for accurate results
**SIMULIA’s Power of the Portfolio**

### Abaqus
- Routine and Advanced Simulation
- Linear and Nonlinear, Static and Dynamic
- Thermal, Electrical, Acoustics
- Extended Physics through Co-simulation
- Model Preparation and Visualization

### Isight
- Process Integration
- Design Optimization
- Parametric Optimization
- Six Sigma and Design of Experiments

### Tosca
- Non-Parametric Optimization
- Structural and Fluid Flow Optimization
- Topology, Sizing, Shape, Bead Optimization

### fe-safe
- Durability Simulation
- Low Cycle and High Cycle Fatigue
- Weld, High Temperature, Non-metallics

### Simpack
- 3D Multibody Dynamics Simulation
- Mechanical or Mechatronic Systems
- Detailed Transient Simulation (Offline and Realtime)

### Realistic Human Simulation
- High Speed Crash & Impact
- Noise & Vibration

### Material Calibration
- Workflow Automation
- Design Exploration

### Conceptual/Detailed Design
- Weight, Stiffness, Stress
- Pressure Loss Reduction

### Safety Factors
- Creep-Fatigue Interaction
- Weld Fatigue

### Complete System Analyses
- (Quasi-)Static, Dynamics, NVH
- Flex Bodies, Advanced Contact
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Lesson content:

- Motivation
- Abaqus Capabilities
- Thermal Stress Examples
- Course Overview
Lesson 2: Heat Transfer Basics

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 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: Properties and Elements (IA)
- Workshop 1: Reactor: Properties and Elements (KW)

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: Analysis Procedures (IA)
- Workshop 2: Reactor: 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: Loads and Boundary Conditions (IA)
- Workshop 3: Reactor: Loads and Boundary Conditions (KW)

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
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: Thermal Contact and Analysis (IA)
- Workshop 4: Reactor: Thermal Contact and Analysis (KW)

> Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
Lesson 8: Thermal-Stress Analysis

Lesson content:

- Thermal Stress Analysis Overview
- Thermal-Stress Procedures
- Element Selection
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: Stress Response (IA)
- Workshop 5: Reactor: Stress Response (KW)

Both interactive (IA) and keywords (KW) versions of the workshop are provided. Complete only one.
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: Disc Brake Analysis (IA)
- Workshop 6: Disc Brake Analysis (KW)

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

30 minutes