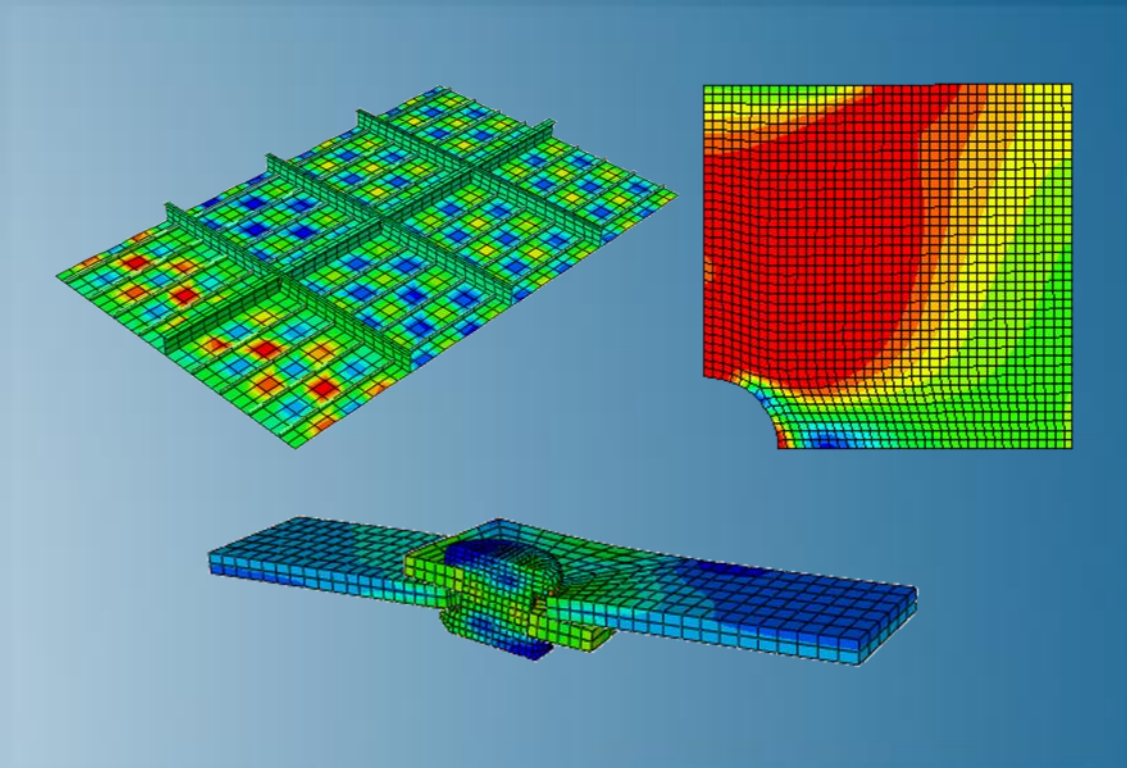


# Modeling Contact and Resolving Convergence Issues with Abaqus

Abaqus 2020



**3DEXPERIENCE**<sup>®</sup>



# 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

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- ▶ 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

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- ▶ 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

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- ▶ 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 - Appendices

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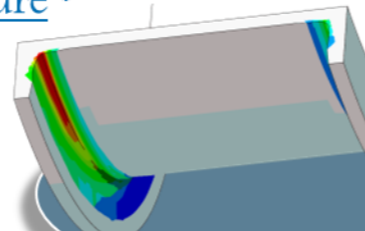
- ▶ Appendix 1      Node-to-Surface Formulation
- ▶ Appendix 2      Contact Elements
- ▶ Appendix 3      Dynamic Contact using Implicit Integration
- ▶ Appendix 4      Contact Logic and Diagnostics Tools
- ▶ Appendix 5      Additional Contact Features
- ▶ Appendix 6      Additional Contact Output
- ▶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

# SIMULIA

- ▶ SIMULIA is the Dassault Systèmes brand for Realistic Simulation solutions
- ▶ Portfolio of established, best-in-class products
  - Abaqus, Isight, Tosca, fe-safe, Simpack

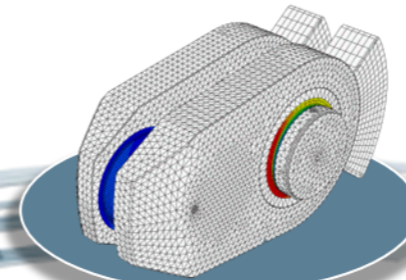
## Design Optimization: Tosca Structure \*

Simulation-driven design refinement to improve performance



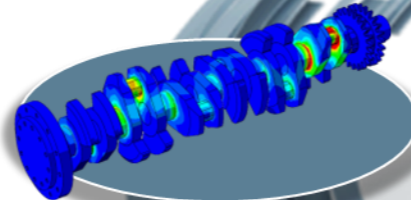
## Durability Assessment: fe-safe \*

Accurate life estimation to achieve certification



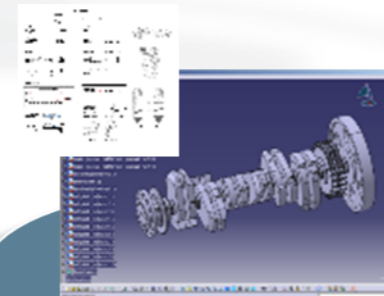
## FEA Stress Analysis: Abaqus \*

Detailed stress analysis using extracted load history from MBS



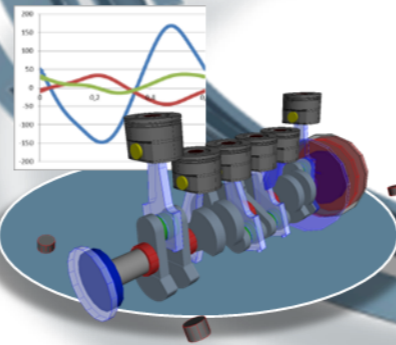
## CAD Geometry: CATIA

Fully parameterized 3D geometry; FEA model generation via associative interface



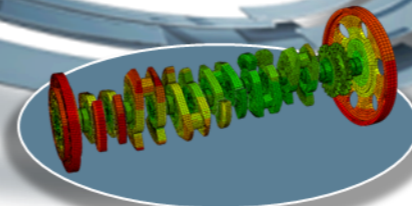
## Multibody Simulation: Simpack

System analysis to extract virtual load history of complete working cycle



## Mesh Calibration: Isight \*

Automated mesh calibration; sufficient mesh quality for accurate results

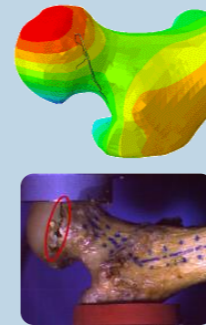


\* Included in extended licensing pool

# SIMULIA's Power of the Portfolio

## Abaqus

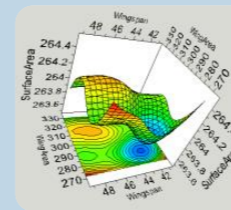
- Routine and Advanced Simulation
- Linear and Nonlinear, Static and Dynamic
- Thermal, Electrical, Acoustics
- Extended Physics through Co-simulation
- Model Preparation and Visualization



**Realistic Human Simulation  
High Speed Crash & Impact  
Noise & Vibration**

## Isight

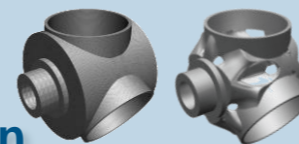
- Process Integration
- Design Optimization
- Parametric Optimization
- Six Sigma and Design of Experiments



**Material Calibration  
Workflow Automation  
Design Exploration**

## Tosca

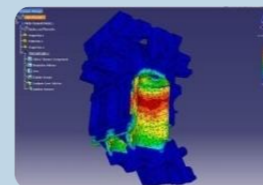
- Non-Parametric Optimization
- Structural and Fluid Flow Optimization
- Topology, Sizing, Shape, Bead Optimization



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

## fe-safe

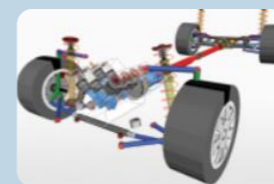
- Durability Simulation
- Low Cycle and High Cycle Fatigue
- Weld, High Temperature, Non-metallics



**Safety Factors  
Creep-Fatigue Interaction  
Weld Fatigue**

## Simpack

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



**Complete System Analyses  
(Quasi-)Static, Dynamics, NVH  
Flex Bodies, Advanced  
Contact**



# Join the Community!

How can you maximize the robust technology of the SIMULIA Portfolio ?  
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**SIMULIA**




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COMPETITIVE.

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<b>North American</b>  <ul style="list-style-type: none"><li>&gt; By Location</li><li>&gt; By Course</li></ul>	<b>International</b>  <ul style="list-style-type: none"><li>&gt; By Location</li><li>&gt; By Course</li></ul>	<b>Live Online Training</b>  <ul style="list-style-type: none"><li>&gt; Full Schedule</li></ul>
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# Revision Status

Lesson 1	11/19	Updated for Abaqus 2020
Lesson 2	11/19	Updated for Abaqus 2020
Lesson 3	11/19	Updated for Abaqus 2020
Lesson 4	11/19	Updated for Abaqus 2020
Lesson 5	11/19	Updated for Abaqus 2020
Lesson 6	11/19	Updated for Abaqus 2020
Lesson 7	11/19	Updated for Abaqus 2020
Lesson 8	11/19	Updated for Abaqus 2020
Lesson 9	11/19	Updated for Abaqus 2020
Lesson 10	11/19	Updated for Abaqus 2020
Lesson 11	11/19	Updated for Abaqus 2020
Lesson 12	11/19	Updated for Abaqus 2020
Appendix 1	11/19	Updated for Abaqus 2020
Appendix 2	11/19	Updated for Abaqus 2020
Appendix 3	11/19	Updated for Abaqus 2020
Appendix 4	11/19	Updated for Abaqus 2020
Appendix 5	11/19	Updated for Abaqus 2020
Appendix 6	11/19	Updated for Abaqus 2020
Appendix 7	11/19	Updated for Abaqus 2020
Appendix 8	11/19	Updated for Abaqus 2020
Appendix 9	11/19	Updated for Abaqus 2020
Appendix 10	11/19	Updated for Abaqus 2020

Workshop 1	11/19	Updated for Abaqus 2020
Workshop 2	11/19	Updated for Abaqus 2020
Workshop 3	11/19	Updated for Abaqus 2020
Workshop 4	11/19	Updated for Abaqus 2020
Workshop 5	11/19	Updated for Abaqus 2020
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Workshop 7	11/19	Updated for Abaqus 2020
Workshop 8	11/19	Updated for Abaqus 2020
Workshop 9	11/19	Updated for Abaqus 2020
Workshop 10	11/19	Updated for Abaqus 2020
Workshop 11	11/19	Updated for Abaqus 2020

# 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
- ▶ 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



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