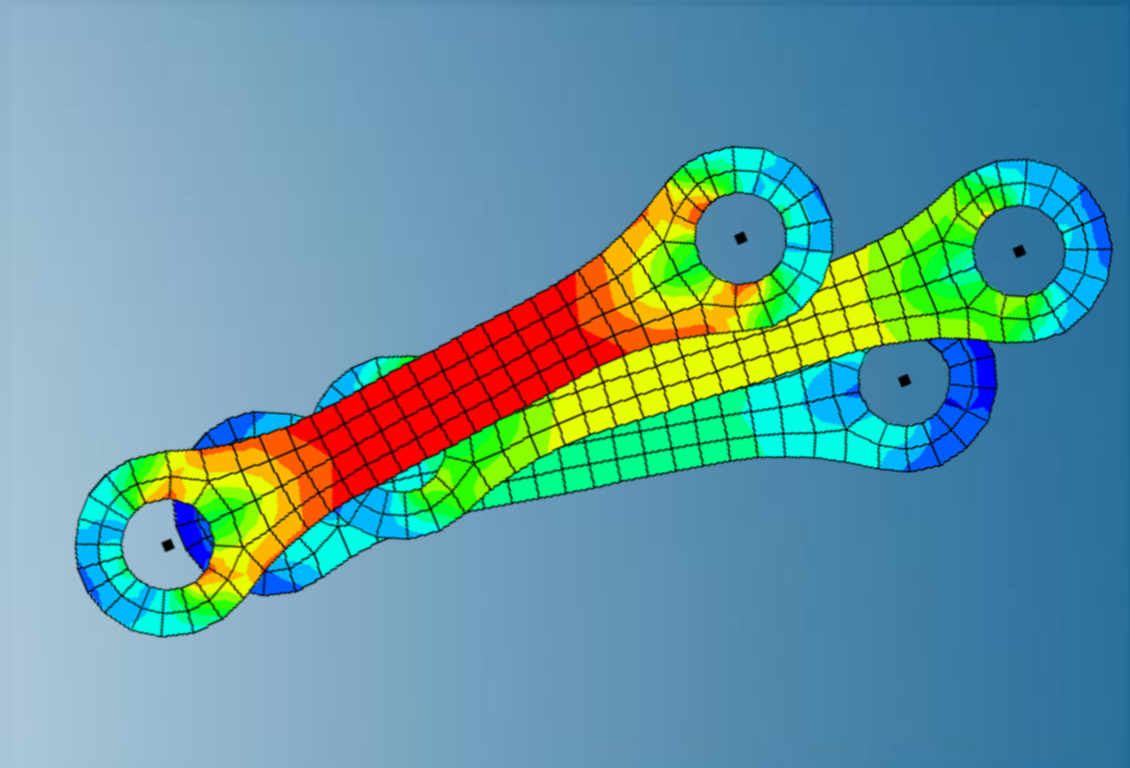


Substructures and Submodeling with Abaqus

Abaqus 2019



3DEXPERIENCE[®]



About this Course

Course objectives

Upon completion of this course you will be able to:

- ▶ Understand the difference between substructuring and submodeling
- ▶ Build, translate, rotate and reflect substructures
- ▶ Build preloads into substructures
- ▶ Design meshes for submodel analysis
- ▶ Perform solid-to-solid, shell-to-shell, and shell-to-solid submodeling

Targeted audience

Simulation Analysts

Prerequisites

This course is recommended for engineers with experience using Abaqus



2 days

Day 1

- ▶ Lecture 1 Introduction to Substructures
- ▶ Lecture 2 Using Static Substructuring in Abaqus
- ▶ Lecture 3 Linear Perturbations about a Preloaded State
- ▶ Lecture 4 Dynamic Substructuring
- ▶ Lecture 5 Substructure Output
- ▶ Lecture 6 Substructuring Examples
 - Workshop 1a Substructures: Plane Frame Analysis
 - Workshop 1b Substructures: Surface Mount Analysis
- ▶ Lecture 7 Using substructures with Abaqus/Explicit
 - Workshop 2 Substructures: Beam Impact (*optional*)

Day 2

- ▶ Lecture 8 Introduction to Submodeling
- ▶ Lecture 9 Submodeling in Abaqus
- ▶ Lecture 10 Abaqus Usage and Examples (Part 1)
 - Workshop 3 Submodeling: Pressure Vessel Nozzle Analysis
- ▶ Lecture 11 Abaqus Usage and Examples (Part 2)
 - Workshop 4 Submodeling: Ceramic-Metal Braze Joint
- ▶ Lecture 12 Submodeling Practices
 - Workshop 5 Submodeling: Composite Tube Joint
- ▶ Lecture 13 Limitations of Submodeling

Additional Material

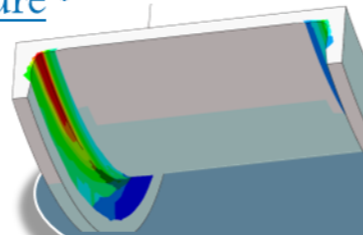
- ▶ Appendix 1 Theory of Substructures

SIMULIA

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

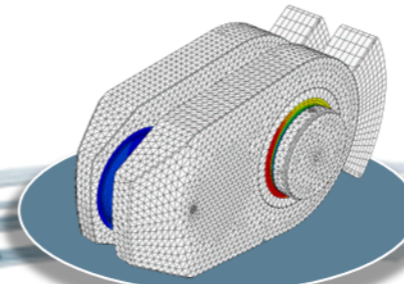
Design Optimization: Tosca Structure *

Simulation-driven design refinement to improve performance



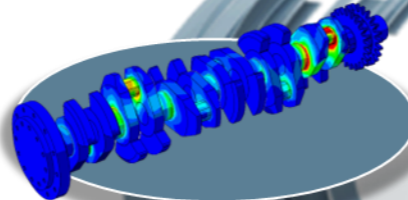
Durability Assessment: fe-safe *

Accurate life estimation to achieve certification



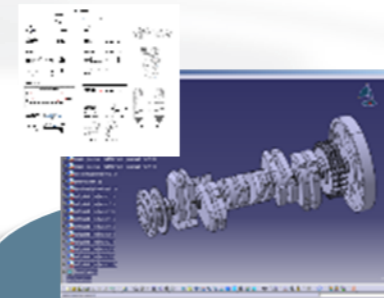
FEA Stress Analysis: Abaqus *

Detailed stress analysis using extracted load history from MBS



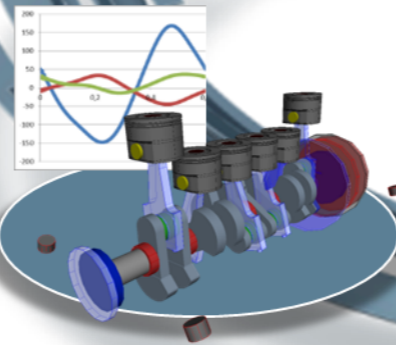
CAD Geometry: CATIA

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



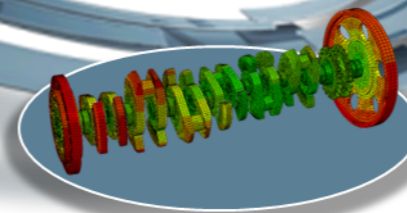
Multibody Simulation: Simpack

System analysis to extract virtual load history of complete working cycle



Mesh Calibration: Isight *

Automated mesh calibration; sufficient mesh quality for accurate results

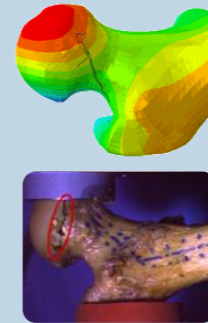


* Included in extended licensing pool

SIMULIA's Power of the Portfolio

Abaqus

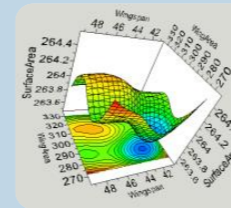
- Routine and Advanced Simulation
- Linear and Nonlinear, Static and Dynamic
- Thermal, Electrical, Acoustics
- Extended Physics through Co-simulation
- Model Preparation and Visualization



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

Isight

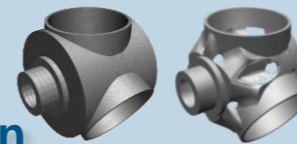
- Process Integration
- Design Optimization
- Parametric Optimization
- Six Sigma and Design of Experiments



**Material Calibration
Workflow Automation
Design Exploration**

Tosca

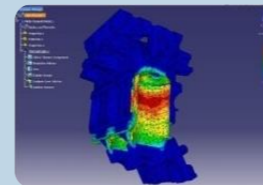
- Non-Parametric Optimization
- Structural and Fluid Flow Optimization
- Topology, Sizing, Shape, Bead Optimization



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

fe-safe

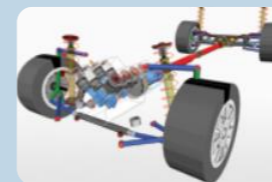
- Durability Simulation
- Low Cycle and High Cycle Fatigue
- Weld, High Temperature, Non-metallics



**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
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Revision Status

Lecture 1	11/18	Updated for Abaqus 2019
Lecture 2	11/18	Updated for Abaqus 2019
Lecture 3	11/18	Updated for Abaqus 2019
Lecture 4	11/18	Updated for Abaqus 2019
Lecture 5	11/18	Updated for Abaqus 2019
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
Lecture 13	11/18	Updated for Abaqus 2019
Appendix 1	11/18	Updated for Abaqus 2019

Workshop 1a	11/18	Updated for Abaqus 2019
Workshop 1b	11/18	Updated for Abaqus 2019
Workshop 2	11/18	Updated for Abaqus 2019
Workshop 3	11/18	Updated for Abaqus 2019
Workshop 4	11/18	Updated for Abaqus 2019
Workshop 5	11/18	Updated for Abaqus 2019

Lesson 1: Introduction to Substructures

Lesson content:

- ▶ Why Substructuring?
- ▶ Static Substructuring
- ▶ Advantages of Substructuring
- ▶ Procedures Supporting Substructures



30 minutes

Lesson 2: Using Static Substructuring in Abaqus

Lesson content:

- ▶ The Basics
- ▶ Substructure Generation
- ▶ Substructure Usage: Abaqus/CAE
- ▶ Substructure Usage: Keywords
- ▶ Substructure Load Cases
- ▶ Substructure Gravity Loading
- ▶ Kinematic Constraints in Substructures
- ▶ Flexible Body Dynamics
- ▶ Limitations



1 hour

Lesson 3: Linear Perturbations about a Preloaded State

Lesson content:

- ▶ Introduction
- ▶ Substructure Tangent Stiffness Calculation
- ▶ Response Quantities
- ▶ Effect of Preloads at the Usage Level
- ▶ Preloading Syntax
- ▶ Preloading Example: Rotating Structure



30 minutes

Lesson 4: Dynamic Substructuring

Lesson content:

- ▶ Guyan Reduction
- ▶ Dynamic Mode Addition
- ▶ Damping with Substructures



Lesson 5: Substructure Output

Lesson content:

- ▶ Introduction
- ▶ Visualizing Substructure Results
- ▶ Output of Eliminated Degrees of Freedom
- ▶ Output of Substructure Matrices
- ▶ Substructure Library Utilities



45 minutes

Lesson 6: Substructuring Examples

Lesson content:

- ▶ Cyclic Symmetry
- ▶ Multilevel Substructuring
- ▶ Workshop Preliminaries
- ▶ Workshop 1a: Substructures: Plane Frame Analysis (IA)
- ▶ Workshop 1a: Substructures: Plane Frame Analysis (KW)
- ▶ Workshop 1b: Substructures: Surface Mount Analysis (IA)
- ▶ Workshop 1b: Substructures: Surface Mount Analysis (KW)



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



3 hours

Lesson 7: Using Substructures with Abaqus/Explicit

Lesson content:

- ▶ Introduction
- ▶ Examples
- ▶ General Concepts
- ▶ Keyword Interface
- ▶ Interactive Interface
- ▶ Postprocessing
- ▶ Technology Notes
- ▶ Workshop 2: Substructures: Beam Impact (IA)
- ▶ Workshop 2: Substructures: Beam Impact (KW)



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



2 hours

Lesson 8: Introduction to Submodeling

Lesson content:

- ▶ Concept of Submodeling
- ▶ Motivation for Submodeling



15 minutes

Lesson 9: Submodeling in Abaqus

Lesson content:

- ▶ Fundamental Assumptions
- ▶ Submodeling Techniques
- ▶ Node-based Implementation
- ▶ Surface-based Implementation



30 minutes

Lesson 10: Abaqus Usage and Examples (Part 1)

Lesson content:

- ▶ Terminology
- ▶ Transfer of Data
- ▶ Prescribed Values
- ▶ Submodeling Workflow
- ▶ Surface-Based Submodel Boundaries
- ▶ Example: Conical Crack in a Half Space
- ▶ Example: Pressure Vessel
- ▶ Workshop 3: Submodeling: Pressure Vessel Nozzle Analysis (IA)
- ▶ Workshop 3: Submodeling: Pressure Vessel Nozzle Analysis (KW)



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



2.5 hours

Lesson 11: Abaqus Usage and Examples (Part 2)

Lesson content:

- ▶ Node-Based Submodel Boundaries
- ▶ Example: Stacked Sheet Metal Assembly
- ▶ Example: Large Displacement Analysis
- ▶ Tolerances at the Submodel Boundary
- ▶ Shell-to-Solid Submodeling
- ▶ Example: Shell-to-Solid Submodel of a Pipe Joint
- ▶ Workshop 4: Submodeling: Ceramic-Metal Braze Joint (IA)
- ▶ Workshop 4: Submodeling: Ceramic-Metal Braze Joint (KW)



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



2 hours

Lesson 12: Submodeling Practices

Lesson content:

- ▶ Perturbation Analysis
- ▶ Changing Procedures
- ▶ The Frequency Domain
- ▶ Submodeling and Thermal Stress Analysis
- ▶ Example: Thermal Strain in a Bar
- ▶ Submodeling in Dynamic Procedures
- ▶ Example: Speaker Diaphragm
- ▶ Workshop 5: Submodeling: Composite Tube Joint (IA)
- ▶ Workshop 5: Submodeling: Composite Tube Joint (KW)



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



1 hour

Lesson 13: Limitations of Submodeling

Lesson content:

- ▶ Elements
- ▶ Procedures
- ▶ Shell-to-Solid



15 minutes

Appendix 1: Theory of Substructures

Appendix content:

- ▶ Static Substructuring
- ▶ Guyan Reduction
- ▶ Restrained Mode Addition



15 minutes