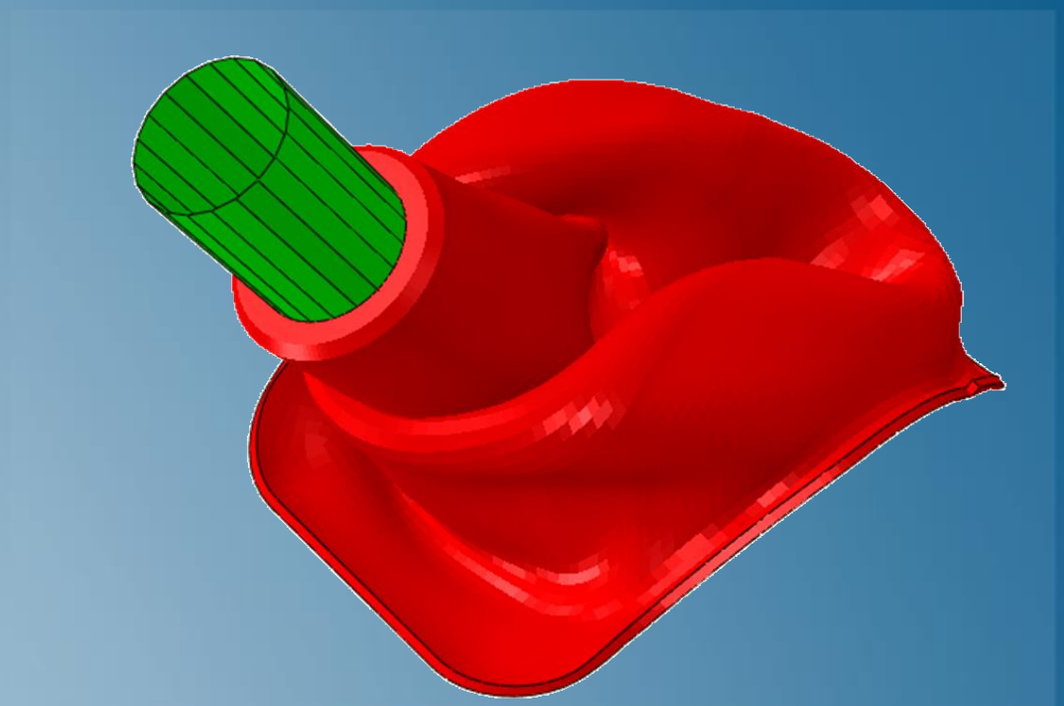
Modeling Rubber and Viscoelasticity with Abaqus

Abaqus 2021



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About this Course

Course objectives

Upon completion of this course you will be able to:

- Use experimental test data to calculate material constants
- Check the stability of the Abaqus material model at extreme strains
- Obtain the best possible material constants from the available test data
- Select elements for modeling rubber and foams
- Design an appropriate finite element mesh
- Model viscoelastic behavior in both the time and frequency domain
- Use a user subroutine to define the hyperelastic behavior

Targeted audience

Simulation Analysts

Prerequisites

This course is recommended for engineers with experience using Abaqus

2 days

Day 1

- Lesson 1 Rubber Physics
- Lesson 2 Introduction to Hyperelasticity Models
- Lesson 3 Mechanical Testing
  - Workshop 1 Axial Deflection of a Rubber Bushing
- Lesson 4 Defining Rubber Elasticity Models in Abaqus
- Lesson 5 Modeling Issues and Tips
  - Workshop 2 Bead Seal Compression

Day 2

- Lesson 6 Viscoelastic Material Behavior
- Lesson 7 Time-Domain Viscoelasticity
  - Workshop 3 Bead Seal Relaxation
- Lesson 8 Frequency-Domain Viscoelasticity
  - Workshop 4 Bead Seal Vibration
- Lesson 9 Permanent Set in Solid Elastomers
- Lesson 10 Anisotropic Hyperelasticity

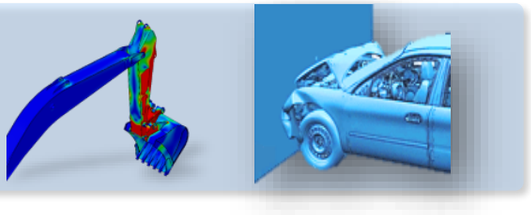
Additional Material

- Appendix 1 Finite Deformations
- Appendix 2 Rubber Elasticity Models: Mathematical Forms
- Appendix 3 Linear Viscoelasticity Theory
- Appendix 4 Harmonic Viscoelasticity Theory
- Appendix 5 Suggested Reading

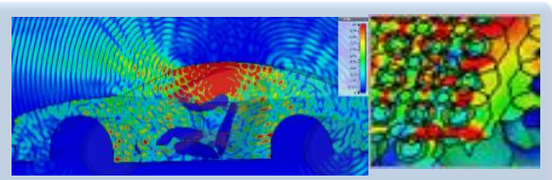
SIMULIA

- SIMULIA is the Dassault Systèmes brand for realistic simulation solutions.
- Advanced simulation portfolio covering simulation disciplines such as structural mechanics, computational fluid dynamics and electromagnetic field simulation, for a true multiphysics simulation approach.

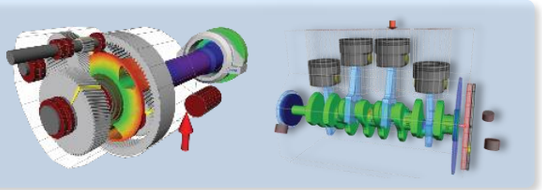
Structures



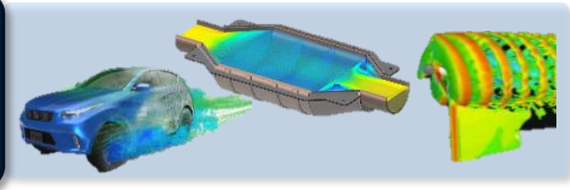
Electromagnetics



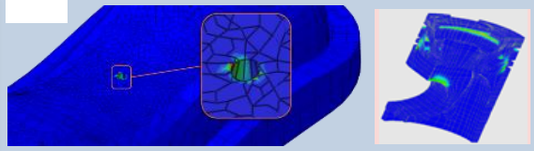
Multibody



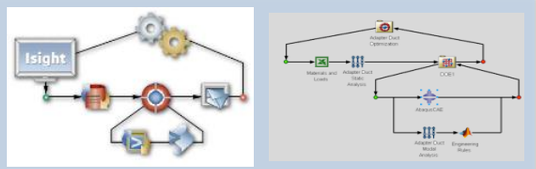
Fluids



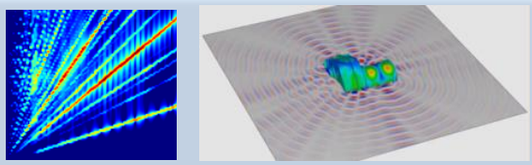
Durability



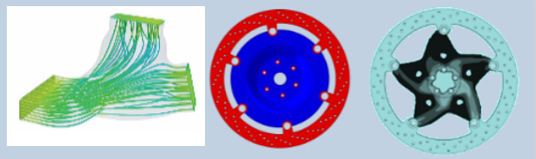
Automation



Vibro-acoustics



Optimization



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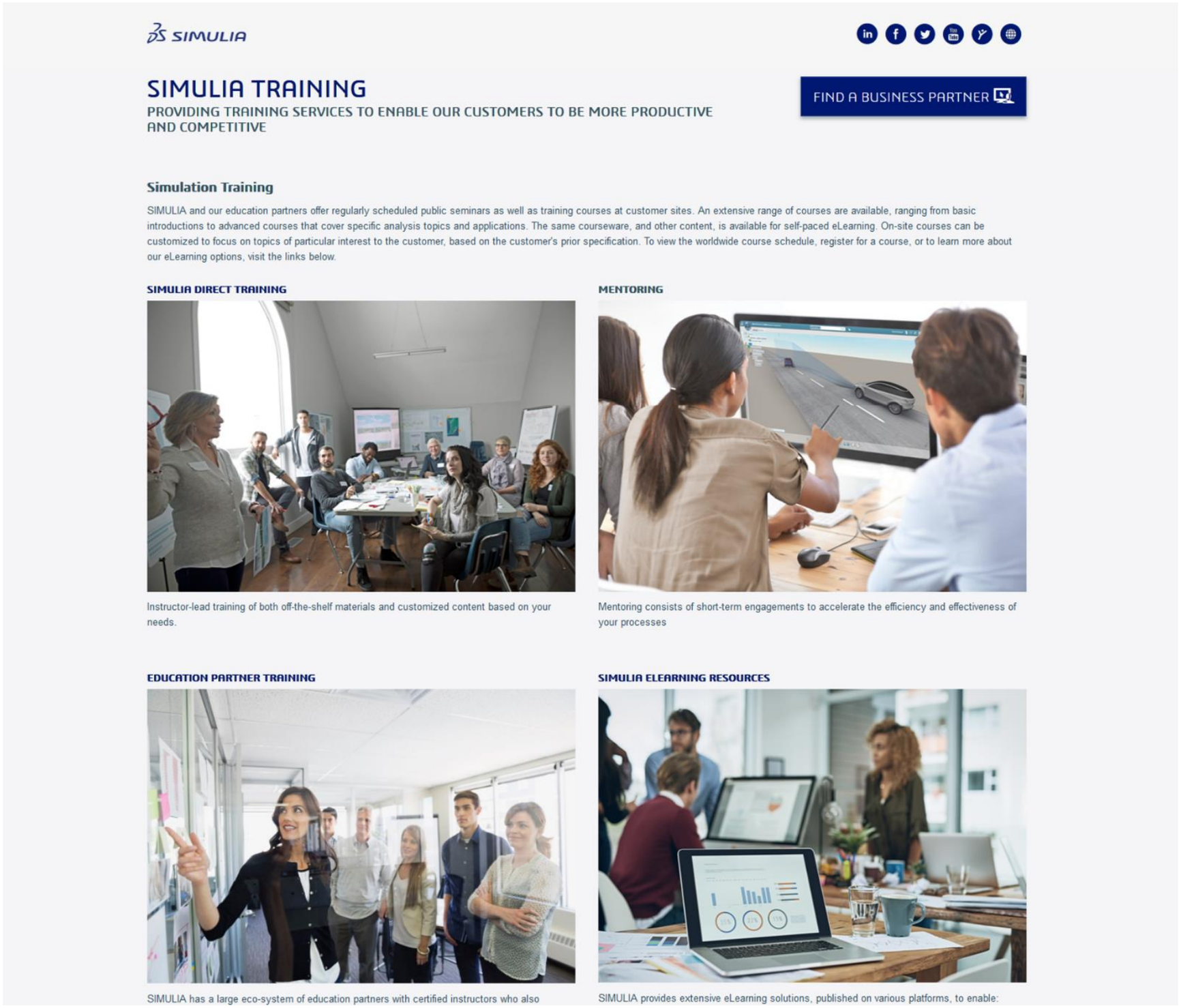

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Revision Status

Lesson 1	11/20	Updated for Abaqus 2021
Lesson 2	11/20	Updated for Abaqus 2021
Lesson 3	11/20	Updated for Abaqus 2021
Lesson 4	11/20	Updated for Abaqus 2021
Lesson 5	11/20	Updated for Abaqus 2021
Lesson 6	11/20	Updated for Abaqus 2021
Lesson 7	11/20	Updated for Abaqus 2021
Lesson 8	11/20	Updated for Abaqus 2021
Lesson 9	11/20	Updated for Abaqus 2021
Lesson 10	11/20	Updated for Abaqus 2021
Appendix 1	11/20	Updated for Abaqus 2021
Appendix 2	11/20	Updated for Abaqus 2021
Appendix 3	11/20	Updated for Abaqus 2021
Appendix 4	11/20	Updated for Abaqus 2021
Appendix 5	11/20	Updated for Abaqus 2021
Workshop 1	11/20	Updated for Abaqus 2021
Workshop 2	11/20	Updated for Abaqus 2021
Workshop 3	11/20	Updated for Abaqus 2021
Workshop 4	11/20	Updated for Abaqus 2021

Lesson 1: Rubber Physics

Lesson content:

- Motivation
- Solid Rubber
  - Molecular structure
  - Material processing
  - Glass transition temperature
  - Nearly incompressible behavior
  - Typical stress–strain response
  - Hysteresis and damping
  - Damage
  - Anisotropy
- Thermoplastic Elastomers
  - Physical description
  - Advantages and disadvantages
- Rubber Foam
  - Physical description
  - Cellular structure
  - Typical stress–strain response
  - Poisson’s effect
- The Nonlinear Elastic Assumption

30 minutes

Lesson 2: Introduction to Hyperelasticity Models

Lesson content:

- Introduction
- Models for Nearly Incompressible Hyperelasticity
- Model for Foam Rubber Hyperelasticity

30 minutes

Lesson 3: Mechanical Testing

Lesson content:

- Modes of Deformation
  - Uniaxial tension
  - Planar tension
  - Uniaxial compression
  - Equibiaxial tension
  - Confined compression
- Loading History
  - Testing at temperature
- Test Specimens
- Test Data Guidelines
- Testing for Time-Dependent Properties
- Workshop Preliminaries
- Workshop 1: Axial Deflection of a Rubber Bushing (IA)
- Workshop 1: Axial Deflection of a Rubber Bushing (KW)

2 hours

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

Lesson 4: Defining Rubber Elasticity Models in Abaqus

Lesson content:

- Curve-Fitting for Hyperelasticity of Nearly Incompressible Materials
- Material Stability
- Curve-fitting in Abaqus/CAE
- Choosing a Hyperelastic Model
- Augmenting Data
- Defining Hyperelastic Models
- Mullins Effect
- Hyperfoam Model
- UHYPER

1.5 hours

Lesson 5: Modeling Issues and Tips

Lesson content:

- Contact
- Element Selection
- Meshing Considerations
- Constraints and Reinforcements
- Instability
- Output Variables
- Using Abaqus/Explicit for Rubber Analyses
- Special Features
- Example: Column Shifter Boot
- Example: Weather Seal
- Workshop 2: Bead Seal Compression (IA)
- Workshop 2: Bead Seal Compression (KW)

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

2 hours

Lesson 6: Viscoelastic Material Behavior

Lesson content:

- Introduction
- Effects of Viscoelasticity
  - Creep
  - Stress relaxation
  - Damping and hysteresis
- Linear Viscoelasticity
- Finite-strain Nonlinear Viscoelasticity
- Temperature Dependence

30 minutes

Lesson 7: Time-Domain Viscoelasticity

Lesson content:

- Classical Linear Viscoelasticity
- Prony Series Representation
- Finite-Strain Linear Viscoelasticity
- Relaxation and Creep Test Data
- Prony Series Data
- Automatic Material Evaluation
- Time-Temperature Correspondence
- Usage Hints
- Finite-Strain Nonlinear Viscoelasticity
- Structural Relaxation in Glass
- Workshop 3: Bead Seal Relaxation (IA)
- Workshop 3: Bead Seal Relaxation (KW)

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

2.5 hours

Lesson 8: Frequency-Domain Viscoelasticity

Lesson content:

- Frequency-Domain Response
- Storage and Loss Moduli
- Classical Isotropic Linear Viscoelasticity
- Frequency-Temperature Correspondence
- Isotropic Finite-Strain Viscoelasticity
- Procedures
- Workshop 4: Bead Seal Vibration (IA)
- Workshop 4: Bead Seal Vibration (KW)

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

1.75 hours

Lesson 9: Permanent Set in Solid Elastomers

Lesson content:

- Motivation
- Defining Permanent Set
- Example
- Summary

30 minutes

Lesson 10: Anisotropic Hyperelasticity

Lesson content:

- Motivation
- Models Available in Abaqus
- Examples

45 minutes

Appendix 1: Finite Deformations

Appendix content:

- Motions and Displacements
- Extension of a Material Line Element
- The Deformation Gradient
- Strain for Large Deformations
- Decomposition of a Deformation
- Principal Stretches and Principal Axes of Deformation
- Strain Invariants
- Deformation Example – Simple Shear
- Summary

45 minutes

Appendix 2: Rubber Elasticity Models: Math. Forms

Appendix content:

- Energy Functions for Solid Rubbers (Isotropic)
  - Polynomial Model
  - Mooney-Rivlin Model
  - Reduced Polynomial Model
  - Neo-Hookean Model
  - Yeoh Model
  - Ogden Model
  - Marlow Model
  - Arruda-Boyce Model
  - Van der Waals Model
- Foam Rubber Model
- Mullins Effect

30 minutes

Appendix 3: Linear Viscoelasticity Theory

Appendix content:

- Classical Linear Viscoelasticity

30 minutes

Appendix 4: Harmonic Viscoelasticity Theory

Appendix content:

- Classical Linear Viscoelasticity
- Harmonic Excitation

15 minutes

Appendix 5: Suggested Reading

Appendix content:

- Suggested Reading

15 minutes