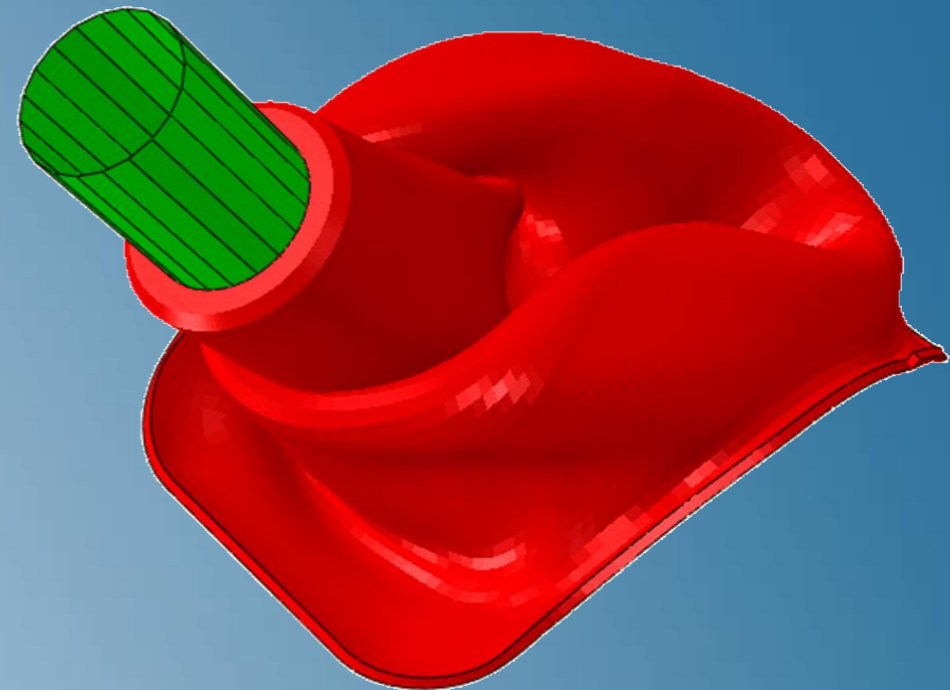


# Modeling Rubber and Viscoelasticity with Abaqus

Abaqus 2021



**3DEXPERIENCE**<sup>®</sup>

# 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

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- ▶ 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

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- ▶ 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

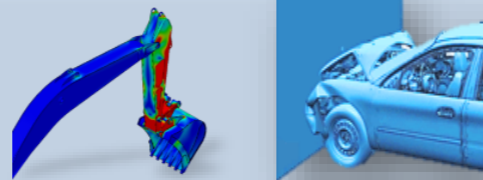
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- ▶ Appendix 1      Finite Deformations
- ▶ Appendix 2      Rubber Elasticity Models: Mathematical Forms
- ▶ Appendix 3      Linear Viscoelasticity Theory
- ▶ Appendix 4      Harmonic Viscoelasticity Theory
- ▶ Appendix 5      Suggested Reading

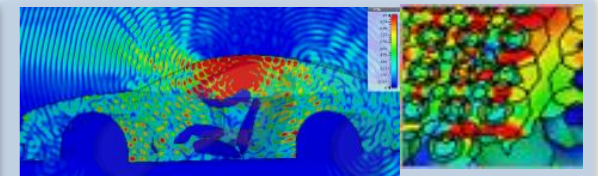
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- ▶ SIMULIA is the Dassault Systèmes brand for realistic simulation solutions.
- ▶ Advanced simulation portfolio covering simulation disciplines such as structural mechanics, computational fluid dynamics and electromagnetic field simulation, for a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

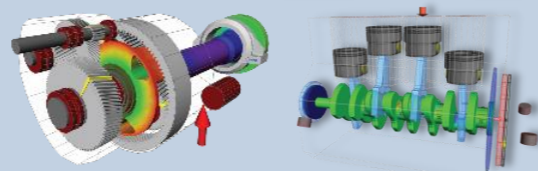
## Structures



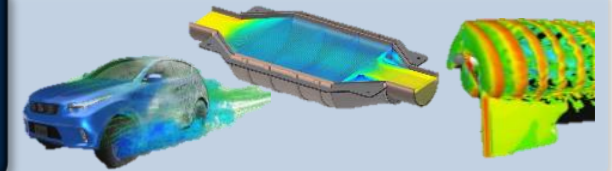
## Electromagnetics



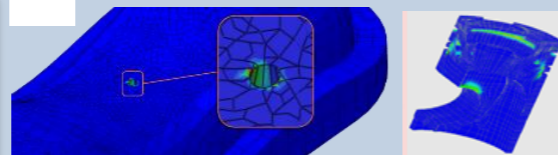
## Multibody



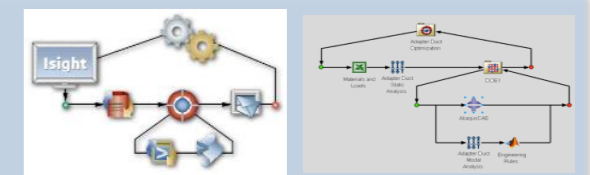
## Fluids



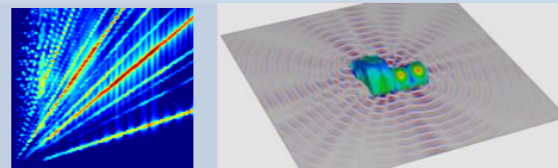
## Durability



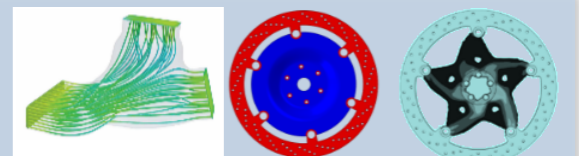
## Automation



## Vibro-acoustics



## Optimization



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# Revision Status

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

# 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



# 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





# 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



# Lesson 10: Anisotropic Hyperelasticity

## *Lesson content:*

- ▶ Motivation
- ▶ Models Available in Abaqus
- ▶ Examples



# 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



# 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



# Appendix 3: Linear Viscoelasticity Theory

## *Appendix content:*

- ▶ Classical Linear Viscoelasticity



30 minutes

# Appendix 4: Harmonic Viscoelasticity Theory

## *Appendix content:*

- ▶ Classical Linear Viscoelasticity
- ▶ Harmonic Excitation





# Appendix 5: Suggested Reading

## *Appendix content:*

- ▶ Suggested Reading



15 minutes