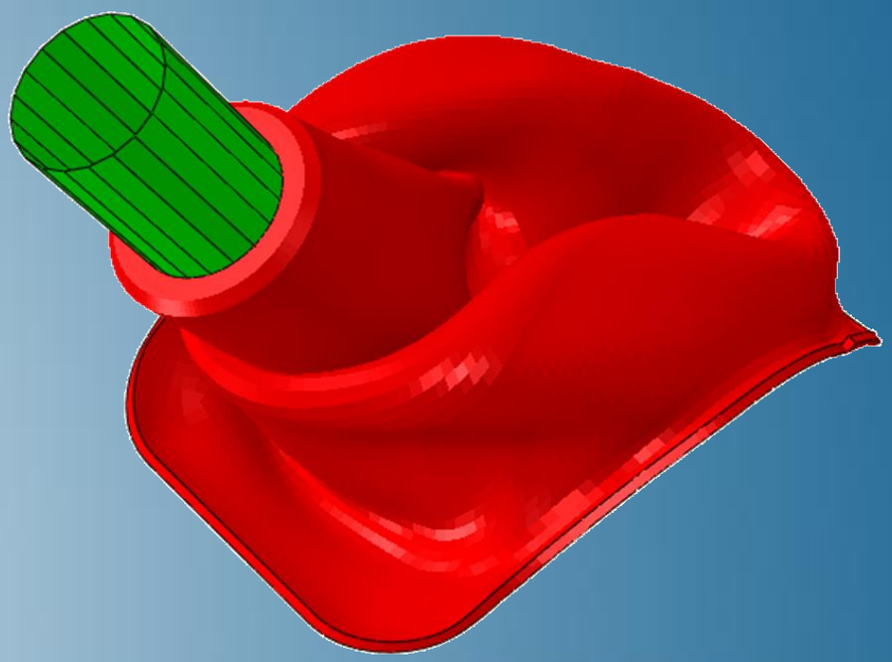
# Modeling Rubber and Viscoelasticity with Abaqus

## Abaqus 2018




3DEXPERIENCE®

# 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

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

# Day 2

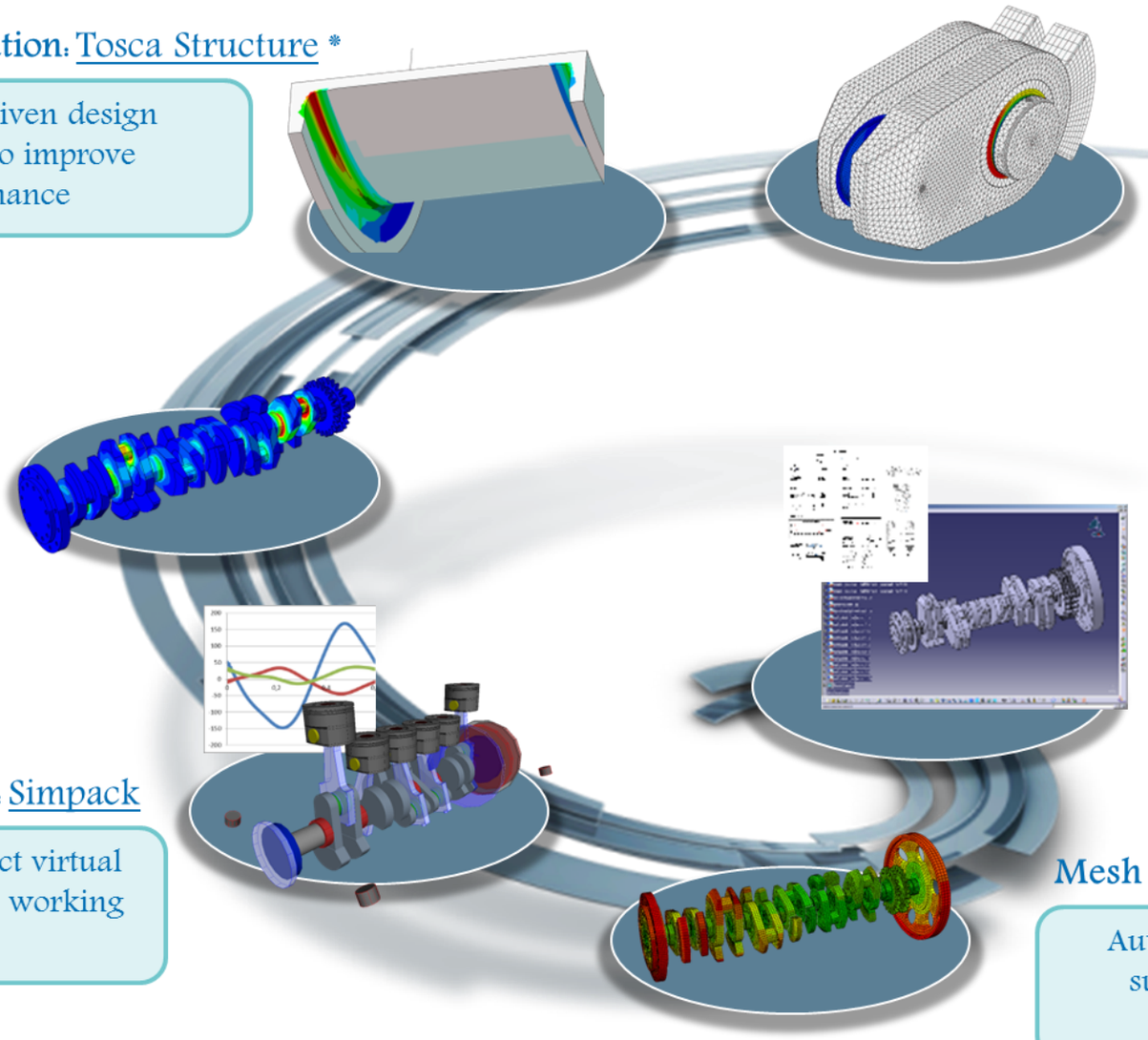
- Lecture 6 Viscoelastic Material Behavior
- Lecture 7 Time-Domain Viscoelasticity
  - Workshop 3 Bead Seal Relaxation
- Lecture 8 Frequency-Domain Viscoelasticity
  - Workshop 4 Bead Seal Vibration
- Lecture 9 Permanent Set in Solid Elastomers
- Lecture 10 Anisotropic Hyperelasticity

# 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
- 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 ***

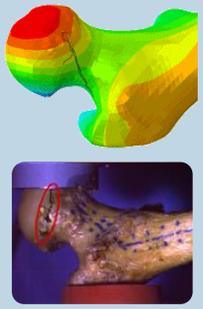
Automated mesh calibration: sufficient mesh quality for accurate results

* Included in extended licensing pool

# SIMULIA's Power of the Portfolio

**Abaqus**

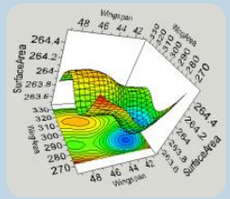
- Routine and Advanced Simulation
- Linear and Nonlinear, Static and Dynamic
- Thermal, Electrical, Acoustics
- Extended Physics through Co-simulation
- Model Preparation and Visualization



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

**Isight**

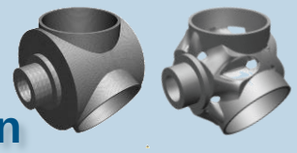
- Process Integration
- Design Optimization
- Parametric Optimization
- Six Sigma and Design of Experiments



**Material Calibration**
**Workflow Automation**
**Design Exploration**

**Tosca**

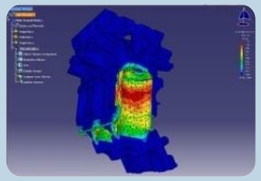
- Non-Parametric Optimization
- Structural and Fluid Flow Optimization
- Topology, Sizing, Shape, Bead Optimization



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

**fe-safe**

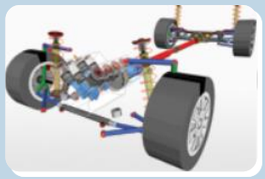
- Durability Simulation
- Low Cycle and High Cycle Fatigue
- Weld, High Temperature, Non-metallics



**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 ?**

Connect with peers to share knowledge and get technical insights

Go to www.3ds.com/slc
to log in or join!

SIMULIA

**Let the SIMULIA Learning Community be *Your* Portal to 21st Century Innovation**

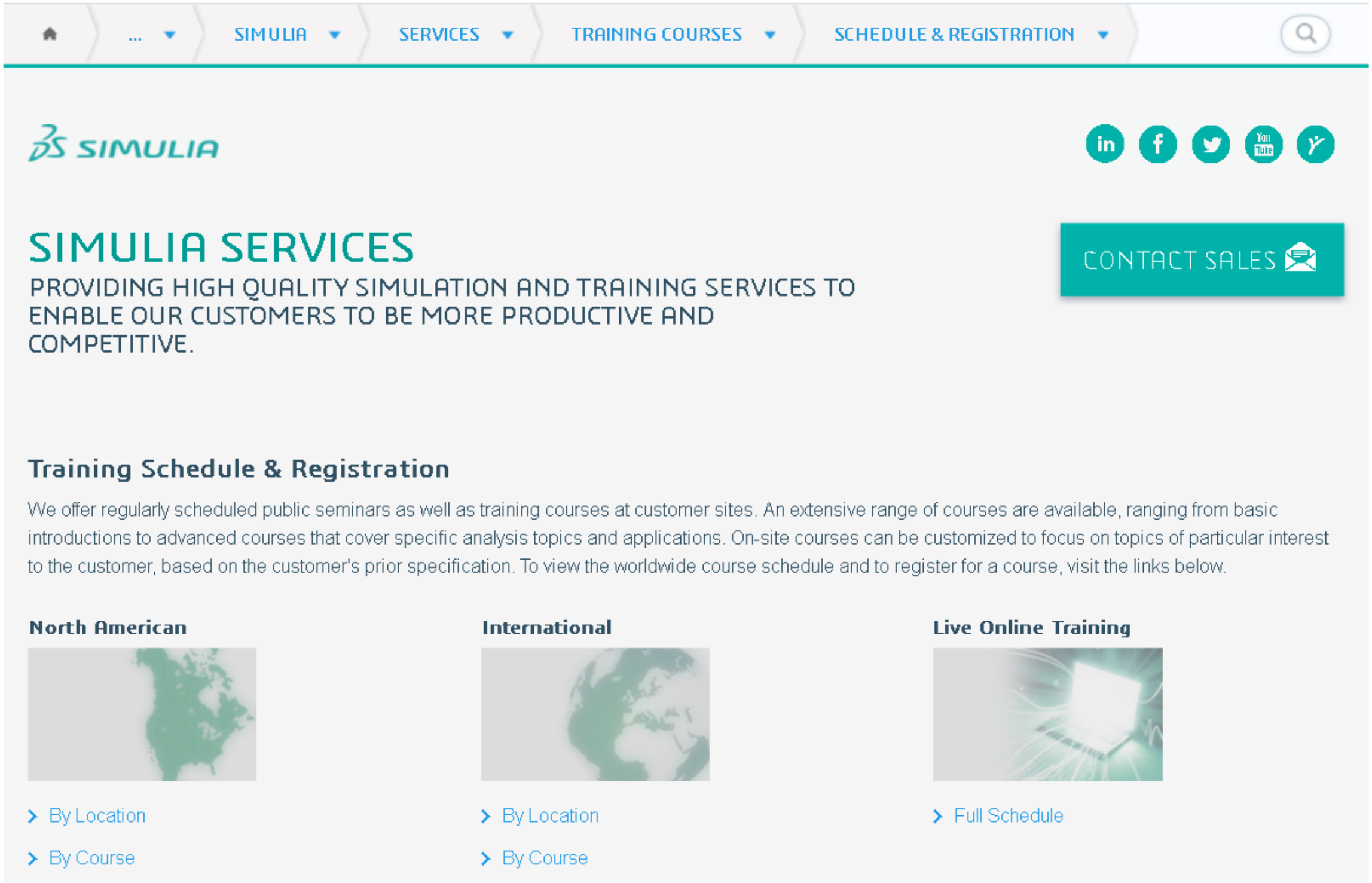
Discover new ways to explore how to leverage realistic simulation to drive product innovation. Join the thousands of Abaqus and Isight users who are already gaining valuable knowledge from the SIMULIA Learning Community.

For more information and registration, visit **3ds.com/simulia-learning**.
**Connect. Share. Spark Innovation.**

DASSAULT SYSTEMES | The **3D**EXPERIENCE Company

# SIMULIA Training

http://www.3ds.com/products-services/simulia/services/training-courses/



# Legal Notices

# Revision Status

| | | |
|---|---|---|
| Lecture 1 | 11/17 | Updated for Abaqus 2018 |
| Lecture 2 | 11/17 | Updated for Abaqus 2018 |
| Lecture 3 | 11/17 | Updated for Abaqus 2018 |
| Lecture 4 | 11/17 | Updated for Abaqus 2018 |
| Lecture 5 | 11/17 | Updated for Abaqus 2018 |
| Lecture 6 | 11/17 | Updated for Abaqus 2018 |
| Lecture 7 | 11/17 | Updated for Abaqus 2018 |
| Lecture 8 | 11/17 | Updated for Abaqus 2018 |
| Lecture 9 | 11/17 | Updated for Abaqus 2018 |
| Lecture 10 | 11/17 | Updated for Abaqus 2018 |
| Appendix 1 | 11/17 | Updated for Abaqus 2018 |
| Appendix 2 | 11/17 | Updated for Abaqus 2018 |
| Appendix 3 | 11/17 | Updated for Abaqus 2018 |
| Appendix 4 | 11/17 | Updated for Abaqus 2018 |
| Appendix 5 | 11/17 | Updated for Abaqus 2018 |
| Workshop 1 | 11/17 | Updated for Abaqus 2018 |
| Workshop 2 | 11/17 | Updated for Abaqus 2018 |
| Workshop 3 | 11/17 | Updated for Abaqus 2018 |
| Workshop 4 | 11/17 | Updated for Abaqus 2018 |

# 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 (Hyperfoam)



**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
- 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**