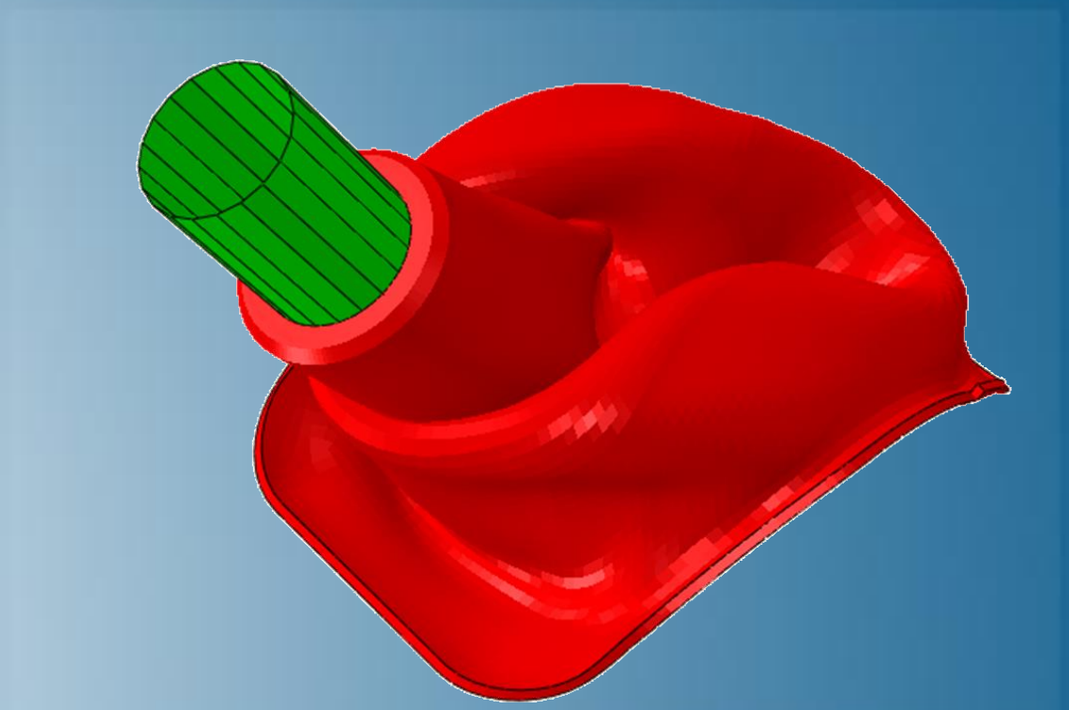
Modeling Rubber and Viscoelasticity with Abaqus

Abaqus 2020



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

- 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

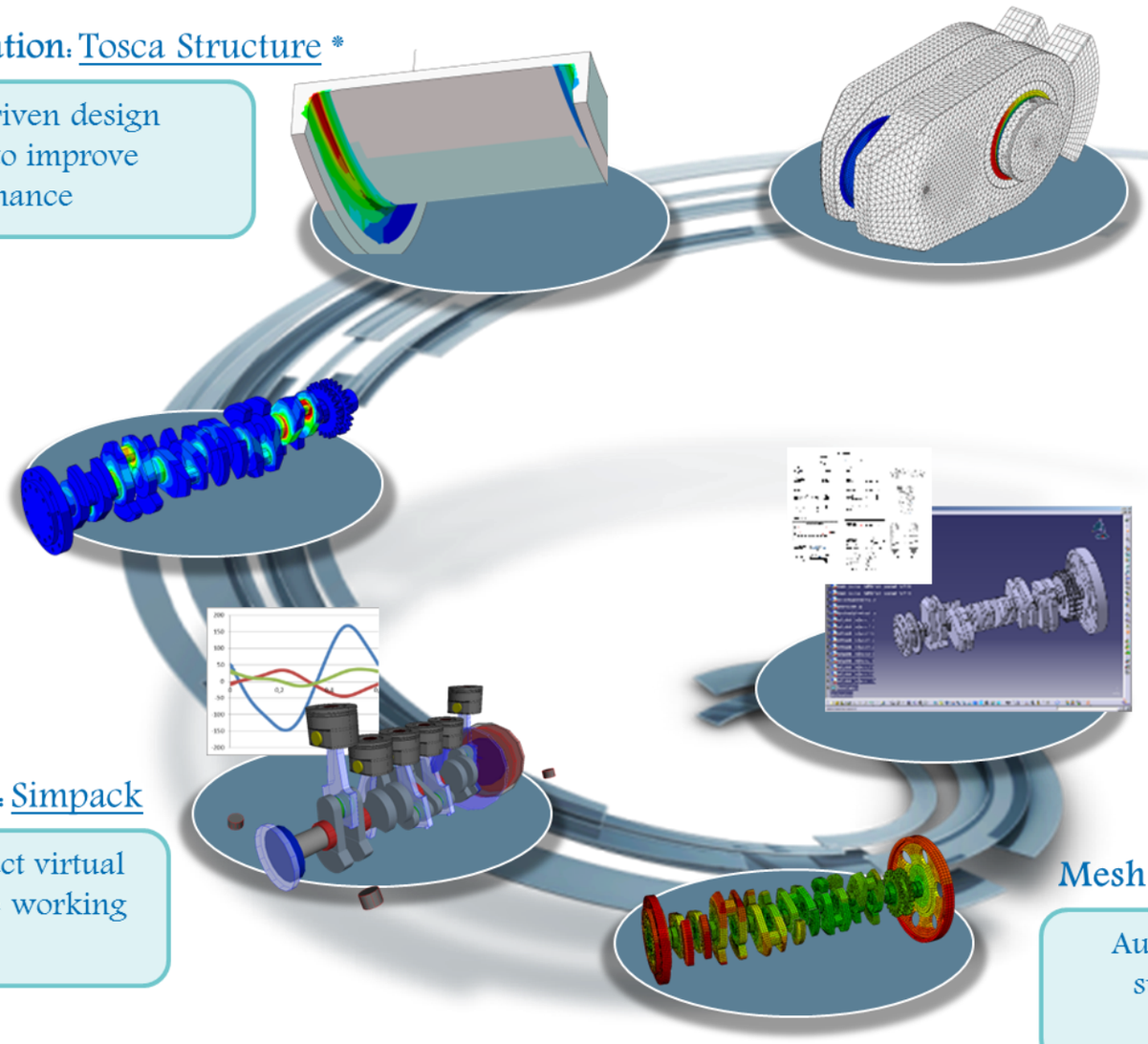
- SIMULIA is the Dassault Systèmes brand for Realistic Simulation solutions
- Portfolio of established, best-in-class products
  - Abaqus, Isight, Tosca, fe-safe, Simpack

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 *

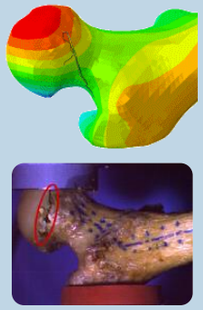
Automated mesh calibration: sufficient mesh quality for accurate results

* Included in extended licensing pool

SIMULIA's Power of the Portfolio

Abaqus

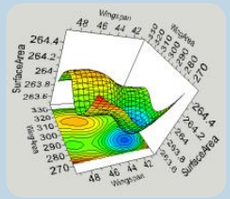
- Routine and Advanced Simulation
- Linear and Nonlinear, Static and Dynamic
- Thermal, Electrical, Acoustics
- Extended Physics through Co-simulation
- Model Preparation and Visualization



Realistic Human Simulation
High Speed Crash & Impact
Noise & Vibration

Isight

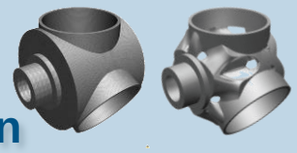
- Process Integration
- Design Optimization
- Parametric Optimization
- Six Sigma and Design of Experiments



Material Calibration
Workflow Automation
Design Exploration

Tosca

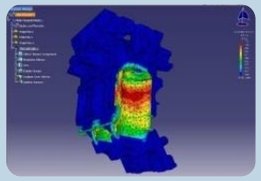
- Non-Parametric Optimization
- Structural and Fluid Flow Optimization
- Topology, Sizing, Shape, Bead Optimization



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

fe-safe

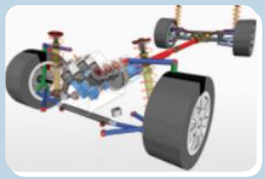
- Durability Simulation
- Low Cycle and High Cycle Fatigue
- Weld, High Temperature, Non-metallics



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

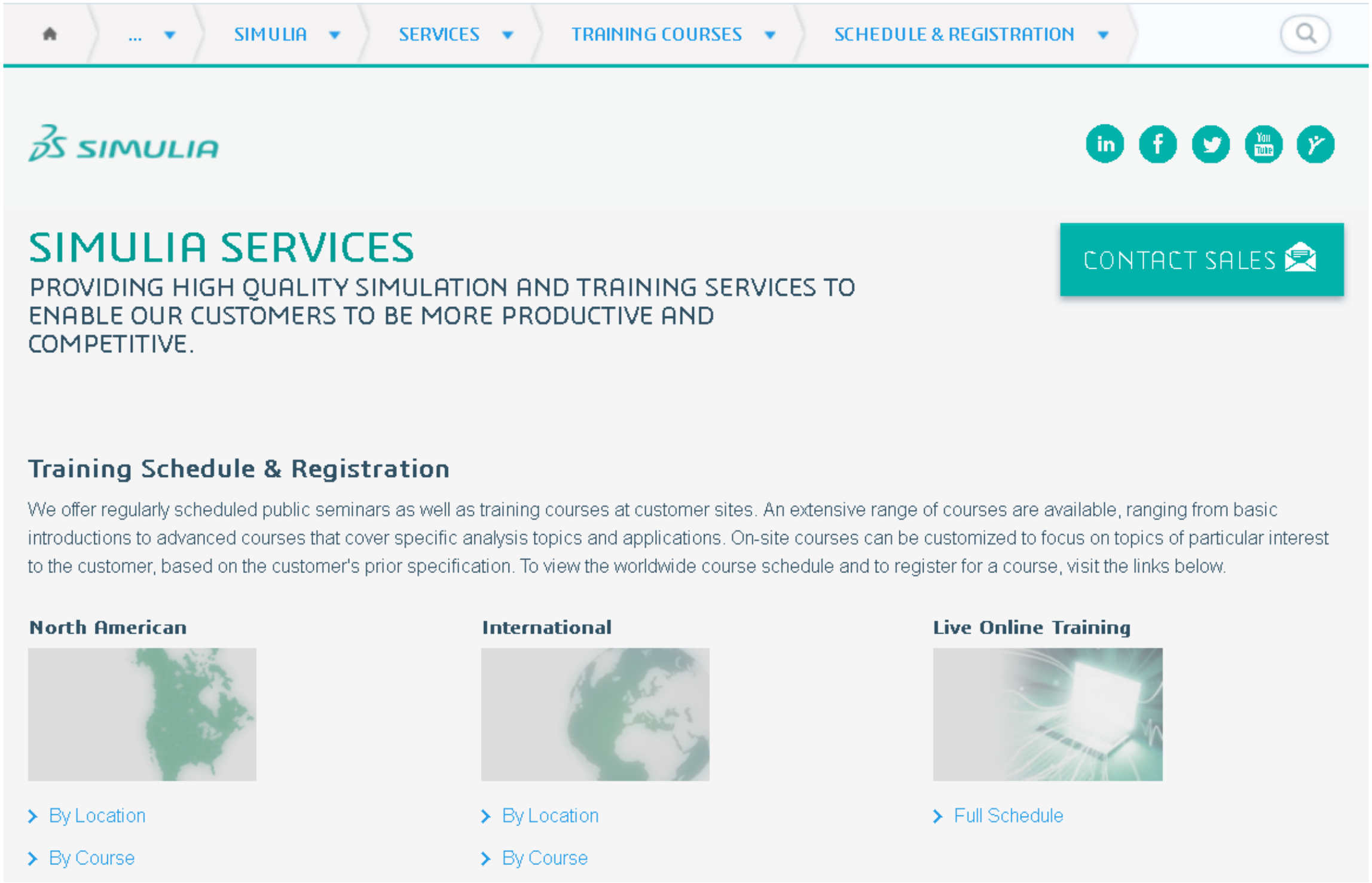
Discover new ways to explore how to leverage realistic simulation to drive product innovation. Join the thousands of Abaqus and Isight users who are already gaining valuable knowledge from the SIMULIA Learning Community.

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

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
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
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

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