Modeling Rubber and Viscoelasticity with Abaqus

Abaqus 2018
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

About this Course
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 is the Dassault Systèmes brand for Realistic Simulation solutions

Portfolio of established, best-in-class products
- Abaqus, Isight, Tosca, fe-safe, Simpack

* 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

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

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

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

Simpack
- 3D Multibody Dynamics Simulation
- Mechanical or Mechatronic Systems
- Detailed Transient Simulation (Offline and Realtime)

Realistic Human Simulation
High Speed Crash & Impact
Noise & Vibration

Material Calibration
Workflow Automation
Design Exploration

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

Safety Factors
Creep-Fatigue Interaction
Weld Fatigue

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!

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 SolidWorks 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.

©2013 Dassault Systèmes. All rights reserved.
SIMULIA SERVICES
PROVIDING HIGH QUALITY SIMULATION AND TRAINING SERVICES TO ENABLE OUR CUSTOMERS TO BE MORE PRODUCTIVE AND COMPETITIVE.

Training Schedule & Registration
We offer regularly scheduled public seminars as well as training courses at customer sites. An extensive range of courses are available, ranging from basic introductions to advanced courses that cover specific analysis topics and applications. On-site courses can be customized to focus on topics of particular interest to the customer, based on the customer’s prior specification. To view the worldwide course schedule and to register for a course, visit the links below.

North American
› By Location
› By Course

International
› By Location
› By Course

Live Online Training
› Full Schedule
Legal Notices

The software described in this documentation is available only under license from Dassault Systèmes or its subsidiaries and may be used or reproduced only in accordance with the terms of such license.

This documentation and the software described in this documentation are subject to change without prior notice.

Dassault Systèmes and its subsidiaries shall not be responsible for the consequences of any errors or omissions that may appear in this documentation.

No part of this documentation may be reproduced or distributed in any form without prior written permission of Dassault Systèmes or its subsidiaries.

© Dassault Systèmes, 2017

Printed in the United States of America.

Abaqus, the 3DS logo, and SIMULIA are trademarks or registered trademarks of Dassault Systèmes or its subsidiaries in the US and/or other countries.

Other company, product, and service names may be trademarks or service marks of their respective owners. For additional information concerning trademarks, copyrights, and licenses, see the Legal Notices in the SIMULIA User Assistance.
### Revision Status

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Updated for Abaqus 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture 1</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 2</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 3</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 4</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 5</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 6</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 7</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 8</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 9</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Lecture 10</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Appendix 1</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Appendix 2</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Appendix 3</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Appendix 4</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Appendix 5</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Workshop 1</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Workshop 2</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Workshop 3</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
<tr>
<td>Workshop 4</td>
<td>11/17</td>
<td>Updated for Abaqus 2018</td>
</tr>
</tbody>
</table>
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)
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)**

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.
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 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 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.
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
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
Appendix 3: Linear Viscoelasticity Theory

Appendix content:

- Classical Linear Viscoelasticity
Appendix 4: Harmonic Viscoelasticity Theory

Appendix content:
- Classical Linear Viscoelasticity
- Harmonic Excitation
Appendix 5: Suggested Reading

Appendix content:

- Suggested Reading