Introduction to fe-safe/Rubber

fe-safe 2019
Course objectives
Upon completion of this course you will be able to:

- Understand rubber physics and fatigue crack growth behavior of rubber.
- Use Abaqus/CAE to create and run models for use in fe-safe/Rubber.
- Use fe-safe/Rubber to create complete rubber component fatigue analysis models.
- Use fe-safe/Rubber to submit and monitor rubber fatigue analysis jobs.
- Use Abaqus/Viewer and other tools to view and evaluate fe-safe/Rubber results.

Targeted audience
Simulation Analysts

Prerequisites
Introduction to Abaqus
Introduction to fe-safe

2 days
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Day 2

Lesson 6  Using fe-safe/Rubber

Demo 4  fe-safe/Rubber Model with Bushing Component (optional)

Workshop 4  fe-safe/Rubber Set-up for Bushing Component

Lesson 7  Loading Definition for Rubber Fatigue

Demo 5  Fatigue Loading Scenarios

Workshop 5  Complex Loading for the Bushing Component

Lesson 8  Postprocessing fe-safe/Rubber Results

Demo 6  Additional Postprocessing Examples and Insights

Workshop 6  Postprocessing Jobs and Exports using the Bushing Model

Lesson 9  Additional Tips for using fe-safe/Rubber

Demo 7  Bushing Workflow with fe-safe/Rubber, Isight and Tosca (optional)
Additional Material

Appendix 1  The fe-safe and fe-safe/Rubber GUI
Appendix 2  Rubber Elasticity Models: Formulations
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- Extended Physics through Co-simulation
- Model Preparation and Visualization

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- 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
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Lesson 1: Overview of fe-safe/Rubber

Lesson content:

- What is fe-safe/Rubber?
- Starting fe-safe/Rubber
- Overview of fe-safe/Rubber GUI
- Running fe-safe/Rubber Analysis
- Documentation
- Useful Resources on the Web by Endurica on fe-safe/Rubber
- Workshop Preliminaries
- Demonstration 1: A First Look at fe-safe/Rubber
- Workshop 1: Solid Rubber Model Life Prediction
Lesson 2: Rubber Physics and Rubber Fatigue

Lesson content:

- Overview of Elastomers
- Types of Elastomers
- Solid Rubber
- Thermoplastics
- Rubber Foams
- Characteristics of Rubber
- Overview of Rubber Fatigue
- Material Tests for Rubber
- Material Models for Rubber
- Using the Ogden Model in Abaqus
- Material Parameter Calibration Methods
- Useful Tips
- References
- Demonstration 2: Stress-strain Definition in Abaqus for Rubber
Lesson content:

- Overview of Fatigue Process in fe-safe/Rubber
- Crack Growth Models
- Tearing Energy
- Two Extremes of Tearing Energy
- Critical Tearing Energy
- Intrinsic Strength of Rubber
- Loading Ratio
- Crack Growth Under Fully Relaxing Loading
- Material Parameters in fe-safe/Rubber Database
- References
Lesson content:

- Strain Crystallization
- Crack Growth Models
- Crack Growth Under Non-Relaxing Loading
- Material Parameters in fe-safe/Rubber Database
- Fatigue Life of Rubber
- Crack Precursor Size Calibration
- Other Effects
  - Creep Crack Growth
  - Ozone Attack
  - Treatment of Time-dependent Crack Growth
- The fe-safe/Rubber Material Database
- References
- Demonstration 3: Handling Material Parameters in fe-safe/Rubber
- Workshop 2: Editing Materials in fe-safe/Rubber
Lesson 5: FEA Modeling for fe-safe/Rubber

Lesson content:

- Key Ingredients for Rubber Component FEA
- Element Types and Mesh
- Material Models
- Analysis Procedures
- Loading and Boundary Conditions
- Output
- Workshop 3: Bushing Model Construction for fe-safe/Rubber
Lesson 6: Using fe-safe/Rubber

Lesson content:

- Steps for fe-safe/Rubber Analysis
- Reading FEA Solution Files
- Import Options
- Fatigue from FEA
- Specifying a Material
- Assigning a Plug-in Algorithm
- Defining Fatigue Loading
- Requesting Output
- Parallel Processing
- Running fe-safe/Rubber
- Damage Sphere Settings
- Factors for Computation Time and Accuracy
- Demonstration 4: fe-safe/Rubber Model with Bushing Component (optional)
- Workshop 4: fe-safe/Rubber Set-up for Bushing Component

30 Minutes
Lesson 7: Loading Definition for Rubber Fatigue

Lesson content:

- Loading Definition Options for fe-safe and fe-safe/Rubber
- Typical Fatigue Loading for fe-safe/Rubber
- Defining Time in a Fatigue Loading
- Loading Definition File
- Multiple Block Loading
- Repeats
- Transitions
- Calculating the Effect of Transitions for Rubber
- Mullins Effect and Multi-block Loading
- Order of Blocks in Multi-Block Loading
- Effect of Number of Datasets between peaks
- Useful Tips on Loading Definition
- Demonstration 5: Fatigue Loading Scenarios
- Workshop 5: Complex Loading for the Bushing Component
Lesson 8: Postprocessing fe-safe/Rubber Results

Lesson content:

- Steps for Postprocessing fe-safe/Rubber Analyses:
  - fe-safe Built-in Export and Output
  - fe-safe/Rubber Plug-in Export
  - Endurica Viewers
  - Postprocessing using Abaqus/Viewer
  - Useful Tips
  - Workshop 6: Postprocessing Jobs and Exports Using the Bushing Model
  - Demonstration 6: Additional Postprocessing Examples and Insights

Contact: support@endurica.com to request a download of the Endurica viewers if you want to try them!
**Lesson 9: Additional Tips for Using fe-safe/Rubber**

**Lesson content:**

- LCF vs. HCF
- Types of Rubber
- Rubber Material Database included with fe-safe/Rubber Installation
- Severe Loading and Element Types
- Case Study: Bushing Workflow using Abaqus, fe-safe, Isight and Tosca
- Demonstration 7: Bushing Workflow with fe-safe/Rubber, Isight and Tosca (optional)

30 Minutes
Appendix 1: The fe-safe and fe-safe/Rubber GUI

Appendix content:

- Starting fe-safe
- GUI Components
- Documentation
- Project Directory
- Message Log Window
- View FEA Fatigue Results Log
- Loaded Data Files Window
- Adding Data Files
- Removing Data Files
- Plotting Data Files
- Plot Types
- Interacting with Plots
- Copying, Printing and Saving Plot Images
- Adding Data
- Zooming
- Panning
- Display of Max/Min Tags
- Displaying Cursor Values
- Displaying Range Extremes
- Plot Properties
- Data File Editing
- Material Databases Window
- Materials Databases
- Materials Sorting
- Copying Materials
- Extended Materials Database
- Current FE Models Window
- Opening a Model & Pre-scanning
- Abaqus ODB Interface Options
- Pre-scanning and the Select Datasets to Read Dialog
- Loaded FE Model Units
- Expanded Tree View
- FED Directory: Proprietary, Binary File Structure
- Reload All Models
- Groups & Group Files
- Using Project Directories to Repeat or Automate FEA Fatigue Analysis
- Analysis Options

60 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