

# Choosing the right material in a rubber bushing operating under variable amplitude loading

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Simulia Central RUM Minneapolis MN  
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# Agenda

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- About Endurica
- Solution Overview
- Case study: Rubber bushing under 3D loading
  - Geometry
  - Load History
  - Materials
- Brief fe-safe/rubber tour
- Results

# About Endurica LLC

- Mission: Provide solutions for managing durability issues **early**
- Founded in 2008
- Based in Findlay, Ohio, USA
- 100% focus - elastomers and durability
- Strong growth since founding



# Partner Relationships



Materials Characterization partner



Solutions for managing elastomer durability



fe-safe/Rubber sales/support



Global fe-safe/Rubber sales/support



# Solution Overview



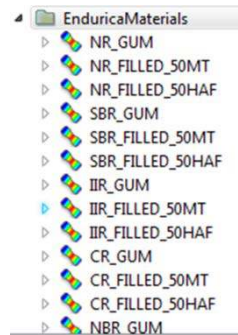
powered by  
**Endurica**

Elastomer Durability Software for Finite Element Models

Analysis  
Software

Pre-defined  
Materials

Documentation



Training  
Principles and  
Practices

Characterization  
Know Your Material

Support / Consulting  
World Leading  
Expertise

Validation Case

**Endurica**

Accelerating Reliable Design

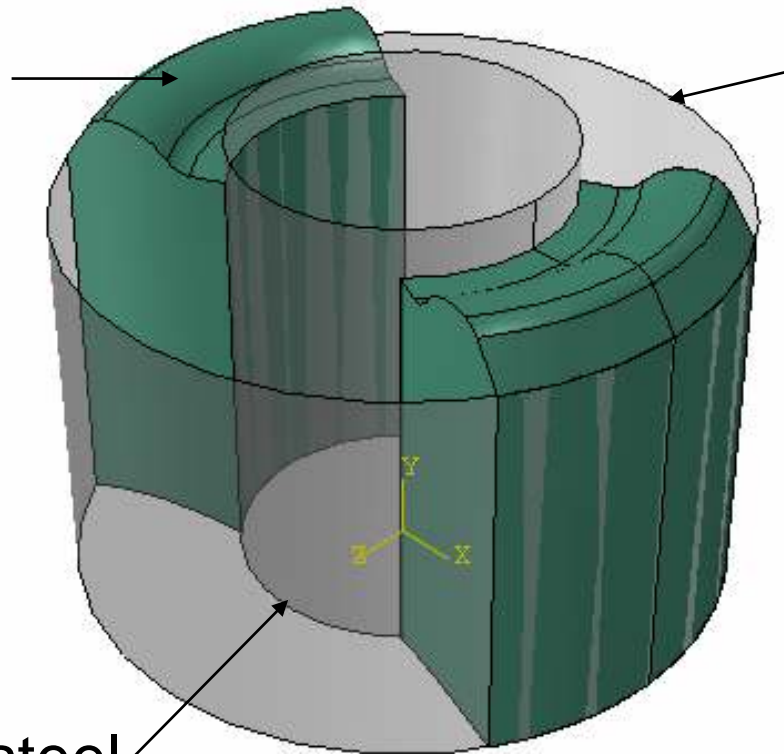
www.endurica.com

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# Case Study: Rubber bushing

Rubber

Outer steel housing



Function:

- Carry loads in X direction, while allowing for motion in Z and Y direction.
- Survive multiaxial, variable amplitude load history to meet warranted life

Inner steel

Costs of a bushing test program:

- Mold development
- Prototype production
- Multiaxial servohydraulic component testing
- 4-poster testing
- Fleet testing

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**\$20-200k**

# Design Decisions Determine Durability

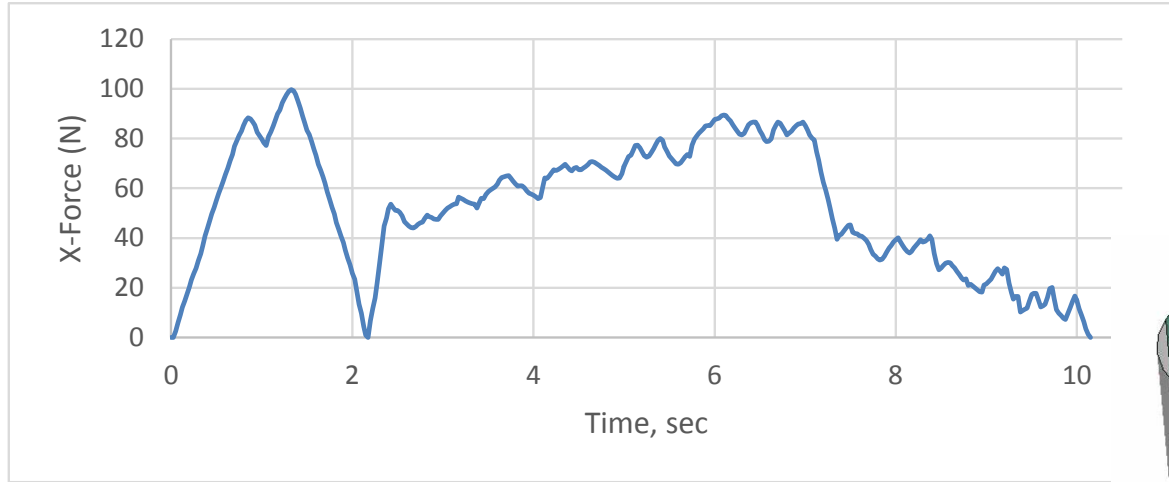
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- Geometry
  - Shape factor
  - Radii
- Material
  - Polymer
  - Filler
  - Cure
- Loads
  - Peak loads
  - Frequently repeated loads
  - Multichannel loads

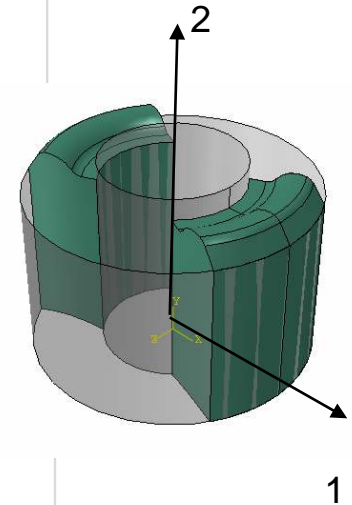
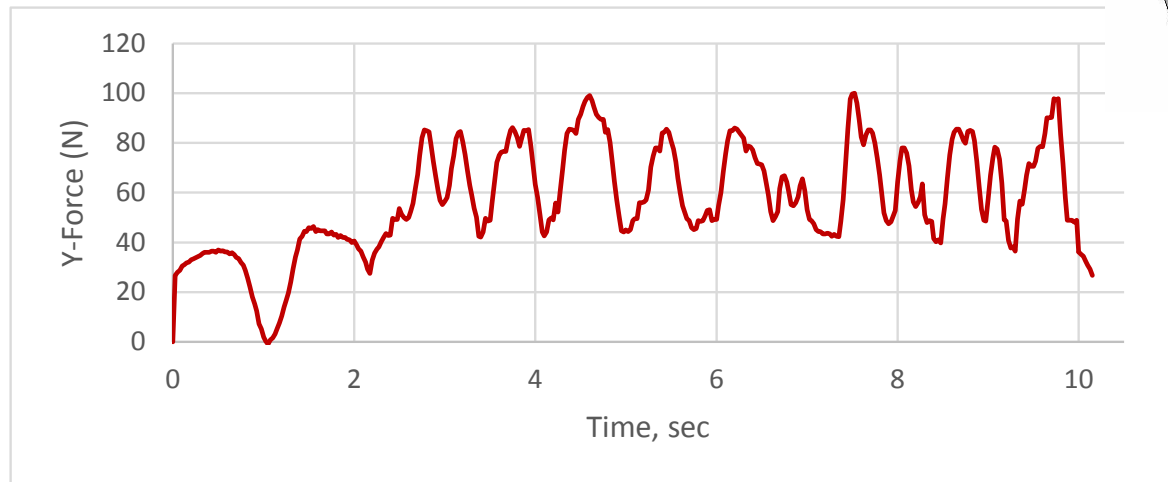
Objective: simulate  
the influence of these  
effects on part  
durability

# Load History – a particular road load event...

Channel 1

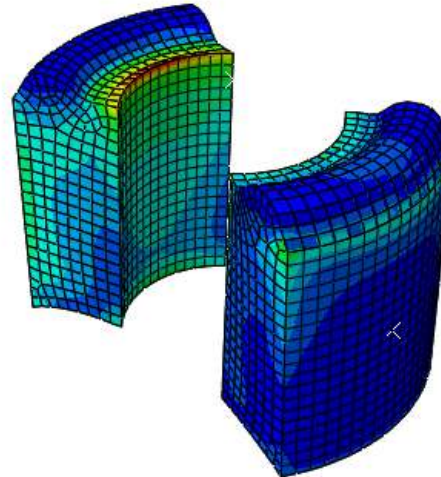
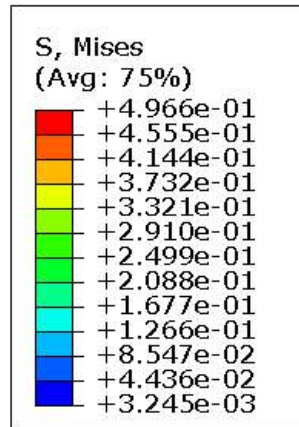
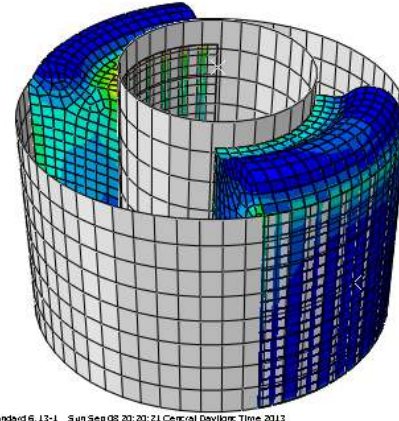
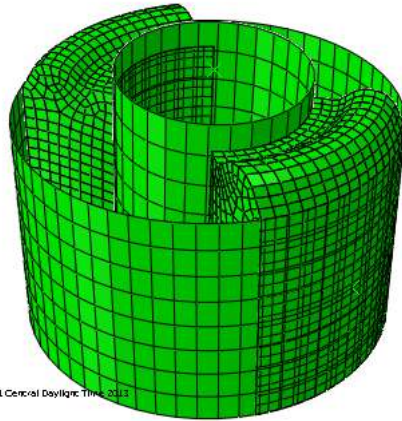


Channel 2





# Finite Element Analysis of Rubber Bushing



# Fe-safe/Rubber fatigue analysis software

The screenshot displays the fe-safe (Endurica - Non-Production Licence) version 6.4 interface. The main window is titled "Fatigue from FEA" and contains several panels:

- Analysis Settings:** A panel on the left with "Loading Settings" selected. It includes a "Group Parameters" section with a table for defining material groups.
- Material Properties Database:** A central panel showing a tree view of material properties. The "EnduricaMaterials\_writable" folder is expanded, listing various material types like NR\_GUM, NR\_FILLED\_50MT, SBR\_GUM, etc.
- FE Model Results:** A panel at the bottom right showing the current FE models, including datasets, groups, and assemblies.
- Execution Log:** A panel at the bottom showing the software's internal messages, such as "Loading settings from C:\Users\wvmars\documents\fe-safe.version.6.4\master\_node\_settings.xml".

Subgroup	Surface Finish	Material	
PART-1-1_BUSHING-1_SKIN-1 **	Whole	1	NR_FILLED_50MT
Default	Whole		

**Fatigue Analysis Setup**

**Material Properties Database**

**FE Model Results**

**Execution Log**

# Materials used in Bushing Analysis

- Same hyperelastic properties.
- Different fatigue properties.

## Material A

Fatigue properties:

$c_0 = 250$  microns

$c_f = 1$  mm

$F_0 = 2$

$R_c = 0.01$

$T_0 = 0.001$  kJ/m<sup>2</sup>

$T_c = 164$  kJ/m<sup>2</sup>

$T_t = 0.003$  kJ/m<sup>2</sup>

**Strain crystallizing material**

## Material B

Fatigue properties:

$c_0 = 250$  microns

$c_f = 1$  mm

$F_0 = 4.95$

$R_c = 0.01$

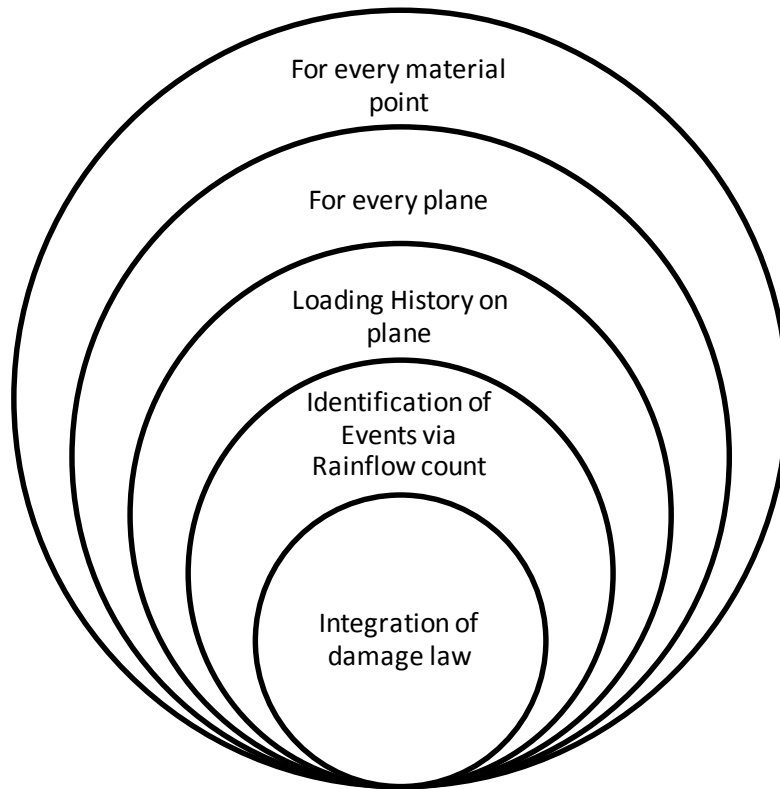
$T_0 = 0.001$  kJ/m<sup>2</sup>

$T_c = 24.9$  kJ/m<sup>2</sup>

$T_t = 0.003$  kJ/m<sup>2</sup>

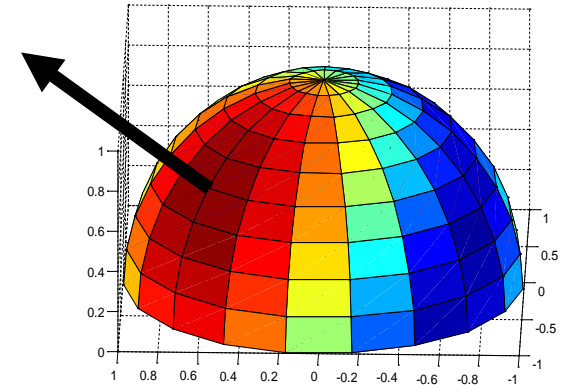
**Do not strain crystallize**

# Critical Plane Analysis



$$N_f(\theta, \phi) = \int_{c_0}^{c_f} \frac{1}{f(T, R)} dc$$

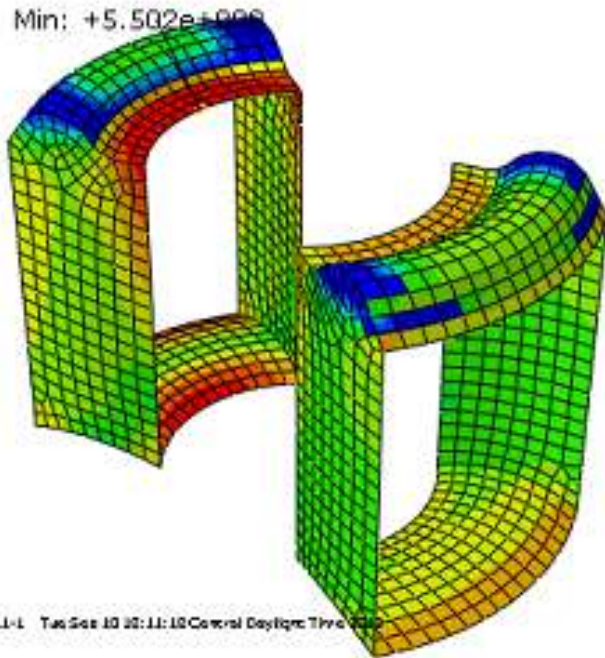
Identification of material point and plane with minimum life



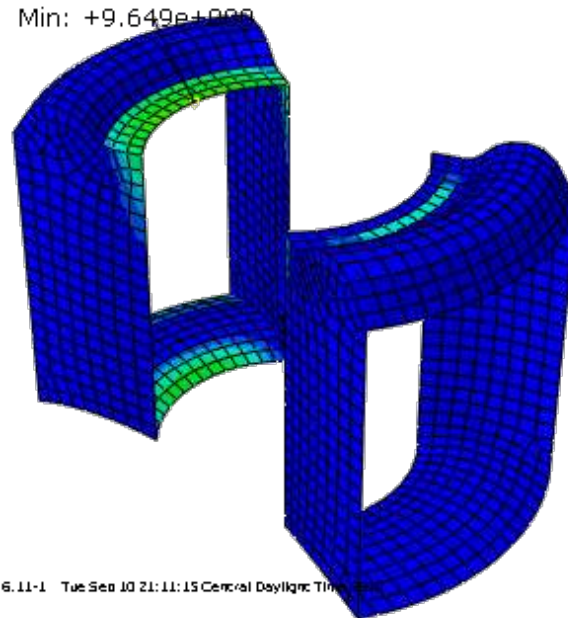
- Continuum / nucleation viewpoint
- Accounts for finite straining
- Crack closure in compression
- Failure plane identification
- Crack precursor loading experience

**US Patent No. 6,634,236 B1**

# Fatigue Life of Rubber Bushing

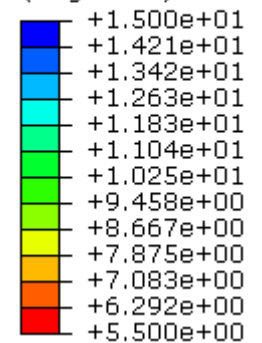


Material A



Material B

LOGLife-Repeats  
(Avg: 75%)



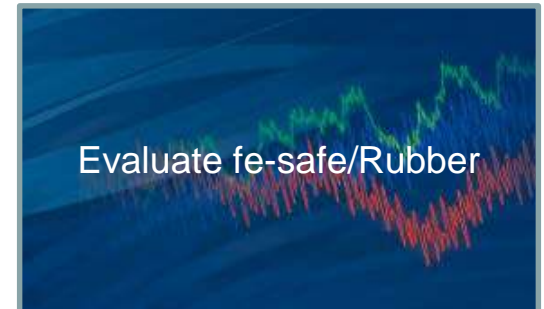
# Forward Paths...



Learn More about Principles and Practices

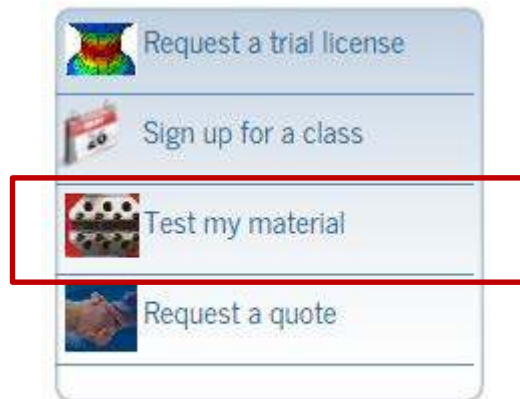


Characterize Your Material



Evaluate fe-safe/Rubber

•12-14 Nov : Characterizing elastomer fatigue behavior for analysis & engineering, (Ann Arbor, USA)



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