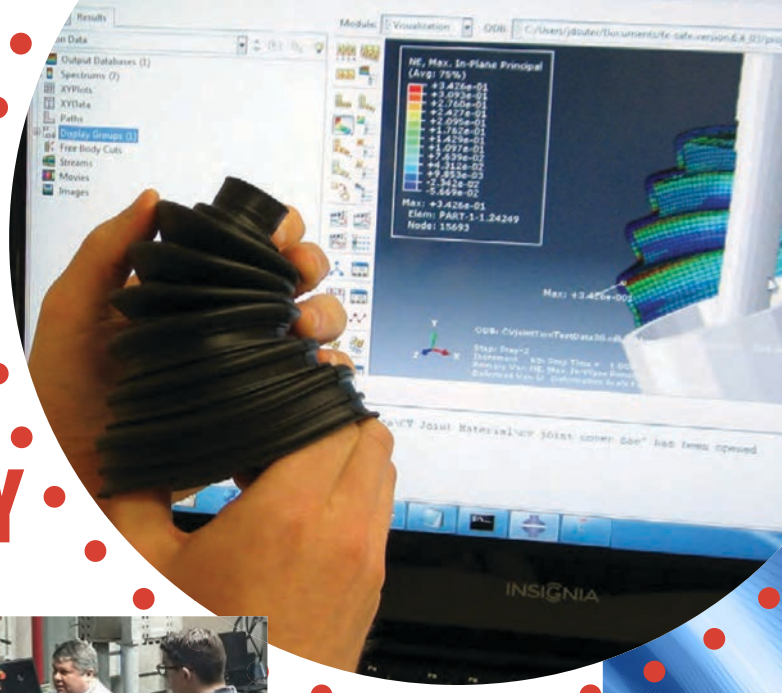


SOLUTIONS FOR DEVELOPERS

FATIGUE & DURABILITY FOR RUBBER

Endurica's production-ready workflows for mastering rubber durability are used throughout the world by leading firms in many business sectors. Endurica CL™ is the original and only commercial fatigue simulation application that accurately predicts elastomer durability.

ELASTOMER FATIGUE ANALYSIS SOFTWARE

For Finite Element Models

Endurica CL™ Our original, full-featured solver for elastomer fatigue analysis.

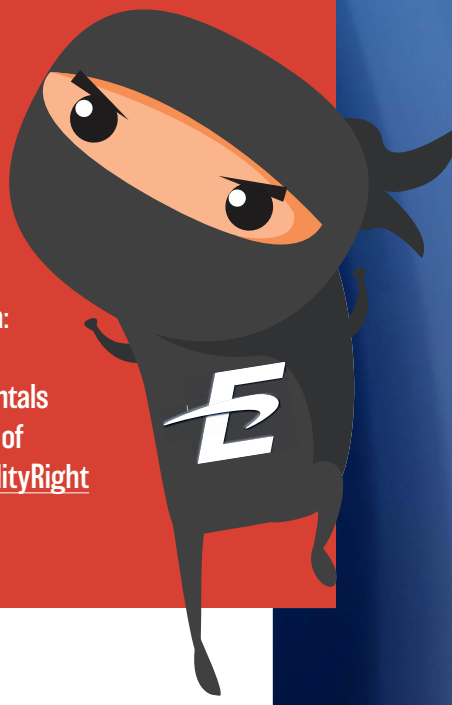
Endurica DT™ Digital Twin option for incremental analysis of multiple load histories and residual life.

Endurica EIE™ Efficient Interpolation Engine option – speeds lengthy calculations from days to minutes.

MASTER TRAINING

Principles and practices for reliable design of components:

- Application of Rubber Fatigue Analysis
- Characterizing Elastomer Fatigue Behavior for Analysis & Engineering



Become an Endurica #FatigueNinja: a highly-skilled engineer who understands the fatigue fundamentals of rubber and is trained in the use of Endurica solutions to: #GetDurabilityRight

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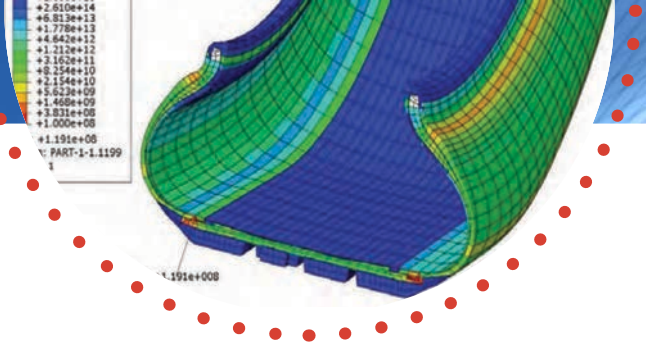


TESTING INSTRUMENTS

Endurica methods in your own lab. Our testing solutions provide time-efficient, high-accuracy, reliable results.

Our partnership with instrument producer Coesfeld GmbH & Co. KG offers you proven, fully supported testing systems that are specialized for engineering analysis of elastomer durability.

For more information:
endurica.com/testing-instruments


Intrinsic Strength Analyser


Tear & Fatigue Analyser


Instrumented Chip & Cut Analyzer

"In the automotive industry, from design to launch is becoming more and more of a time crunch. This is what the Endurica software does in conjunction with our testing. It allows us to cut that timing down, and allows our customer base — the automotive, heavy truck and off-highway engineering staffs — to do their job and not worry about if they have a durability problem."

Steve Pohlman, Tenneco Inc.,
Vice President and General Manager of Global Elastomers

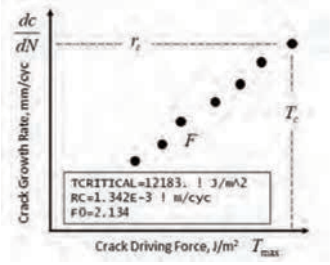
As reported by Kyle Brown in *Rubber & Plastics News*, July 24, 2017

TESTING SERVICES

Fatigue Property Mapping™
Know Your Material

Inventory of the fatigue capabilities of your material:

- Material parameters ready to use with nonlinear finite element codes: Abaqus, ANSYS and MSC/MARC through fe-safe/Rubber™ and Endurica CL™.
- Full support for both nucleation (Є-N or σ-N) and crack propagation (dc/dN) analysis methods.
- Accurate and timely results via uniquely reliable and productive test strategies.

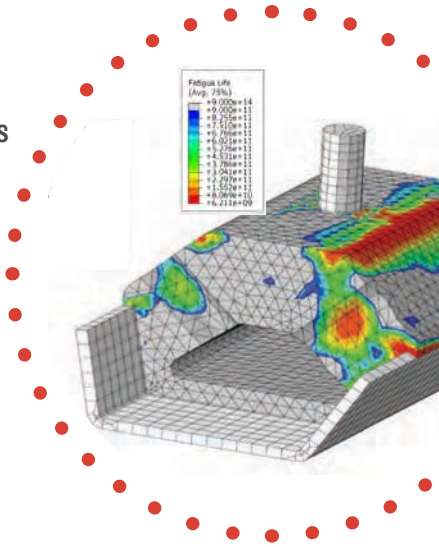


Take your material's fatigue capabilities into account to reduce risk and cost of development iterations.

Endurica's elastomer and rubber durability consulting services lead the industry with proven results and can make the difference in your project's success. Engage our fatigue specialists to solve your durability issues quickly and confidently.

Endurica offers:

- 100% Focus on Elastomers and Durability
- Leading Technology
- Deep Experience
- Legal Sensitivity



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ENDURICA PRESENTS

RUBBER FATIGUE SIMULATION SOFTWARE

Endurica's fatigue solvers show how your design will endure in specific application scenarios within all three major nonlinear finite element codes: Abaqus, ANSYS and MSC/MARC.

Endurica's software is the first (and only) commercial FEA software to predict when and where cracks will show up in an elastomer product with complex loading history and geometry. Endurica's methods are in use across the globe by virtually all industry sectors.

BENEFITS

- Save the costs of build and break experiments for well-qualified designs.
- Quickly see how changes to material behavior, part geometry, or load history influence fatigue life.
- Inform design decisions with a patented tool that has been continuously developed for more than a decade, and successfully validated against a wide range of benchmarks and real-world problems.
- Find out where your part might develop a crack, how long it can be expected to endure, which events are damaging and which are harmless.
- Communicate effectively about durability issues with realistic, physics-based presentation of simulation results.

THE ENDURICA DIFFERENCE

Learn more at:
www.endurica.com/fatigue-solver-software
Call today to request a trial: +1.419.957.0543

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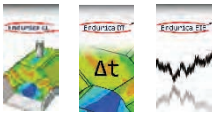
COMPREHENSIVE SOLUTIONS FEATURES GRID



	MATERIALS DATABASE	CL	DT	EIE	fe-safe/Rubber™
MATERIAL MODELS	Materials database	x	x		x
	Hyperelastic laws: Neohookean, Arruda-Boyce, Mooney-Rivlin, Reduced Polynomial, Van der Waals, Ogden	x	x		x
	Mullins Effect	x	x		x
	Crack Growth Rate laws: Thomas, Lake-Lindley, table-lookup	x	x		x
	Crystallization laws: None, Mars-Fatemi, table lookup	x	x		x
	Ozone attack, creep crack growth	x	x		x
	Temperature dependence: coefficient or table-lookup	x	x		coefficient only
	Hysteresis / Self-heating: powerlaw, Kraus, Table-Lookup	x	x		
PROCEDURES	Critical plane analysis	x	x		x
	Total formulation fatigue solver	x			x
	Rainflow counting w/time indices preserved for event identification	x	x		x
	Block cycle generation from road loads	x			
	Signal defeaturing	x			
	Rolling structures (ie tires) with axi- or cyclic- symmetry	x	x		
	Periodic results transfers for tires	x	x		
	Diagnostics: critical plane vector, load history on critical plane, crack open/close history	x	x		x
	Endurica Viewer	x	x		Note 1
	Incremental formulation fatigue solver		x		
	Ageing	x	x		
	Security encryption	x	x		
	Block cycle schedules / multi-step protocols		x		Miner's rule
	Sequence effects		x		
	Restart capability		x		
	Stiffness loss cosimulation		x		
	Residual life		x		
	Digital Twin applications		x	x	
	Nonlinear load/displacement->stress/strain map			x	
	Auto-generation of FE model boundary conditions for map generation			x	
	1, 2 or 3 independent input channels			x	
	Mapping methods: Case Vectors, Spiral Grid, User-Defined			x	
	Accelerated strain history generation			x	
	Multi-threading / parallel processing	x	x	x	x
	Damage extrapolation		x		
FE CODES	Abaqus	x	x	x	x
	Ansys	x	x	x	
	MSC/Marc	x	x	x	
	fe-safe/Rubber			x	
LICENSING	Node-locked	x	x	x	Available only through Dassault Systems
	Network floating	x	x	x	
	Annual lease	x	x	x	
	Perpetual	x	x	x	
	Maintenance and support	x	x	x	
	Single site, Regional, Global	x	x	x	

Note 1 - Available as free download from Endurica for licensed fe-safe/Rubber™ users.

2021-09

C-SUITE INSIGHTS

DURABILITY WINS NEW BUSINESS

Show your customer who is the boss of durability. Let us help you win their business.

RIGHT THE FIRST TIME SAVES BIG

Missing the durability qualification resets your development cycle and puts you back big time. Let us support your people with our tools and expertise.

GET THERE FIRST

Getting design decisions right for durability will get you to market faster.

START WITH QUALITY

Don't let poor durability turn into costly reliability or warranty issues.

FUTURE PROOF YOUR BUSINESS

Ask about our Digital Twin capabilities. Get durability online for your IoT and Big Data applications.

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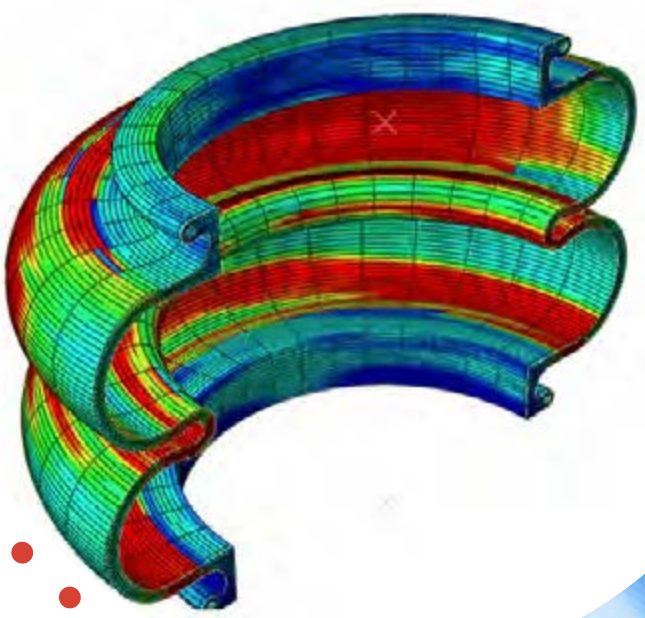

Endurica CL™

FATIGUE ANALYSIS SOFTWARE

Give Endurica CL™ a finite element simulation of your loading history, specify your material(s), then CL computes the fatigue life of your rubber part.

BENEFITS

- Calculate fatigue life and failure location on your part.
- Diagnose and resolve material, geometry, and loading issues to get durability right.
- Mobilize quickly with ready-to-use workflows that give you the edge.
- Scope analyses to fit your aim and budget with support for both "draft quality" and "high accuracy" simulations.

FEATURES

- CL offers the right material models for capturing your elastomer's behavior.
  - Nonlinear hyperelastic stress-strain behavior, Mullins effect, and cyclic softening.
  - Rate laws for both cycle- and time-dependent crack growth, including threshold effects and ozone attack.
  - R-ratio effects for both strain crystallizing and amorphous materials.
  - Temperature and ageing dependence of material properties.
  - Viscoelastic dissipation.
- CL provides support for:
  - Infinite Life method
  - Safe Life method
  - Safety Factor
  - Repeats to failure
- CL offers accurate accounting of damage accrual under multiaxial, variable amplitude loading history.
  - Crack precursor growth tracking based on Fracture Mechanics.
  - Critical Plane Analysis checks every potential crack orientation and location to find the true worst case.
  - Rainflow Counting on history of the critical plane.
  - Reports fatigue life as repeats of the given history.

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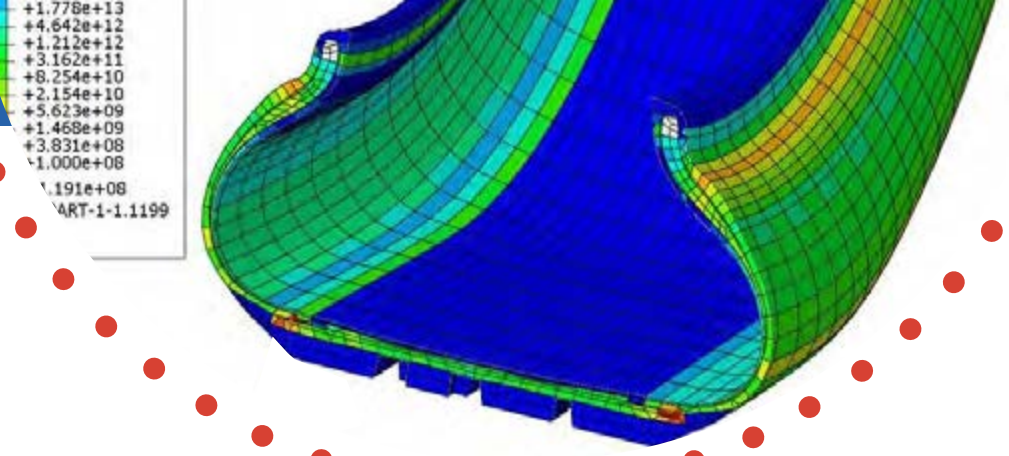
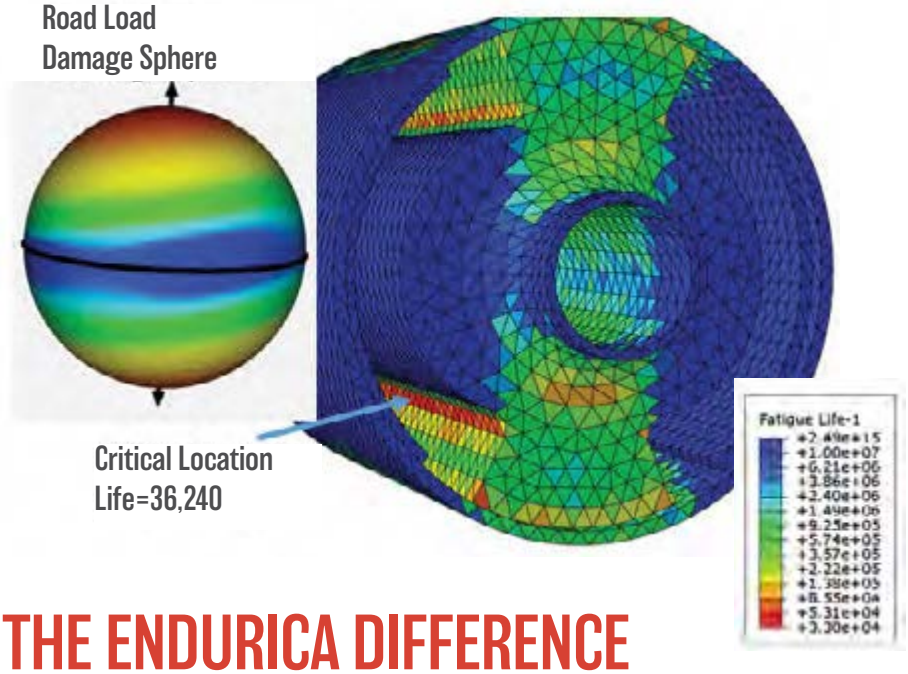


TECHNICAL NOTES

- Compatible FEA solvers: Abaqus, Ansys, MSC/Marc
- OS: Windows or Linux
  Licensing: node-locked or network shared; lease or perpetual

Road Load
Damage Sphere



Critical Location
Life=36,240

THE ENDURICA DIFFERENCE

Learn more at:
www.endurica.com/fatigue-solver-software/endurica-cl
Call today to request a trial:
+1.419.957.0543

C-SUITE INSIGHTS

FOCUS ON PRODUCT TECHNOLOGY

Our tools free you up to focus on getting your product right. Avoid the costs of deep methods development programs.

UNMATCHED ACCURACY

Don't waste your time with outdated, low-accuracy methods. Critical Plane Analysis is the gold standard for handling realistic load cases.

SHORT LEARNING CURVE, LARGE USER BASE

Our tried-and-true workflows will have your team winning on durability. We've trained hundreds of "fatigue ninjas," and we can bring your team up to speed in a few days.

LIGHTWEIGHTING, SUSTAINABILITY, COST-REDUCTION

The trick is to do it without sacrificing durability. Use our code to quickly eliminate non-viable solutions.

SUPPORT FOR POPULAR FEA CODES

One license gives you support for all of the major elastomer FEA codes: Abaqus, Ansys and MSC/Marc.

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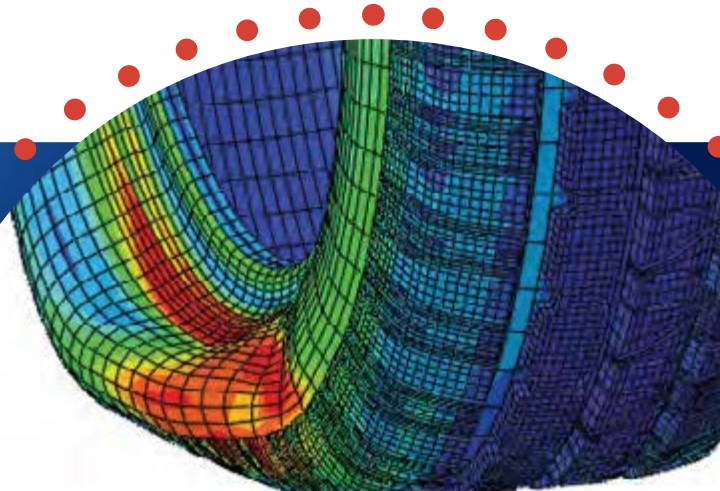
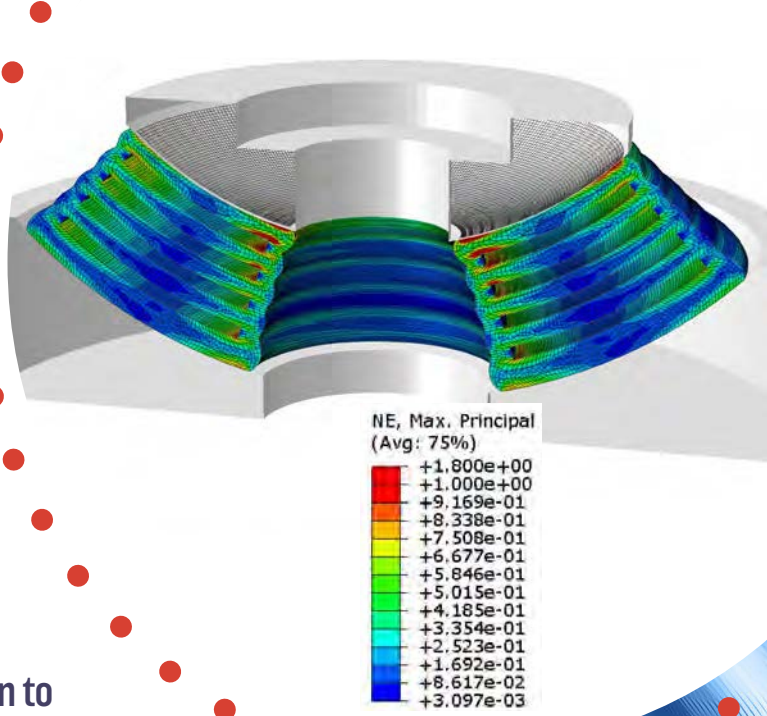


Endurica DT™

INCREMENTAL FATIGUE SOLVER



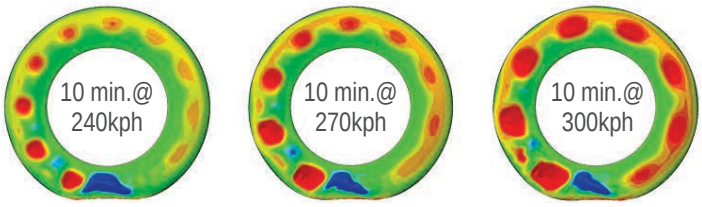
Endurica DT™ is our incremental solver and is an add-on to Endurica CL™. Give DT a series of load cases and it updates you on the remaining life of your rubber part. DT simulates how rubber changes over time.

BENEFITS

- Realistic use cases. Match the load cases and schedule for simulation with what your part experiences during product durability testing.
- Realistic material behavior. Account for load and material property evolution with time.
- Realistic end-of-life criterion. Simulate stiffness-based end of life criteria (i.e. end of life at a percentage of component stiffness loss).

FEATURES

- DT analyzes damage over a series of load cases that you specify (examples: block cycle schedule, FMVSS multi-step tire testing, histogram bins).
- DT tracks damage state evolution in terms of cycles applied, crack size, maximum-ever strain energy density, equivalent ageing time, and cyclic softening.
- DT calculates residual life / residual strength at the end of each scheduled load case.
- DT offers co-simulation workflows for ageing and cyclic stiffness loss analyses in which the stress-strain solution is updated due to material property evolution.
- DT offers a Digital Twin capability for structural health monitoring applications.



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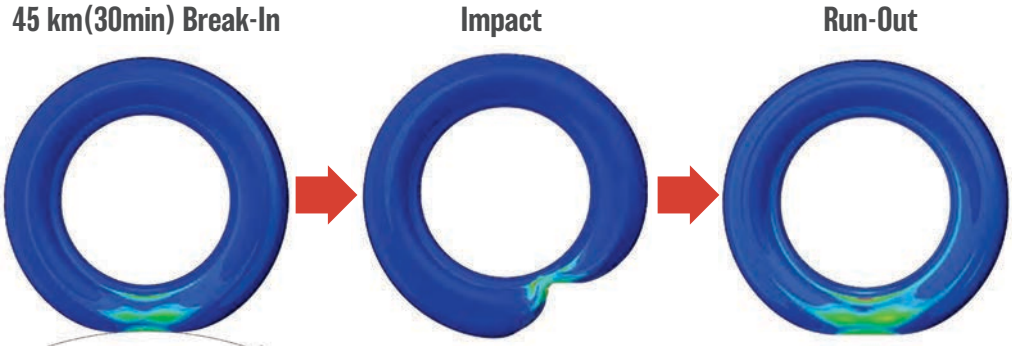
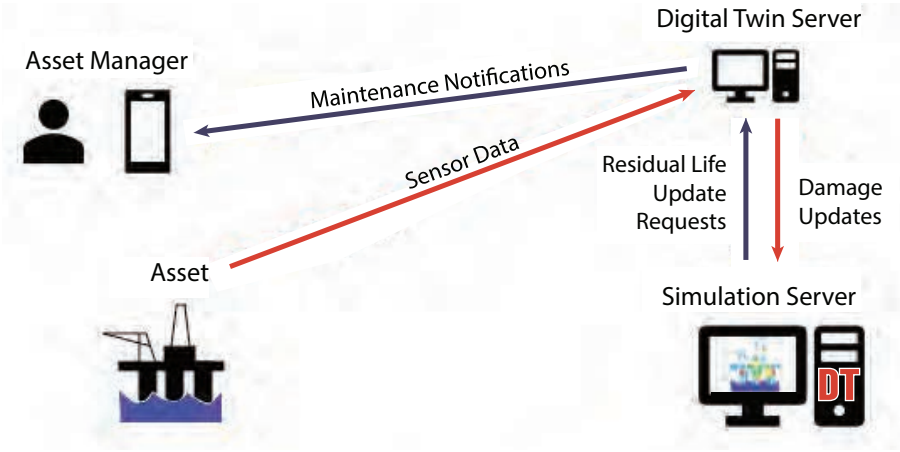
TECHNICAL NOTES

- Compatible FEA solvers: Abaqus, Ansys, MSC/Marc*
- OS: Windows or Linux
- Licensing: node-locked or network shared, lease or perpetual

*CoSimulation workflow not yet supported.



Digital Twin Applications



THE ENDURICA DIFFERENCE

Learn more at:
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C-SUITE INSIGHTS

DURABILITY WINS NEW BUSINESS
Show your customer who is the boss of durability. Let us help you win their business.

RIGHT THE FIRST TIME SAVES BIG
Missing the durability qualification resets your development cycle and puts you back big time. Let us support your people with tools and expertise.

GET THERE FIRST
Getting design decisions right for durability will get you to market faster.

START WITH QUALITY
Does your product still function after misuse or abuse? Calculate residual life to find out.

FUTURE PROOF YOUR BUSINESS
Ask about our Digital Twin capabilities. Get durability online for your IoT and Big Data applications.

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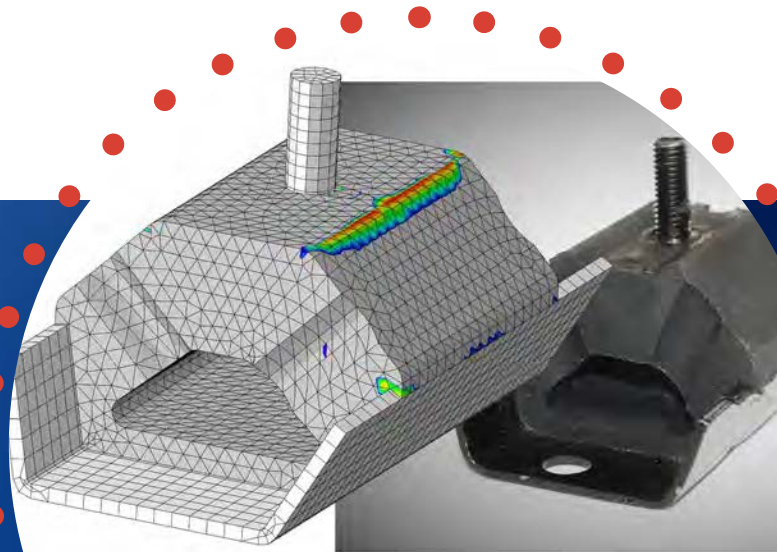
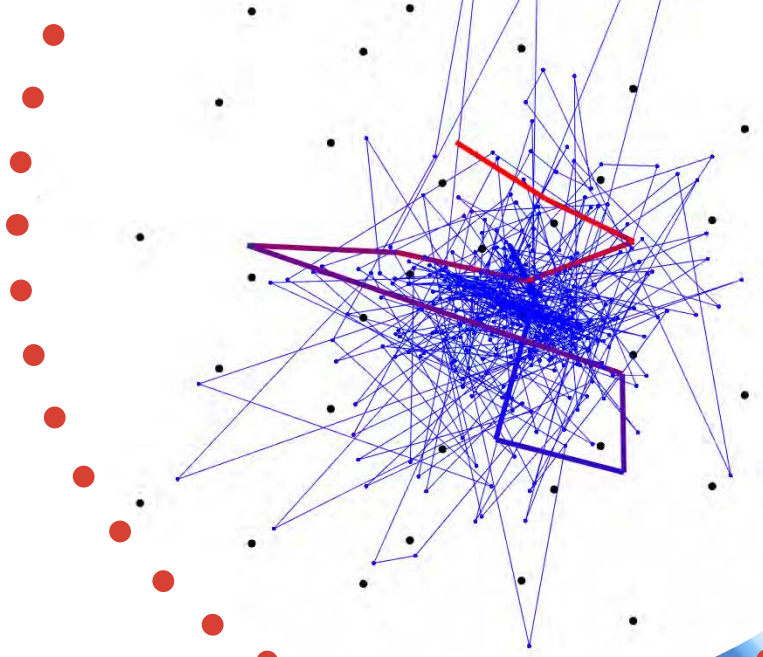


Endurica EIE™

FAST LOADS PROCESSING



Endurica EIE™ is the fast way to go from lengthy multi-channel load signals to fatigue life prediction. Use EIE with either CL or DT to simulate the full experience of your part in service.

BENEFITS

- Simulate durability impacts of full-length loading signals.
- Speed up strain history generation by orders of magnitude, compared to direct FEA solution.
- Achieve real-time load processing speeds for digital twin applications.

FEATURES

- EIE makes it easy to map nonlinear load spaces having up to 6 independent channels (channel can be load, displacement, rotation, etc.). User has full control over map discretization.
- EIE automatically generates boundary condition commands to drive your finite element model(s) through motions required to map grid points.
- EIE's channel reduction feature optimizes efficiency for map generation and interpolation.
- EIE interpolates multichannel input signals in .csv format via the map to rapidly generate strain history for your finite element model.
- EIE offers multi-threading and binary I/O for unprecedented execution speed.
- EIE produces strain history ready for analysis with CL, DT, and fe-safe/Rubber™.

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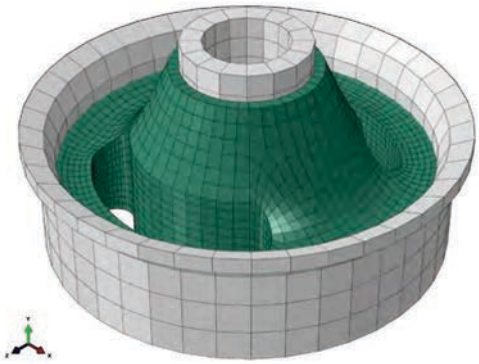
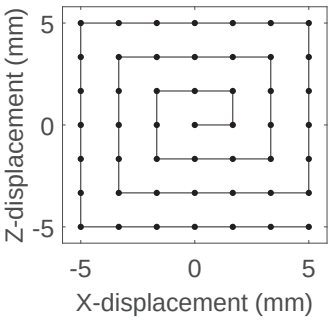
TECHNICAL NOTES

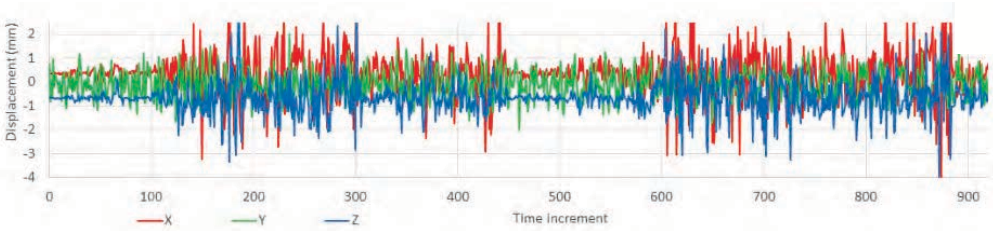
1) Define the input channels

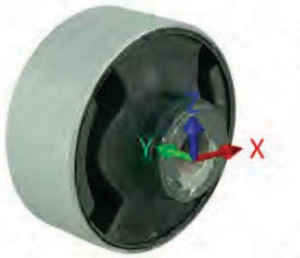


2) Populate the nonlinear interpolation map



3) Solve for strain history





4) Solve fatigue life

THE ENDURICA DIFFERENCE

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Call today to request a trial: +1.419.957.0543

Endurica
Get Durability Right®

C-SUITE INSIGHTS

MAKE THE MOST OF YOUR FEA LICENSE

Free up your finite element solver license. With EIE, FE solve time is reduced by orders of magnitude! What once took days is now completed in minutes.

MORE REALISM

Get closer to your customer's true use cases - Model full road load histories.

MORE LOAD CASES

EIE's high efficiency lets you look at ALL of your customer's use cases.

BREAK THE ANALYSIS PARALYSIS

Don't get stuck on convergence issues. EIE's flexible load space mapping methods get you out of 'convergence jail'.

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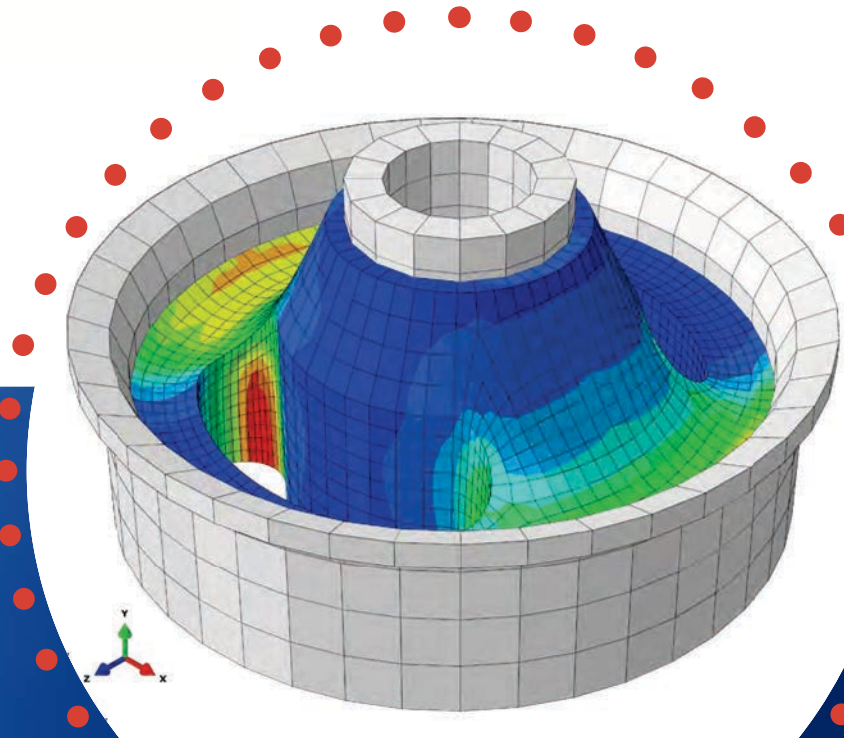

MATERIAL CHARACTERIZATION

Fatigue Property Mapping™

Know Your Material

Success is riding on your compound. Don't leave its fatigue behavior uncharted. Our characterization service offers test modules for probing each of the behaviors that govern your material's fatigue performance.

Whether you seek higher durability, or lower cost without compromising durability, Endurica's Fatigue Property Mapping™ service offers you a comprehensive inventory of the fatigue capabilities of your material. Get Durability Right® in your development and analysis projects with our uniquely efficient, reliable, and physics-based testing protocols.

BENEFITS

- Material parameters ready to use with simulation software: Abaqus, ANSYS, Marc, fe-safe/Rubber™ and Endurica CL™.
- Full support for both nucleation (ε-N) or (σ-N) and crack propagation (da/dN) analysis methods.
- Accurate and timely results via uniquely reliable and productive test strategies.
- Reduced risk and cost of development iterations when you take your material's fatigue capabilities into account.
- Leverage your material's full potential by properly aligning its capabilities with the application's demands.

THE ENDURICA DIFFERENCE

Learn more at:
www.endurica.com/elastomer-testing-characterization/
Call today to discuss your testing project: +1.419.957.0543

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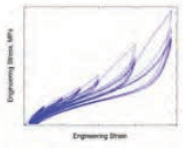
GET DURABILITY RIGHT® WITH ENDURICA'S FATIGUE PROPERTY MAPPING

Hyperelastic Module

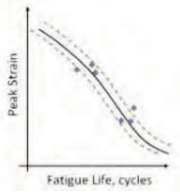
Simple, planar, equibixial tension Mullins Effect



- Required as prerequisite to Finite Element Analysis, lab ambient temperature
- One temperature between -40°C and 150°C

Core Fatigue Module

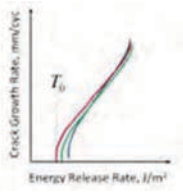
Fully relaxing behavior from both nucleation and fracture mechanical perspectives



- Required for fatigue analyses
- User specifies one temperature between -40°C and 150°C
- Fully relaxing (R=0) Conditions for all fatigue tests

Intrinsic Strength Module

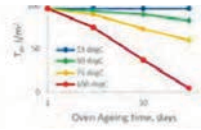
Quantify endurance limits



- Recommended for cases with fatigue life longer than 10^6 cycles

Extended Life Module

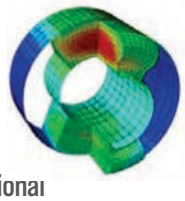
Quantify endurance limit, estimate aging rate of stiffness, intrinsic and ultimate strength



- Recommended for cases with fatigue life longer than 10^6 cycles, and when aging must be taken into account
- Quantify Arrhenius ageing law parameters
- Basic and Advanced time/ temperature options available

Thermal Module

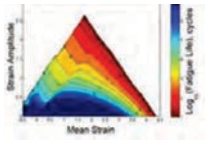
Quantify dissipative properties, thermal properties, temperature dependence



- Recommended for cases involving significant self-heating, thermal expansion, or thermal gradients
- User specifies three additional (to FPM-C) temperatures between -40°C and 150°C.
- Basic and Advanced options available

Nonrelaxing Module

Quantify strain crystallization min and mean strain effects



- Recommended for cases where fatigue loading is never fully relieved to zero
- One temperature between -40°C and 150°C Test is run under range of nonrelaxing (R>0) conditions

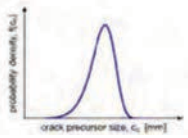
Ozone Module

Quantify ozone attack critical tearing energy and rate

- Required when rubber has a susceptibility to ozone attack and is operating in an environment with ozone

Reliability Module

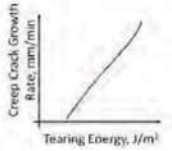
Weibull statistics for strength and crack precursor size populations



- Recommended when probability of failure needs to be estimated
- Testing is conducted at room temp. 23°C
- Weibull analysis parameters relating frequency of occurrence to size of crack precursor

Creep Module

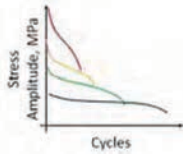
Quantity creep crack growth rate effects



- Recommended for cases involving long periods under static load
- User specifies one temperature between -40°C and 150°C

Cyclic Softening Module

Quantify cyclic softening effects



- Recommended for cases where degradation limits durability
- User specifies one temperature between -40°C and 150°C

C-SUITE INSIGHTS

RIGHT-SIZE YOUR TESTING

Use our modular framework to meet your program requirements, from rapid screening to deep characterization.

LEVERAGE YOUR STRENGTH

Know your material's physics so you can leverage its full capabilities in your application.

PLUG AND PLAY

Our testing modules deliver compatible results that plug right into our fatigue solvers.

SCALE UP YOUR CAPACITY

Planning to implement these in your own lab? Use our testing service to keep product development moving while you scale up.

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THE AMERICAS DISTRIBUTOR OF COESFELD

TESTING INSTRUMENTS

Test Fatigue Performance in your own lab using Endurica protocols running on Coesfeld instruments. Our partnership with instrument producer Coesfeld GmbH & Co. KG offers you proven, fully supported testing systems that are specialized for engineering analysis of elastomer durability.

COESFELD MATERIALTEST

Intrinsic Strength Analyser

- Measures cutting forces on an instrumented blade of controlled sharpness.
- Indicates the threshold fracture mechanical strength of a polymer network (i.e. the mechanical fatigue threshold) with a test that runs in an hour.
- Based on the Lake and Yeoh procedure.

BENEFITS

- Fully automated test execution with high test productivity.
- High test reliability via built-in quality control and noise minimization strategies.
- Full compatibility with modern durability simulation codes Endurica CL™ and fe-safe/Rubber™.
- Easy-to-use, works-every-time test setup – take the guess-work out of specifying test conditions.
- Fully supported by the world's leading experts in elastomer durability and in testing instrumentation for the rubber industry.
- Intuitive operation. Automated control, data acquisition and reporting.
- Supported in the Americas by the world leaders in elastomer durability testing methods.

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Tear & Fatigue Analyser

- Measures crack growth under dynamic loading cycles.
- Produces the crack growth rate curve as a function of applied tearing energy.
- Produces parameters for describing effects of strain-crystallization on crack growth.
- Includes protocols for both fully relaxing (R=0) and nonrelaxing (R>0) conditions.
- 50% less data scatter than prior art methods.

Instrumented Chip & Cut Analyser

- Measures chip and cut resistance of rubber compounds under cyclic impact loadings.
- Highly instrumented to enable control and measurement of forces and displacements during impact to mimic conditions experienced in demanding applications.
- The instrument can be also be operated in full contact mode as a friction and wear measurement device.

COESFELD MATERIALTEST

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C-SUITE INSIGHTS

PLUG AND PLAY

Go with the solution that works right out of the box and integrates with your CAE workflows.

HIGH PRODUCTIVITY

Traditional open-duration fatigue tests mean lack of control over testing schedule. Use our finitely-scoped methods to take back control of your testing schedule.

LOW NOISE

Endurica testing methods significantly reduce scatter and get more reliable data.

AUTOMATE YOUR TESTING

Free up lab techs with fully automated test execution.

QUALITY

Go with the global market leader for vision-based crack growth testing systems: Coesfeld.

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FATIGUE & DURABILITY FOR RUBBER
CAE SERVICES

WORLD LEADING EXPERTISE

Endurica's fatigue specialists are rubber industry experts who engage our technology portfolio to quickly and confidently solve your issues.

A few examples:

For a **MARINE** customer with **wave-induced loads and a tight design deadline**, Endurica:

- characterized the client's material.
- completed FEA.
- performed fatigue analysis of design options.

OUTCOME: Demonstrated capability to operate safely for target life.

An **AUTOMOTIVE PARTS SUPPLIER** bidding on OEM business was **looking for an extra edge**. Endurica completed analysis of the proposed design under OEM-specified load cases.

OUTCOME: Enabled supplier to demonstrate the durability of their design to the OEM and captured the contract.

Company making **ELECTRIC CARS** needed **bushing redesigned to support battery weight**. Engaged Endurica for study of three proposed designs. Endurica:

- simulated bushing under road loads.
- identified most durable option.

OUTCOME: Successful product launch on a tight timeline.

AGRICULTURAL SYSTEMS DEVELOPER Endurica **investigated a case of cracks developing in early product returns** from the field.

OUTCOME: Endurica's analysis diagnosed the cause of the cracking and provided insights the developer used to correct the issue.

RAW MATERIALS SUPPLIER with a new material needed to show benefit to clients. Endurica:

- characterized new material and several current alternatives.
- compared simulated performance in a range of products: tires, transmission mount, bushing, flex joint.

OUTCOME: Enabled raw materials supplier to build prospect confidence in the new material leading to increased sales.

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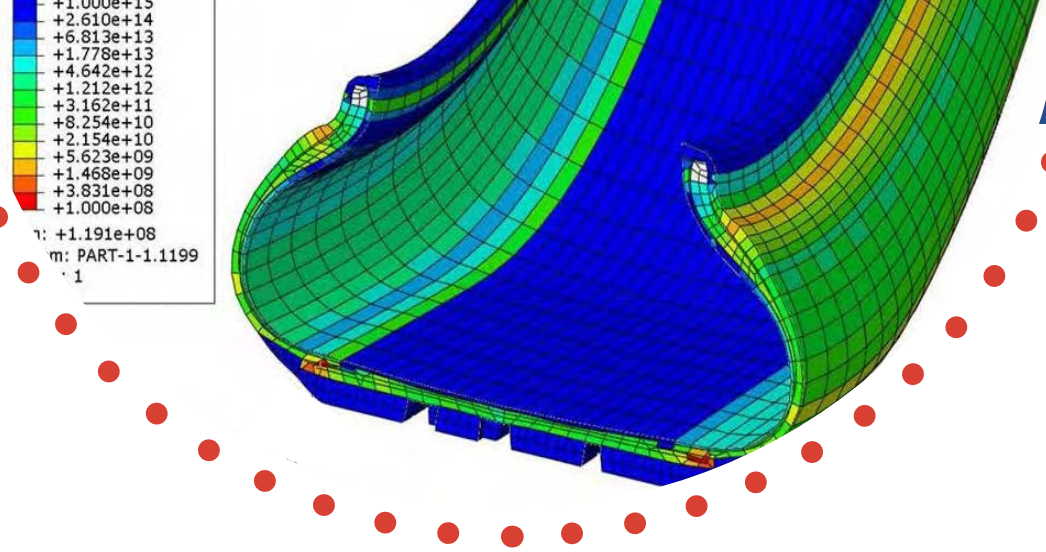

LIFELEFT™ DURABILITY SIMULATION SERVICE

Send us your specifications:

- part geometry
- load cases
- material properties (or let us test them)

Our report contains:

- expected life and failure mode
- life contours plotted on finite element model
- failure location
- identification of most damaging load case(s)
- design diagnostics to optimize durability

LEGAL SENSITIVITY

Durability studies frequently center on sensitive intellectual property and liability concerns. Endurica routinely works under customer non-disclosure agreements. Get Durability Right® with confidence that you've engaged professionals who will put your interests up front and deliver the highest quality results.

THE ENDURICA DIFFERENCE

Learn more at:
www.endurica.com/rubber-durability-consulting
Call today to discuss YOUR special project:
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C-SUITE INSIGHTS

TOP EXPERTISE

We'll take you straight to the answers you need. We wrote the Endurica and fe-safe/Rubber™ fatigue solvers, and the testing specs for the Fatigue Property Mapping™ testing service. We have partner relationships with top labs and simulation companies globally.

ON DEMAND

Get simulation capacity for your organization right when you need it and avoid the costs of maintaining permanent capacity.

FLEXIBLE SCOPE

Endurica has experience with project scopes ranging from 1 day to several years and multiple partners. We have worked with leading companies in many sectors: aero, auto, civil, offshore, consumer, medical devices, electronics, raw materials.

TECHNOLOGY TRANSFER

Looking for a fast way to implement Endurica methods in your organization? Engage us on a startup project to build momentum and maximize technology transfer.

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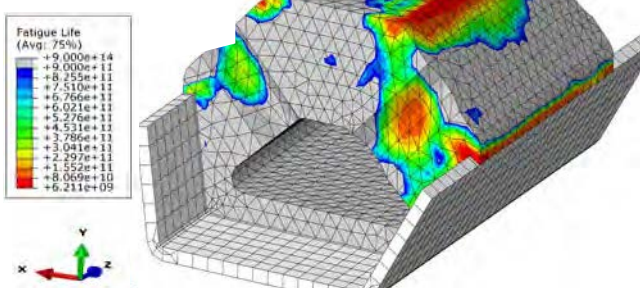

FATIGUE & DURABILITY FOR RUBBER
TRAINING

Endurica's training brings you up to speed quickly on the principles governing fatigue failure and on the best practices for testing, design and analysis of rubber components.

YOUR INSTRUCTOR

Dr. Will Mars the founder of Endurica, is a registered Professional Engineer with a PhD in Mechanical Engineering and the Mars-Fatemi Law of Durability to his credit, along with multiple patents. He is an international authority on the failure mechanics of rubber and an engaging instructor who makes highly-technical theories understandable.

"I want others in my company to take the Endurica training — durability is a complex subject and Endurica's framework is very helpful in navigating durability issues successfully. There is value here for our testing people, for our product engineers, for our materials people, and of course for our simulation people."

— Pedro Bastias, Ph.D.,
Trelleborg Sealing Solutions Americas

#FatigueNinja: a highly-skilled engineer who understands the fatigue fundamentals of rubber and is trained in the use of Endurica solutions to Get Durability Right®.

TRAINING IS AVAILABLE AT YOUR SITE

Endurica's professionals can provide customized training at your location anywhere in the world.

Contact us with your durability challenge via email at info@endurica.com.

Endurica
Get Durability Right®

MASTER WORKSHOPS

Endurica's training will enlighten you on the principles that govern fatigue failure in rubber, and on best practices for testing, design and analysis that let you win on durability.

Characterizing Elastomer Fatigue Behavior for Analysis and Engineering

Plan and execute effective fatigue testing programs to take your simulations further

Application of Rubber Fatigue Analysis with Endurica Software

Make the most of Endurica's simulation workflows: CL, DT, and EIE

REVIEWS

"Great hands-on, very applicable to my FEA work."

"The course content was great and the depth given throughout was really impressive."

"Gave me an awareness of issues we need to consider."

C-SUITE INSIGHTS

SPEAK ENDURICA

Make durability a core competence for your material and product teams, Supercharge your development programs by getting your team on the same page with Endurica training.

BENCHMARK BEST PRACTICES

Our testing and simulation strategies are the most productive and reliable in the industry. We dare you to learn why and how.

DON'T REINVENT THE WHEEL

Struggling with fragile, homebrewed methods? Our tried and true methods have been used successfully in many applications. Why not yours?

DELIVER RESULTS

Our tools and training are science-based and application-focused. Lectures, demos, and exercises will put you in a position to deliver durability.

COMPLETE DURABILITY WORKFLOW

Align your internal processes to consistently produce durability. Our programming addresses the whole process from raw materials to finished product in the field.

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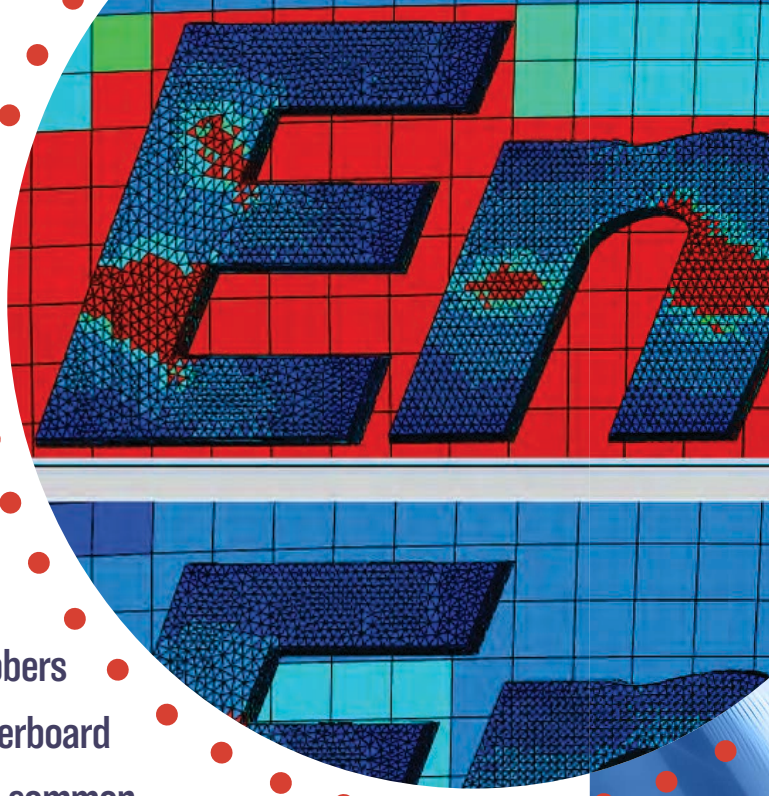

OZONE ATTACK

TEST AND SIMULATE OZONE AND FATIGUE EFFECTS IN RUBBER

Ozone is a trace gas that strongly reacts with some rubbers to produce surface cracking following exposure. Checkerboard cracking on an old tire sidewall or rubber hose are both common examples of ozone-induced cracks. Ozone cracking can limit useful product life, even when mechanical cycles operate below the mechanical fatigue threshold.

Test and simulate using Endurica's Fagitue Property Mapping Ozone Effect (FPM-OZ) and the Endurica solvers (Endurica CL™ and Endurica DT™) to ensure adequate ozone (O_3) resistance.

BENEFITS

- View as many of your tire sidewall compound options and designs as you wish with a year, a decade, or even two decades of ozone effect to see the impact of time and exposure.
- Understand the impact of both ozone exposure and rubber fatigue in your product.
- Accurate and timely results via uniquely reliable and productive test strategies.
- Reduced risk and cost of development iterations when you take your material's ozone effect and fatigue capabilities into account.
- Leverage your design's full potential by choosing the best option for environmental effects.

THE ENDURICA DIFFERENCE

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Call today to discuss your testing project: **+1.419.957.0543**

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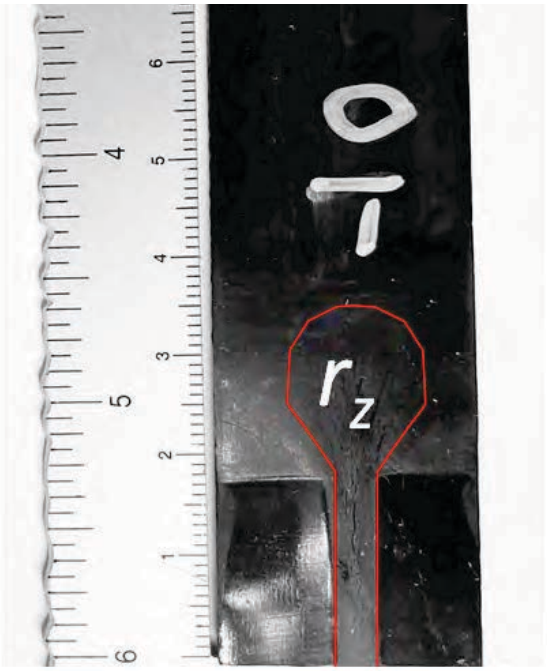
Fatigue Property Mapping™
Know Your Material

Endurica CL™
Fatigue Analysis Software

Endurica DT™
Incremental Fatigue Solver

TEST

Find your material's parameters with Endurica's Ozone Effect module (FPM-OZ).



SIMULATE

Predict ozone resistance in your application with Endurica CL™ and Endurica DT™

C-SUITE INSIGHTS

AGILE MATERIALS DEVELOPMENT

Endurica's ozone attack capability lets you quickly see the effects of ozone and fatigue in your product with your material under actual service conditions. Standard ASTM/ISO tests are not enough.

SUSTAINABILITY

Balance sustainable materials development with long-term performance. Endurica's Ozone Attack capabilities enable you to quickly and confidently sort your options.

SEE THE EFFECTS

Our characterization services provide the parameters you need for visualizing typical and atypical ozone exposure. This workflow enables you to rank your candidate materials based on their long-term performance.

INFORMED DECISIONS / REDUCED RISK

Use our code to quickly eliminate non-viable solutions and optimize the most promising choices.

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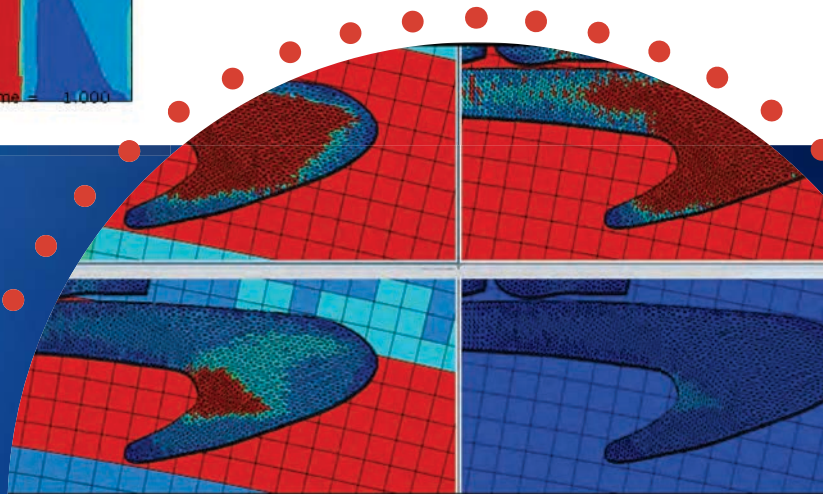


APPLICATION SPOTLIGHT

TIRE MANUFACTURERS

Endurica provides the world's most complete CAE workflows for fatigue analysis of tires. Use our tool set and proven procedures to meet your development requirements.

CAPABILITIES

- Evaluate the durability of tire compound formulations long before molding your first tire.
- Understand the impact of tension, shear, bending, and compression on tire durability during design work.
- Check every potential failure site in the tire, and every potential crack orientation.
- Evaluate your tire design's durability under different loads, speeds, inflation pressures and temperatures early in development.
- Simulate the FMVSS and ECE R30 durability and high-speed tire tests.
- Understand the effects of road hazards and tire abuse.

SIMULATION PROCEDURES FOR TIRES

- Support for both steady state and transient rolling
- Symmetric results transfer for 2D to 3D and 3D to 2D
- Support for axi- and cyclic- symmetry
- Material models:
  - Temperature
  - Ageing
  - Strain crystallization
  - Ozone attack

Endurica CL™

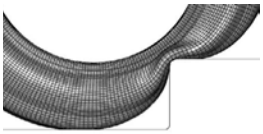
Fatigue Analysis Software

Endurica DT™

Incremental Fatigue Solver

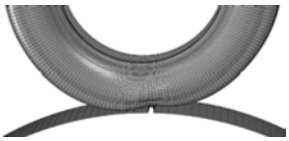
TRANSIENT ROLLING /IMPACT

- Compute damage due to impacts by combining results from steady state and transient rolling.
- Use Endurica's symmetric results transfer procedures (2D to 3D and 3D to 2D) to maximize computational efficiency.



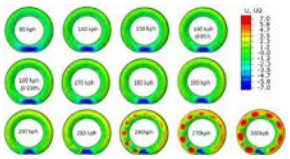
ROLLING RESISTANCE

- Use Endurica's steady state rolling features with hysteresis and temperature dependent material models.



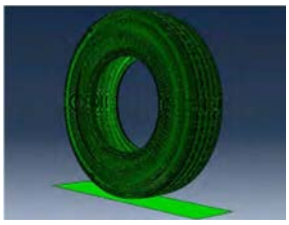
HIGH SPEED / FMVSS / ECE30

- Combine multiple-stress/strain and temperature solutions according to the FMVSS / ECE30 schedule to accrue damage and calculate tire residual life.
- Predict speed rating during design.



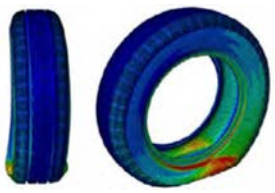
STEADY STATE ROLLING

- Endurica automatically recognizes Eulerian streamlines in steady state rolling analyses.



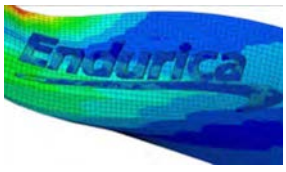
TREADED TIRE

- Endurica's steady state rolling procedure also supports cyclic symmetry / treaded tire.



SIDEWALL LETTERING

- Surface cracking on tire sidewalls is a key indicator of ozone attack which can limit useful life.



C-SUITE INSIGHTS

DEAL WITH RUBBER'S "SPECIAL EFFECTS"

Endurica material models capture the essence of tire material behavior: strain crystalization, temperature and rate dependence, ozone attack, ageing, etc.

SUSTAINABILITY BEGINS HERE

Sustainable development does not have to risk performance. Validate durability with Endurica models. Pre-cycling is the key - Endurica's workflow saves energy, time, money, and materials.

RIGHT THE FIRST TIME

Avoid unnecessary development iterations by simulating early in the design phase. Right the first time equals new products to market faster.

PROVEN RESULTS

Endurica's workflows have been extensively validated over the past two decades, Find out why 13 of the top 20 global rubber product manufacturers use Endurica solutions in their operations.

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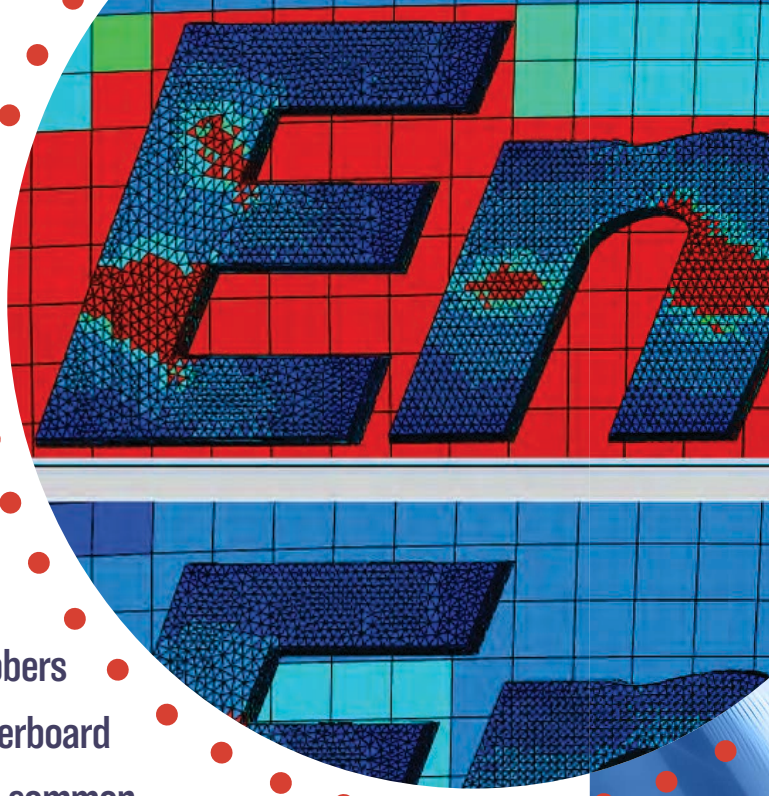

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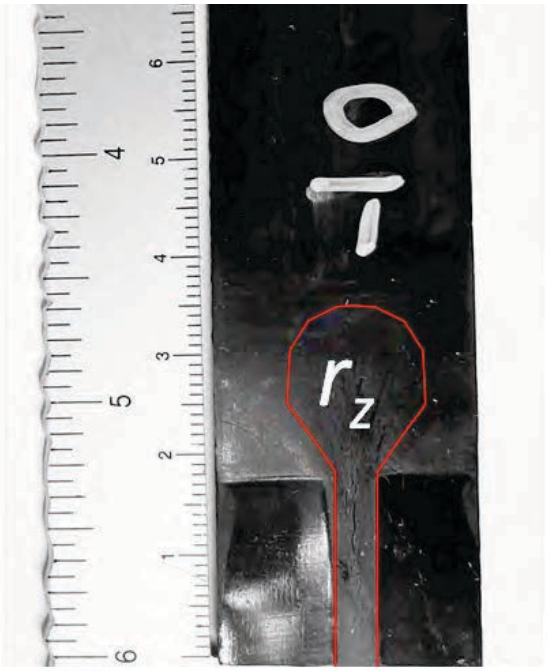

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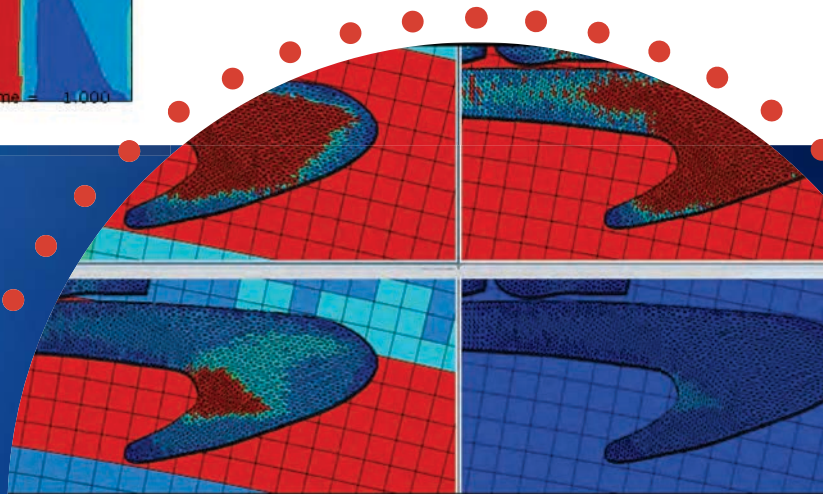


APPLICATION SPOTLIGHT

RAW MATERIALS SUPPLIERS

Imagine the impact your team can make with simulation results highlighting the benefits of your new additive, polymer or filler.

CAPABILITIES

Simulation, combined with Endurica's testing methods, provides the ability to realistically account for actual service conditions as no other standard testing can.

Simulate the effect of your raw material on product performance:

- Durability
- Heat build-up
- and more
- Rolling resistance
- Handling / stiffness

Simulations are available for a range of rubber applications including:

- Suspensions
- Tires
- Engine mounts
- and more

BENEFITS

- Show how your raw materials perform in your customer's applications
- Combine Testing + Simulation to generate confidence in your product offerings
- Cut learning curve and gain speed to market with shorter development iterations
- Achieve light weighting and sustainability while managing risks of performance / durability loss

Test fatigue performance in your own lab using Endurica protocols running on Coesfeld instruments. Endurica is the exclusive distributor of Coesfeld instruments in North and South America

Intrinsic Strength Analyser

- Indicates the threshold fracture mechanical strength of a polymer network (the mechanical fatigue threshold)
- Stay under the mechanical fatigue threshold for optimum durability

Tear & Fatigue Analyser

- Measures crack growth under dynamic loading cycles

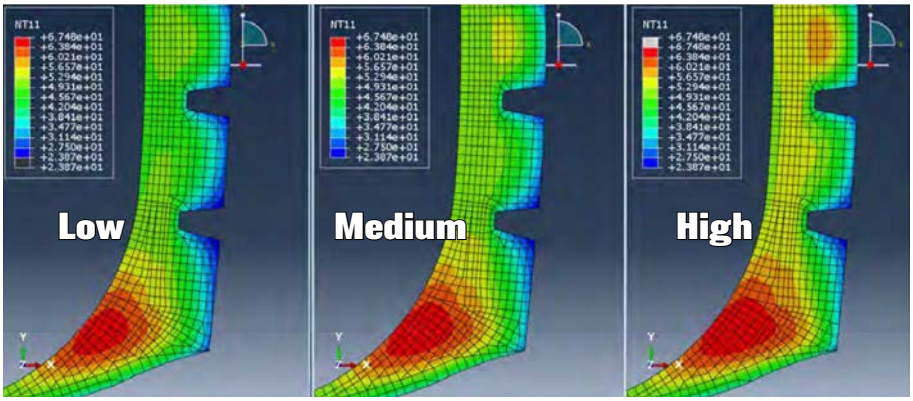
Instrumented Chip & Cut Analyser

- Measures chip and cut resistance of rubber compounds under cyclic impact loading

We can help you demonstrate

THE BENEFITS OF YOUR RAW MATERIALS

in your client's applications

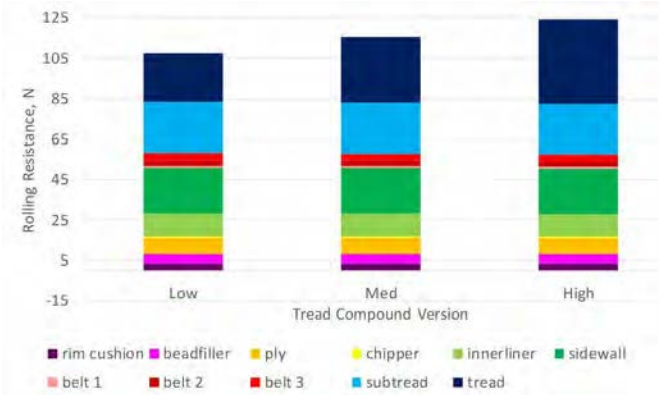


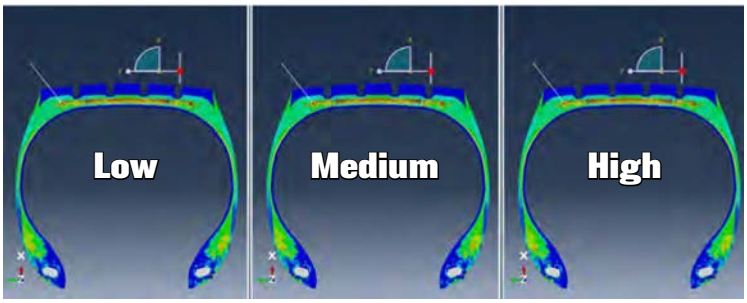
Temperature Distribution

- Differences in tire temperature distribution were computed with Endurica CL™, using heat build up properties measured with our Fatigue Property Mapping Thermal Module. Here, tread compound carbon black loading was varied at 3 levels: low, medium and high.

Compute Rolling Resistance

- The simulation shows the contribution of every compound to total tire rolling resistance. The tread contributes between 20-30% of the total rolling resistance.



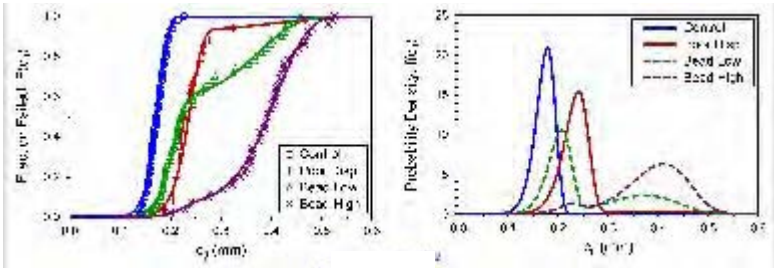


Durability

- Fatigue behavior of rubber compounds depends strongly on temperature. Changing tread carbon black levels can therefore affect belt edge operating temperatures and fatigue life. The impact on life can be realistically simulated so that the first project tire build has the best chance to get durability right.

Filler Dispersion

- The mix quality with which fillers are incorporated to the rubber compound has a strong impact on the size of crack precursors and on fatigue performance. Endurica's Fatigue Property Mapping Reliability module gives you frequency statistics on crack precursor size distribution.



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WINNING ON DURABILITY

Endurica User SPOTLIGHT

Rassini

Rassini is a global company that designs and manufactures components for suspension, brake and anti-vibration systems for the automotive industry, including both electric and internal combustion urban, family, off-road, sport, luxury and commercial vehicles. More than a manufacturer, Rassini is a design and solutions company, recognized worldwide as a pioneer in the development of new technologies as well as constant innovation in product and process engineering.

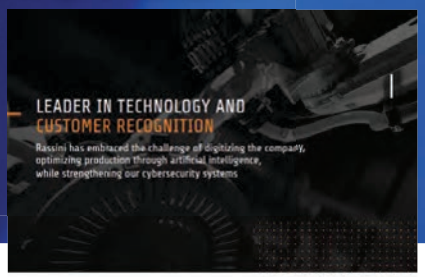
The company's 6,500+ employees work from eight production plants, five technology centers and offices in Mexico, the United States, Brazil, Germany and Japan. Rassini provides components to automakers in 10 countries, supplying over eight million vehicles every year. Furthermore, 51 vehicle models around the world use at least one Rassini product amid major original equipment manufacturers including General Motors, Ford, Toyota, Volkswagen, Tesla, Daimler, Audi, Mercedes Benz, Nissan, Volvo and Mitsubishi.

"Our customers value durability, and we deliver it with confidence."

- Jaime Calvan, Engineering Manager

Elastomeric Products Include:

Bushing assemblies for springs
Engine bumpers I Jounce bumpers
NVH reducing products
Single and double bonded bushings for shock absorbers
Shot bushings
Bar pin single bonded bushings for shock absorbers



Endurica Value Add for Rassini:

- win new business
- shorten product development cycles
- get to market faster
- make the best design decisions for durability

Rassini wins customer recognition of their technology leadership using Endurica solutions.

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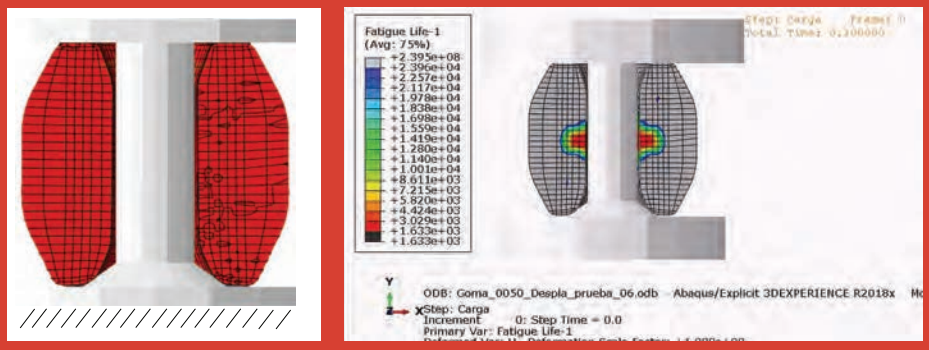
WINNING ON DURABILITY

CLIENT DURABILITY REQUIREMENT

The jounce bumper is a key element of a vehicle's shock absorber system. It prevents the metal shock absorber spring from reaching full compression during big impacts, and it improves the noise, vibration and harshness (NVH) characteristics. The jounce bumper design must qualify by enduring a sufficient number of load cycles without cracking. Rassini quickly gets the bumper material and design right before building a prototype by using Endurica to simulate the fatigue tests that will be used for qualification.

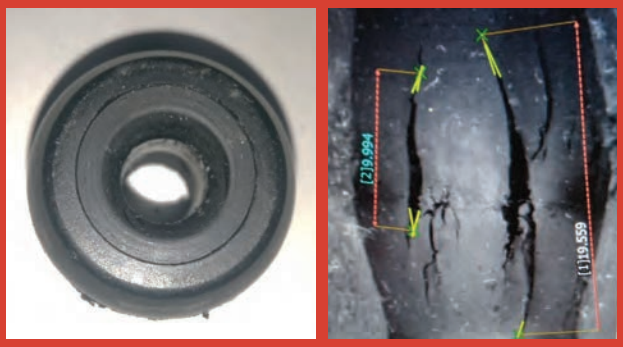
SOLUTION APPROACH



Cross section view of the jounce bumper in the unloaded state. Displacement is applied sinusoidally along the vertical direction so that the jounce bumper is compressed between rigid end plates. Material properties for the simulation were tested using Endurica protocols implemented in Rassini's lab.

Endurica CL™

Endurica CL™ correctly predicts fatigue cracking on the inside diameter of the jounce bumper for this load case.



Top down view of jounce bumper (left). Cracks in the fatigue test occur on the inside diameter (right), in accord with the location and orientation predictions of the Endurica CL simulation.

Rassini

"Durability is a principal requirement of our customers as defined in their specifications. With Endurica we have an advantage. We offer our clients the best technical information and a shorter overall project development time."

- Vladimir Pedraza Otero
Product Engineer

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WINNING ON DURABILITY

Endurica User SPOTLIGHT

AMC MECANOCAUCHO

Aplicaciones Mecánicas del Caucho (AMC) designs and produces anti- vibration mounts as well as noise insulation composites for industrial and building sectors. The firm's noise and vibration solutions include a comprehensive range of anti-vibration mounts based on rubber-metal, spring mounts, metal+ Sylomer® and wire rope mounts. AMC has been on the market since 1969, effectively reducing structurally-born noise and solving vibration problems.

"Our customers value the strong technical service we provide. We get complex applications right when others are just guessing."

- Jon Irazustabarrena, Technical Manager

Elastomeric elements are in AMC's wide range of anti-vibration mounts which include:

Annular	Cones	Marine
Blocks and Mats	Couplings	Noise Reduction
Bobbins	Diabolo	Spring
Buffers	Generator	Transformer
Bushings	Hood	Trapezoidal
Cabin	Levelling	

Endurica Value Add for AMC:

- Speed to market
- Product development risk reduction
- Cost reduction

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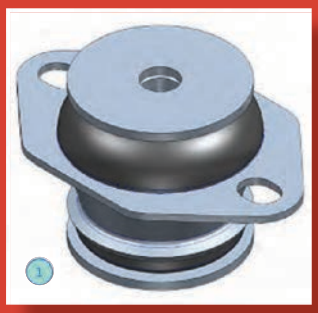
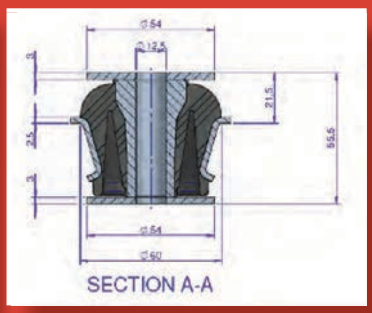
WINNING ON DURABILITY

CLIENT DURABILITY REQUIREMENT

Vibration isolation for an engine in an agricultural application required careful selection of mount stiffness and damping properties, as well as proven durability under variable amplitude 3-axis load inputs. AMC differentiates their company through top-notch technical service and they ensured customer confidence with a full durability analysis taking into account actual part loading history. This analysis showed the AMC solution is superior to alternatives, and they quickly resolved a fatigue issue that was a huge pain point for their customer.

SOLUTION APPROACH





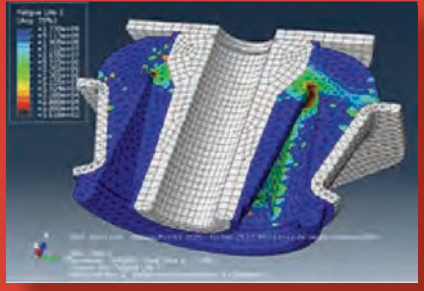
AMC engineers use the Endurica EIE™, CL™ and DT™ solvers to analyze the effects on durability of multi-channel load inputs recorded in the field by the customer. A nonlinear displacement-strain mapping is first generated using EIE and finite element analysis. Next, EIE converts the load history into strain history. Remaining life is tracked until end of life. Validation against customer field results have shown strong correlation, providing high confidence that AMC's innovative solutions will work as shown in the simulation.

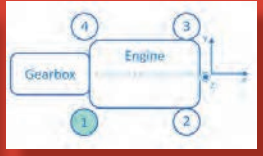
Endurica CL™

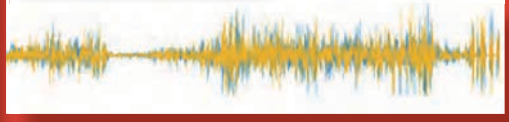
Endurica DT™

Endurica EIE™

Finally, Endurica CL™ computes fatigue life for the part, in terms of repeats of the given history. Or, if there are multiple load cases to consider, these are scheduled and applied using Endurica DT™, and the remaining life is tracked until end of life. Validation against customer field results have shown strong correlation, providing high confidence that AMC's innovative solutions will work as shown in the simulation.







AMC MECANOCAUCHO

"Our customers have many unique and complex applications, so our ability to quickly and confidently propose the right solution – and have it work on the first try – gives us a huge advantage. Endurica's training and tech support are great. After setting up our license, we were able to use the tools immediately. The fast and precise answers they give have allowed us to quickly and successfully apply the workflows we've needed."

- Ander Aldalur
Application Engineer

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WINNING ON DURABILITY

Endurica User SPOTLIGHT

2021 ANNUAL MEETING
THE VIRTUAL TIRE

The Tire Society is the world's leading tire science research, engineering, technology, and innovation organization. The annual conference showcases tire industry innovation.

The keynote presentation, "The Move To Virtual", by Mike Anderson, General Motor's Executive Director of Global Virtual Design, Development and Validation spoke of GM's target of 100% virtual design by 2025.

Highlights included:

- upstart competitors sprinting ahead through the use of simulation in areas like electric vehicles
- simulation increasing the speed of discovery by
  - engineering answers at the pre-build phase
  - exploring more in the design space
  - enabling greater performance outcomes

We need to go beyond just replicating physical tests with simulation. A "right the first time" culture must replace the old "discover and recover" culture.

— Mike Anderson
Executive Director of
Global Virtual Design,
Development and Validation
General Motors
Tire Society 2021
Keynote Address

Three Endurica users made presentations at the 2021 Tire Society Annual Meeting.

CEAT presented "Incremental, Critical Plane Analysis and Experimental Verification for TBR Tyre Bead Endurance Applications."

Goodyear presented "A Model for Predicting Residual Casing Life of a Tire Following an Impact Event."

Maxxis Tires presented "Tire Durability Prediction Using Three-Element Layered Mesh for Cord-Rubber Composites."

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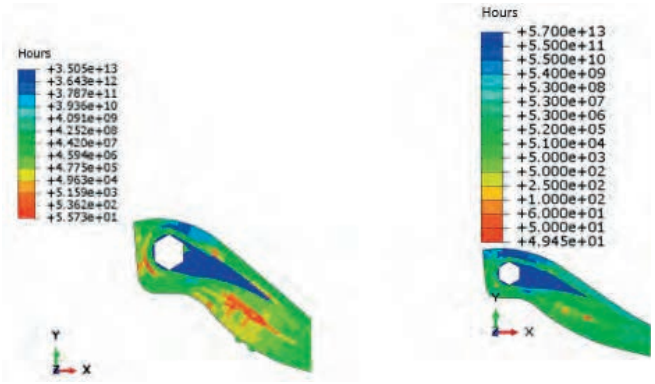
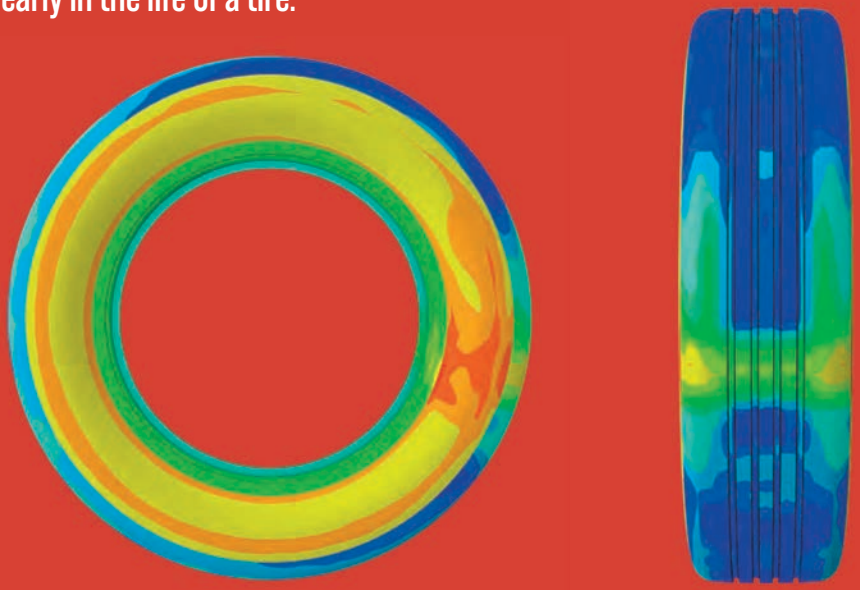
CEAT

Bansal used Endurica DT to simulate a multi-step durability test with loads ranging from 80% to 250%.



GOODYEAR

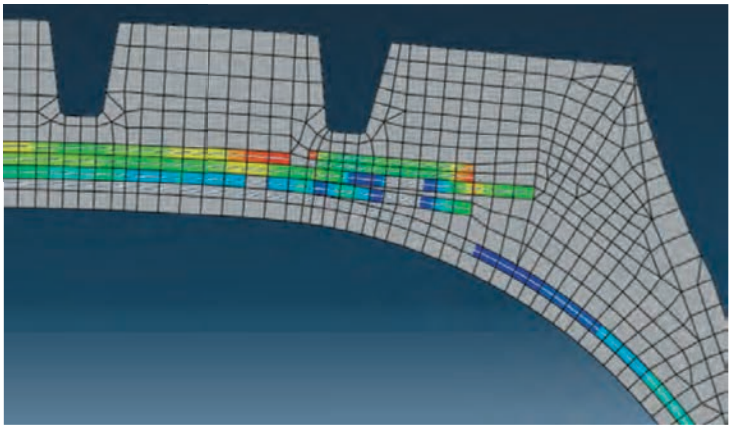
Ebbott and Gobinath used Endurica DT to demonstrate the consequences on tire damage development of a range of impact event scenarios (speeds, impact angles, different wear states) early in the life of a tire.



MAXXIS

Behroozinia shared a tire meshing technique for improving representation of interlaminar shearing.

Using Endurica DT to simulate the damage accruing across all 6 steps in a load durability test, Maxxis predicted the failure modes in multiple scenerios.



The CEAT and Maxxis papers show

- multiple direct comparisons of tire durability tests with simulations
- excellent predictions of both failure mode and tire life

The Goodyear paper illustrates

- an application that is difficult or impossible to evaluate with physical testing
- how the right physics built into the model increases the speed and scope of discovery beyond the limits of physical testing

All three perfectly illustrate that simulation provides for competitive advantage and 'right the first time' engineering.

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ENDURICA USER SPOTLIGHT

Inflatable sealing technology is used in critical applications, from anchoring drill rigs to the seabed to gas loading systems, pipeline welding, and watertight doors/panels. Capable of adapting to varying environmental and service conditions, inflatable seals can be expanded and contracted pneumatically or hydraulically to accommodate changes in components that move in relation to one another, and those that are frequently connected and disconnected.

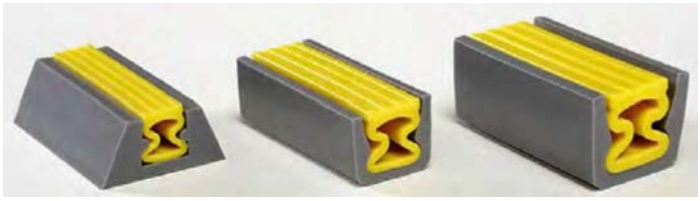
Inside the world's most demanding applications, you'll find trusted engineered solutions from Technetics Group. Along with global manufacturing locations, their experience is vast, and their solutions comprehensive.

From the advanced R&D center to their company-wide commitment to relentless testing and precision, they are committed to improving safety and optimizing performance for each of their clients.

ELASTOMERIC PRODUCTS INCLUDE:

- CEFIL'AIR® Inflatable Seals
- Extruded Profiles
- Plate Seals
- Molded Seals

Technetics Group is one of the world's best-known sealing and component design manufacturing businesses delivering highly engineered seal designs and critical component solutions. With innovative manufacturing and responsive technical expertise, their engineering leadership is respected and admired across the globe.



Delivering confidence to our customers for critical applications in the most demanding environments is our passion.

ENDURICA VALUE ADD FOR TECHNETICS:

- Winning innovation
- Right-the-first-time engineering for demanding environments
- Readiness for Digital Twin applications

WINNING ON DURABILITY

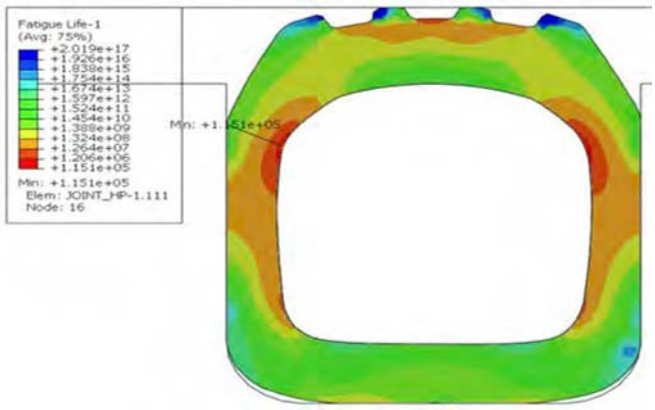
CLIENT DURABILITY REQUIREMENT

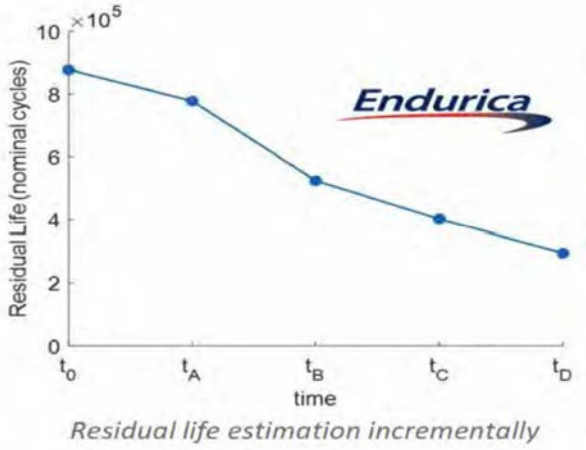
Technetics uses workflow from Endurica to predict the life of CEFIL'AIR inflatable seals which provide a flexible connection between a ship's turret and the riser buoy of an offshore oil and gas rig. Endurica CL™ is used to predict the initiation of a crack with propagation criteria and to study different seal extrusion profiles. Non-linear material models (Ogden Hyperelasticity) were considered for FEA analysis through ABAQUS combined with ENDURICA for fatigue life prediction. Prediction of residual life for the seal is estimated with the help Endurica DT™ software solutions.

"In optimizing a geometry to extend the fatigue life of a product I ran a few iterations of inner-cavity geometries and found one specific geometry with Endurica that achieved 500,000 cycles to failure in contrast to the 30,000 I had before. It's more than a 10-time improvement and that's really significant. These concrete numbers are really powerful in helping us and our customers to make good decisions."

- François Rouillard
R&D Mechanical Engineer,
Maestral Sealing Laboratory,
Technetics

The seals operate at up to 250 kPa inflation pressure, with a mean temperature of 10°C. The seals must function for a specified number of years while enduring lyophilizer cycles without cracking. Analysis with Endurica CL™ and DT™ helped Technetics to design better inflatable seals by considering the large strain behavior, leveraging the parameterized modeling techniques, and fatigue analysis. Prediction of fatigue life has helped engineers at Technetics to accelerate the design life cycle for the best in class products to maintain the market leading position. Additionally, fatigue analysis with Endurica has allowed Technetics to respond quickly and effectively to customer needs and to ensure delivery of "right the first time" solutions.





Residual life estimation incrementally

To learn more about inflatable sealing technology, visit our website to contact a specialist for a custom-engineered solution for your application.

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WINNING ON DURABILITY

Endurica User SPOTLIGHT

Delkor Rail is a worldwide supplier of high-quality, resilient bonded rail baseplates, platform gap filler, and rolling stock products, with over 30 years of experience providing technical advice and quality components to the world's rail construction industry.

Based in Sydney Australia, Delkor Rail has worked on projects in Australia and all over the world, including the London Underground, and projects in Canada, USA, Madrid, Barcelona, Singapore, Hong Kong, Malaysia, Taiwan, Germany, Switzerland, the USA and New Zealand.

Elastomeric Products Include:

Track Products:

- Multiple rail fastening systems including those focused on high vibration and noise attenuation
- Track superstructure components
- Rail fixation components

Rolling Stock:

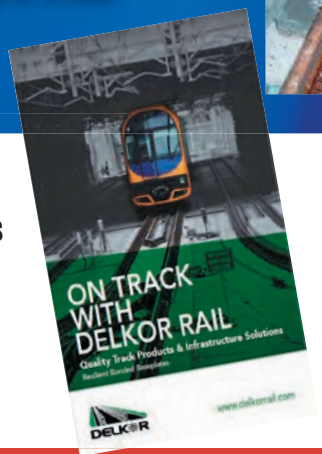
- Suspension components
- Bogie components
- Air spring refurbishment program

Platform Gap Filler:

- A sturdy, hard-wearing rubber strip mounted along the edge of a train platform to reduce the gap between the platform and the entrance of a passenger train

The software has been working well for us. The combination of Ansys, the material data we have obtained and the ability to perform fatigue simulations has allowed us to design products that would not have been possible previously (without extensive physical testing).

– *Robert Barnbrook*
Product Engineer
Delkor Rail Pty Ltd.



Endurica Value Add for Delkor Rail:

- Save costs of multiple physical tests for design iterations
- Make the best design decisions for durability
- Shorten product development cycles

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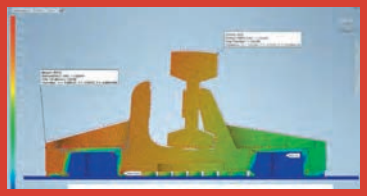
WINNING ON DURABILITY

CLIENT DURABILITY REQUIREMENT

The Northern City Line of the Great Northern Network Rail system in the United Kingdom started operation in 1904. Since 2015 the line has run a minimum of six trains per hour and extended operating hours until midnight. Noise complaints from residents near the Moorgate Branch rose to the attention of London's Mayor and political pressures resulted in a budget being formed to deal with noise complaints – and Network Rail dedicating a team for a quick solution. Delkor Rail's challenges included maximizing N&V reduction, maintaining TOR, using the existing hole centers, retaining BH rail and key protocols, and completing all work through EN13481 Cat C testing. All while assuring sufficient durability.

SOLUTION APPROACH

The Delkor Egg baseplate helps to reduce structure-borne vibration and noise. It is comprised of a top plate and base frame that are vulcanized (bonded) together by means of a natural rubber element which helps achieve a very low static stiffness while still ensuring a high degree of rail stability. Endurica's tools help Delkor to fulfill regulatory requirements on part durability and allows rubber stiffness to be optimized for the type of stock and speed. Delkor's client, UK-based Network Rail Acceptance Panel (NRAP), gave full acceptance of the solution.



Delkor uses Endurica CL™ with ANSYS to model Egg baseplate durability.

Redesigned casting image.

Endurica CL™ Ansys

DELKOR

Before Endurica, we went through 40+ design iterations trying to reduce the strain amplitude as much as possible. We also went through 4 or 5 rounds of physical testing before a successful test. Since we adopted Endurica CL, we have been able to compare the fatigue life for new designs against previous designs that we have been successful with. This has meant that we can produce a suitable design with only a handful of design iterations and a single physical test.

— *Liam Turbet*
Technical Manager
Delkor Rail Pty Ltd

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