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LMS solutions for durability

Challenges in vehicle durability engineering

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Challenges in vehicle durability engineering

A durable design is more than a trendy word

Durability is strongly related to brand image and thus a crucial selling point. Customers simply expect their cars to last at least for 300,000 kilometers. But today's customers have more on their wish list than a durable vehicle. They expect a wide variety of vehicle types, a higher quality, preferably at a lower price.

Also the ecological trend entails new challenges. Seemingly conflicting engineering challenges need to be reconciled to manufacture the cars that will determine the world's future mobility.

Addressing new target markets meets the customer's need of a wide variety of vehicle types, including new vehicle concepts such as hybrid and electric vehicles. More vehicle variants put more pressure on durability engineering departments as they need to design and validate more load-cases in less time, without compromising on accuracy.

In the design itself, the automotive industry aims to minimize the weight of the vehicle. A vehicle with reduced weight meets fuel economy expectations and generally achieves a higher level of overall performance and efficiency. New materials, hybrid engines, progressive vehicle electrification, bring their own challenges as they influence the overall fatigue, vibration, thermal and acoustic aspects of the vehicle. Although the challenges seem tough, the automotive industry is ready to meet their customer's expectations, by integrating durability engineering into an efficient development process.

Today's customers expect

- 300,000 km on the counter
- No compromise on durability and safety
- Wide range of models
- Attractive price
- Better fuel economy

Durability engineering departments

- Guarantee durable and safe designs and avoid product recalls
- Handle more and more vehicle variants on a single platform
- Shorten development cycles
- Understand emerging markets with different roads, environmental conditions and driving styles
- Reduce weight, avoid over design and introduce new materials
- Balance durability against other attributes
- Handle increased complexity of testing scenarios

Why LMS solutions?

The right vehicle, the right durability performance at the right time

LMS™ solutions support with expertise at the concept, design and validation stages of the vehicle development process and brings to market a more efficient durability engineering process. This helps customers set their durability targets and integrate durability engineering into the vehicle systems simulation process. Many of our customers have achieved faster time-to-market cycles while keeping engineering brand values.

Unique portfolio for hybrid durability engineering

From accurate loads captured with LMS SCADAS™ Durability Recorder hardware, to LMS™ Tecware software target setting and test schedule definition, up to LMS Virtual.Lab™ software embedded simulation techniques assessing durability performance in the early part of the design cycle, we have the right products to make those critical go-the-distance improvements to your design process.

Competence, experience and know-how

We have solid hands-on vehicle co-development experience and best-in-industry process know-how. LMS™ Engineering services help customers to explore and define solutions to development-related issues, ranging from full vehicle and subsystem co-development, to technology transfer and method development to quick troubleshooting and design refinement questions.

Scalable partnering model

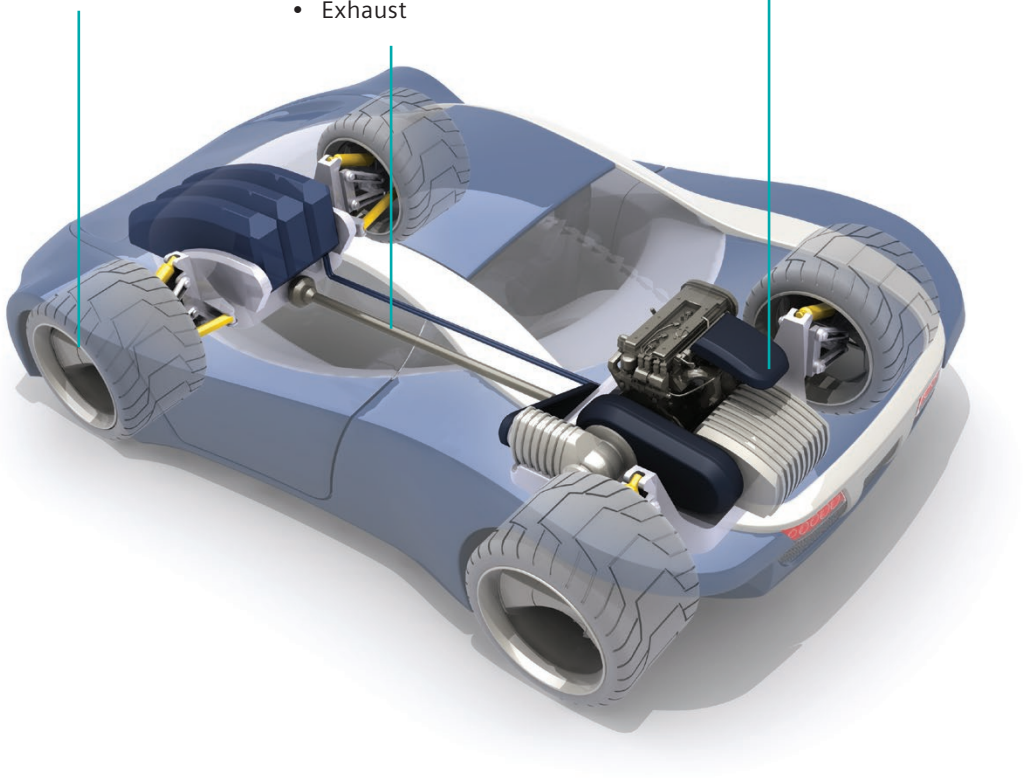
We offer a tailor-made scalable partnering model for each manufacturer, supplier and company worldwide – from a supplier of testing systems and simulation software, to a partner in durability attribute engineering, to a strategic partner in product development and process transformation programs.

Solutions for chassis, powertrain and body

Chassis
- Suspension
- Steering system
- Subframe
- Wheel

Powertrain
- Engine
- Engine auxiliaries
- Transmission, driveshaft
- Differential
- Exhaust

Body
- Body
- Door
- Seat



"Use of LMS Virtual.Lab Durability in Piaggio cut the number of required prototypes in half, effectively reducing the development cycle."

Riccardo Testi
Development and Strategies 2 Wheeler Engines Technical Centre
Piaggio

"System-level simulations in LMS Virtual.Lab Motion are essential in simulating the durability effect of more profound design changes. With the mixed durability simulation approach, we are able to reliably predict the impact of modified bushing characteristics or adapted mount locations on the fatigue life of a tractor cabin or other component. Unlike other software solutions, LMS Virtual.Lab Motion offers generic modeling capabilities that allow us to flexibly and realistically model full-tractor designs."

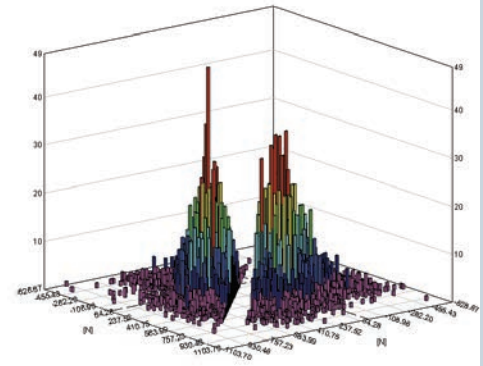
Dr. Christian von Holst
Global Systems Engineer Suspension Systems
John Deere

Durability engineering in practice

LMS solutions combine the best of virtual and physical methods. As key process enabler for accelerating vehicle development, hybrid engineering makes optimal use of existing data early in the design cycle, and makes simulation driven design a practical reality. This is highly effective for design optimization, troubleshooting and problem solving.

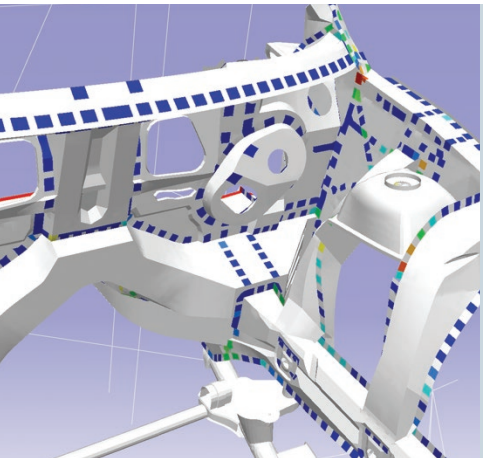
Understanding operational loads

A critical factor for successful durability engineering is gaining a precise understanding of the loads that products will undergo during their anticipated lifetime. Typically, the automotive industry generates road load data on public roads and proving grounds. The availability of realistic load data is essential for virtual and physical product validation and optimization.



Target setting and test procedures

Once realistic load data from public roads has been collected and consolidated, durability-specific characteristics are analyzed and a durability target matching the target customer usage profile is derived. An accelerated durability test procedure is determined – which serves typically as input to the virtual and physical product validation and optimization validation process.

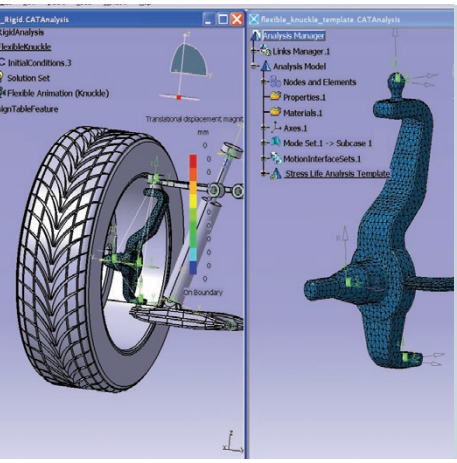


Virtual product validation and design optimization

With manufacturers delivering more complex products with increased quality in shorter development cycles, a traditional test-based test-break-fix development process is no longer an option. Virtual prototyping delivers the right answers on time and with the required accuracy to positively impact the development process. Through the usage of virtual product validation a variety of design alternatives are easily compared leading to an improved physical prototype.

The best of hybrid engineering

- Perform extensive target setting for vehicle, system and component performance
- Frontload durability performance engineering to the early development stages
- Increase durability engineering efficiency – more engineering insight from less prototypes
- Evolve from in-field troubleshooting to durability engineering design-right-first-time
- Develop an optimal balance between loading, structure and material
- Master the durability profile of a multitude of vehicle variants and new powertrain configurations
- Achieve a faster time-to-market cycle



Virtual product validation and design optimization

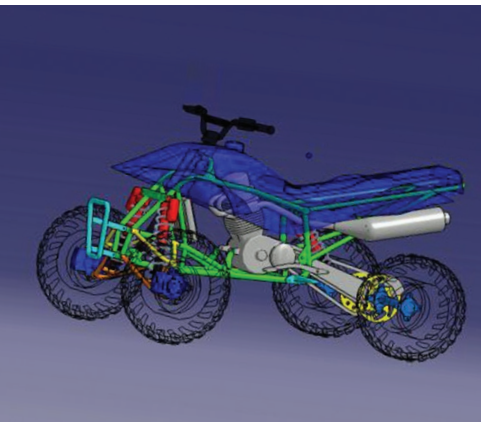
Multi-body technology is used to cascade full-vehicle loads to subsystem and component loads, long before the actual vehicle prototype is created. Starting from virtual driver sessions or road load data from a previously released vehicle, accurate subsystem and component loads are created. By combining loads, finite-element-based stress results and cyclic fatigue material parameters not only critical areas for fatigue and corresponding fatigue life are predicted. Based on the insight gained, the component design is optimized for fatigue performance. The critical loads and events are further analyzed to ensure smarter and more efficient physical testing.

Physical product validation and design optimization

Extensive durability testing on components and subsystems validates the durability performance and confirms the virtual prototyping results. Shortened laboratory testing cycles are applied to reduce resources regarding test facilities and test engineers.

Final product test

The last step in the durability development process involves final vehicle product testing on the road. Durability performance at full vehicle level is validated before final product sign-off. In case of late design issues in-field troubleshooting is applied to implement quick countermeasures.



Unique portfolio for hybrid durability engineering

From realistic design and validation with accurate loads, accelerated durability testing, to simulation techniques assessing durability performance in the earliest part of the design cycle, we have a unique portfolio of products and services to make those critical go-the-distance improvements to your design process.

Test-based durability engineering

Despite the increased use of virtual simulation, test departments are actually faced with an increased volume of testing work they need to complete. The explosion of product variants and increased testing scenario complexity largely compensates for the routine testing tasks eliminated by simulation. In addition, automotive companies are continuing to shorten their product development cycle times, resulting in fewer prototypes – and less time for testing.

Realistic design and validation with accurate loads

- **LMS SCADAS Durability Recorder – mobile data acquisition for tough environments**
  Designed for truly rugged data acquisition in extreme conditions such as water, dust, dirt, shock, vibrations
- **LMS Tecware – efficient durability load data processing**
  Streamlined process of consolidating load data, analyzing durability-specific characteristics and designing customer-correlated test procedures
- **LMS™ Tec.Manager software – scalable test data management**
  Organize, search and share test data in support of virtual and physical design validation

Accelerated durability testing

- **LMS Tecware – shortened laboratory testing cycles**
  Remove nondamaging events from long duration measurements to accelerate durability tests
- **LMS Test.Lab™ Vibration Control software – complete solutions for shock and vibration testing**
  Certification and homologation of components. Accurate closed-loop shaker control and a maximum amount of built-in safety mechanisms, minimizing risks of damaging costly test items
- **The Durability Alliance**
  A close partnership with Instron Structural Testing Systems and Kistler ensures a tight integration of durability related testing and simulation software through joint developments

Simulation-based durability engineering

Shorter development cycles and increased quality requirements have stretched traditional test-based durability processes to the limit. Evaluating and optimizing durability performance on a virtual prototype, before physical testing, is a valid alternative.

Assessing durability performance in the earliest part of the design cycle

LMS Virtual.Lab integrates various virtual prototyping aspects including finite element (FE), modal analysis, multi-body simulation (MBS) and fatigue-life prediction in a single integrated software environment.

- **LMS Virtual.Lab Motion software – robust durability loads prediction**
  Simulate realistic motion and mechanical system loads; quickly create and use multi-body models, efficiently re-use CAD and FE models and perform fast iterative simulations to assess the performance of multiple design alternatives
- **LMS Virtual.Lab Durability software – accurate fatigue life prediction**
  Analyze the strength and fatigue of components and systems; dedicated postprocessing helps engineers to get feedback on critical areas and understand root causes of fatigue problems

Engineering services

It isn't all hardware and software. The LMS durability engineering team is uniquely skilled at balancing functional performance attributes against key program drivers such as fuel economy, weight and overall program cost. Our engineers are experienced in assisting the automotive industry in developing components and vehicles with optimal fatigue and strength characteristics, making sure that parts are not too heavy or too expensive to manufacture profitably.

LMS Engineering offers a broad range of services and can take full responsibility from concept to final validation. Its solutions are fully scalable – from full-vehicle development responsibility for co-development over supporting the development of major subsystems like front or rear suspension, corner modules, body and body parts to troubleshooting and design refinement of individual components.

- Road load data acquisition – measurement of operational loads
- Load data analysis and test schedule development
- Detailed vehicle engineering – multi-body simulation and fatigue life prediction
- Prototype refinement and optimization
- Technology transfers, method development and troubleshooting

Customer services

We support our customers with engineers who not only understand the hardware and software, but also master the related engineering applications. Extensive training, seminars and onsite services help our clients' technical staff gain and maintain their software and system know-how. we offer a complete portfolio of professional services, including full installation management, onsite training and support and continuous knowledge transfer.

For high-channel counts where channels are divided over multiple separated testing units, data is fully synchronized and automatically collected in one measurement file.

Road load data acquisition

Dedicated to durability road load data acquisition, the LMS SCADAS Durability Recorder offers maximum measurement power in one single box. For long and repetitive acquisitions requiring high-channel counts and large data-set storage, you can easily see the need for a dedicated solution like the reliable LMS SCADAS Durability Recorder.

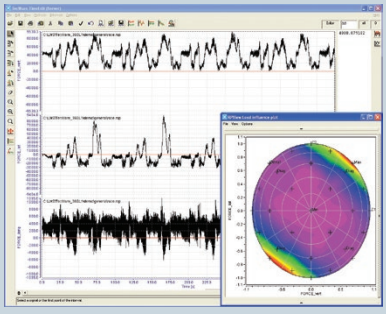
- Top performer in tough conditions: water and dust protected – ingress protection code IP54 and MIL-STD 810F qualified for shock and vibration
- Vibration-resistant cable connections
- High-channel density (from 8 to 72 channels expandable to hundreds of input channels) without compromising speed or quality
- Embedded signal conditioning for wheel force transducers, strain gages, displacement sensors (LVDTs, string pots), thermocouples, DC-type accelerometers, GPS, CAN-bus
- On-the-spot data validation preventing errors and annoying reruns

LMS TecWare ProcessBuilder streamlines consolidation of raw data from road load data acquisition before delivery to laboratory test or simulation teams.

Consolidate vast amounts of acquired load data

LMS Tecware helps test engineers efficiently validate gigabytes of raw data from mobile data acquisition campaigns. A multitude of measurements – containing any combination of force, strain, moment, displacement, acceleration, tacho, pressure, temperature, CAN and GPS are consolidated, either interactively on a channel-by-channel basis, or fully automated through standardized processes. During data consolidation signals are scanned for anomalies (spike and drifts), channels are renamed, base statistics are processed, new channels are derived using math operations, data is low-pass filtered, specific sections are extracted and consolidated data is stored for further usage by simulation and test teams.

- Fast, easy and intuitive time data validation
- Automated anomaly detection and correction
- Streamlined load analysis to increase testing productivity
- Powerful reporting

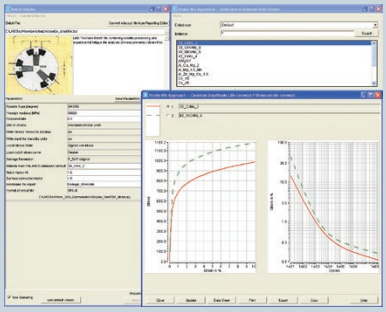


Quickly assess the durability impact of various road surfaces using LMS Tecware multi-axial rainflow counting.

Gain a precise understanding of loads

LMS Tecware focuses on monitoring and comparing essential durability-related aspects to select representative loading scenarios. A core capability of LMS Tecware is its extensive range of dedicated durability-specific data interpretation methods. Co-developed and validated with leading automotive OEMs these methods help engineers efficiently qualify the durability potential from load data. A wide range of embedded display capabilities helps users quickly assess the durability impact of various road surfaces, compare loads collected using multiple sensors or correlate test and simulation results.

- Complete toolset: statistics, rainflow, range pair, level crossing, time at level, power spectral density, pseudo-damage
- Compliant with SAE, AFNOR and DIN standards
- Innovative technology co-developed and validated with leading automotive OEMs

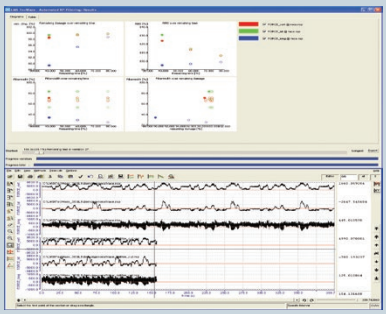


LMS Tecware accurately estimates the fatigue life based on measured strain gages.

Experimental fatigue analysis

LMS Tecware accurately estimates the fatigue life of a component, based on measured strain and cyclic material properties. It helps the user conduct a wide range of design sensitivity studies such as the variability of loading, materials, surface conditions and local geometry. As a result, you optimize the components' fatigue performance.

- Estimate fatigue life of a component
- Based on measured strain histories, individual tensors and cyclic material properties
- Low-cycle and high-cycle fatigue analysis based on strain-life and stress-life
- Design sensitivity studies
- Optimize your components' fatigue performance

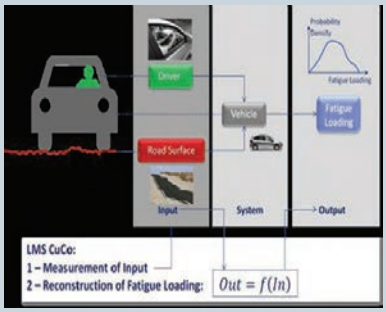


LMS Tecware removes nondamaging events from long duration measurements in order to shorten the durability tests.

Accelerate durability test scenarios

Extensive field tests to validate the durability performance of vehicles are a very expensive and time consuming process. To cut costs, more and more manufacturers are replacing actual vehicle tests with equivalent accelerated laboratory tests or virtual simulations. LMS Tecware supports this critical shift by efficiently defining sets of compressed load time histories that preserve the same damage potential as originally present – making it possible to generate new test schedules and optimize existing ones. Engineers can test more variants in the same amount of time and speed up testing cycles significantly.

- Reduce testing time without losing fatigue content
- Gain a higher return from existing testing facilities



LMS Customer Correlation (CuCo) on multiple vehicles measures driver and road surface input and reconstructs fatigue loading.

Derive customer-correlated durability test schedules

Mapping the real customer usage of your product to a condensed durability test scenario is not simple. The CuCo solution offers a systematic approach to load data synthesis using a two-step approach.

- First, customer-correlated durability target is derived from public road data. Traditionally this is done on a prototype vehicle. Alternatively LMS Customer Correlation (CuCo) is applied; multiple vehicles are instrumented to acquire driver and road surface input and to reconstruct customer correlated durability target based on statistical models.
- Second, the durability target is mapped into a condensed damage-equivalent durability test scenario. Any guesswork is eliminated by calculating the optimal mix of test track sections that match the target customer usage with respect to fatigue.

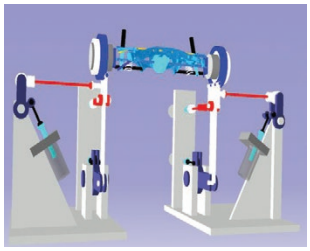
Multibody models are used for the prediction of vehicle performance and load transfer to subcomponents.

Loads prediction for fatigue analysis

Road load prediction is an important step in assessing a component's fatigue life due to operational loads. Using the embedded LMS Virtual.Lab Motion solver, LMS Virtual.Lab System-Level Fatigue lets engineers calculate component loads from a prescribed system motion through multi-body simulation. Current industrial practices for loads prediction can be classified in three categories, with increasing complexity:

- Method 1: Suspension loads
- Method 2: Full vehicle loads based on experimental data
- Method 3: Full vehicle loads based on CAE prediction (digital test track)

LMS Virtual.Lab Motion covers all three load prediction methods.
These component loads are combined with structural stresses. The material fatigue parameters are ultimately applied to predict the component's fatigue hotspots and corresponding fatigue life.

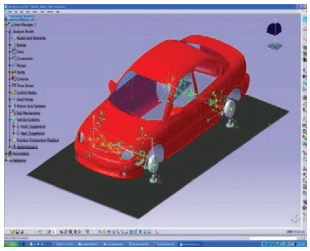


Robust and accurate multi-body solving for suspension component loads calculation.

Method 1: Suspension loads

The multi-body model of the suspension directly uses loads that have been measured in an experimental test on the full vehicle (typically forces and torques at the wheel center). This classical approach is easy to set up and uses the test loads directly. However, one of the two more complex methods should be used for accurate loads at the connection with the vehicle body.

- Straightforward application of measured load to multi-body model
- Ideal for subcomponent analysis

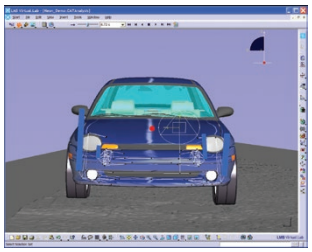


Realistic simulation of full vehicle loads with LMS Virtual.Lab Motion-TWR.

Method 2: Full vehicle loads

Because any small mismatch between the inertial and elastic properties of the model and the real vehicle will cause drifts in the simulation leading to unrealistic loads, the direct application of experimental loads to the multi-body model of the unconstrained vehicle is often unfeasible. The hybrid (Test-CAE) approach implemented in LMS Virtual.Lab Motion-TWR uses the test data to compute an equivalent set of driving functions that guarantee replication of the test data and ensure equilibrium of the simulated vehicle. This methodology has the advantage of not only reproducing realistic simulations but also avoiding the task of modeling the road and the tire.

- Realistic and accurate full vehicle simulation
- Avoids tire, road and driver model

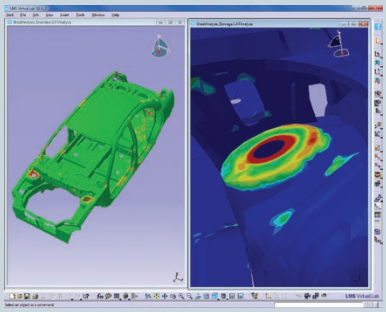


Accurate tire and road models for full vehicle road loads simulation.

Method 3: Digital test track

The full CAE approach consists of the prediction of component loads by replicating real driving conditions. It requires a correlated vehicle model but also an accurate representation of the tire, the road and the driver.

- Realistic road load prediction
- No physical prototype needed



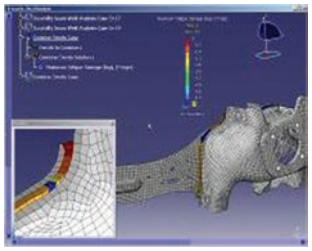
From simple safety factor analysis to detailed multi-axial fatigue.

Fatigue life prediction

Physical testing of a component is expensive and can only be conducted at the end of the design process. LMS Virtual.Lab Durability allows engineers to predict fatigue hotspots and corresponding fatigue life. It combines component loads derived from prototype measurements or multi-body simulations, FE-based stress results and cyclic fatigue material parameters. LMS Virtual.Lab Durability provides direct feedback on critical fatigue areas and the root cause of fatigue issues.

- Validate more design variants for fatigue life within ever-shorter development cycles
- Improve the fatigue behavior of welded structures
- Optimize durability performance with lightweight and eco-friendly materials
- Understand better and improve fatigue testing

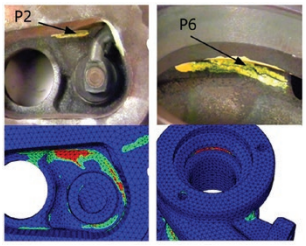
LMS Virtual.Lab Durability designs for optimal durability performance and offers specific solutions for weld fatigue, thermo-mechanical fatigue, random and vibration fatigue, and composite fatigue.



LMS Virtual.Lab Durability Seam Weld supports accurate and efficient simulation of seam welds.

Weld fatigue

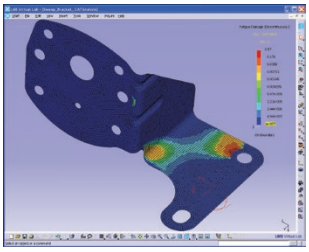
Most fatigue problems often occur on welds. LMS Virtual.Lab Durability offers the most complete and accurate methodologies to assess seam weld fatigue and spot weld fatigue. It provides an enhanced tool to automatically identify all typical seam weld topologies in an FE-mesh. Virtual.Lab Durability also eliminates the need for engineers to tediously model each seam weld connection manually and offers significant speedups for large welded assemblies.



Comparison of the simulated creep and cyclic fatigue with tests.

Thermo-mechanical fatigue

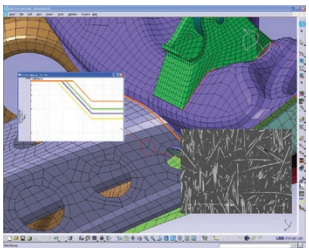
Temperature changes influence the mechanical and the fatigue behavior on metals. The LMS Virtual.Lab Durability Thermal Fatigue module enables the efficient simulation of these influences by using standard fatigue data for several levels of detail. Creep fatigue and visco-elastic stress relaxation can be handled quickly and accurately by a new extension of the strain-life approach; thus thermal shocks can be analyzed for fatigue hotspots and lifetime.



Vibration fatigue allows analysis of the influence of different loads – here vertical and lateral.

Random and vibration fatigue

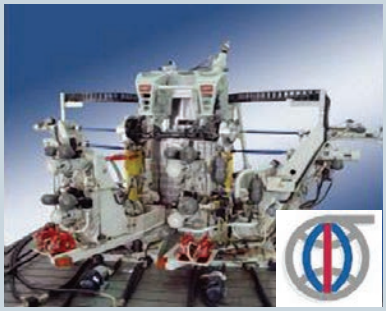
Traditionally, fatigue damage is associated with time-dependent loading in the form of local stress or strain histories. But there are load situations both in the lab testing as well as in the real world, where determination and definition of the loads are more efficiently performed in the frequency domain, either as deterministic sine sweeps or random stationary processes. LMS Virtual.Lab Durability Vibration Fatigue handles all these load situations for uni-axial and multi-axial load efficiently.



Composite fatigue at macro level.

Composite fatigue

The need to reduce the weight of vehicles and the CO_2-regulations promote the use of new lightweight materials, such as composites. By their complex microstructure, the materials need special strategies for fatigue evaluation. LMS Virtual.Lab therefore interfaces with material tools like e-Xstream DIGIMAT™, a software solution that allows the modeling of short fiber composites among others. It assesses the correct local fatigue behavior at each point in the structure and for each load direction.



Fatigue and durability testing of suspension using IST suspension rig, partner of LMS in The Durability Alliance.

Laboratory shaker trials

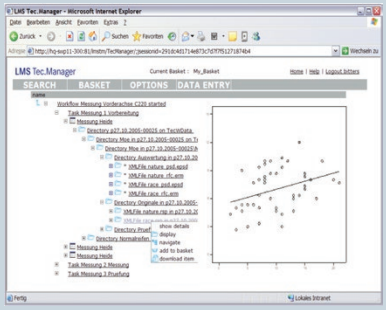
In The Durability Alliance, we teamed up with Instron® Structural Testing Systems (IST) and Kistler to provide world-class hardware and software solutions for durability laboratory shaker trials. Full-vehicle rigs, suspension rigs, vehicle four-poster rigs, multi-axial-shaker-tables (MAST) and component rigs are used to validate key life performance of components, subsystems, systems and full vehicles. LMS technology embedded in IST RS LabSite© modulogic is used for rig test preparation, drive file development and endurance test monitoring.

Shock and vibration testing of components using LMS Test.Lab Vibration Control.

Shock and vibration testing

LMS Test.Lab Vibration Control offers complete solutions for shock and vibration testing. It helps test engineers easily certify and homologate their products, ensuring they can cope with external excitation and vibration conditions. These can range from normal to extreme conditions, and include rough transportation circumstances.

- Control and analysis software for sine, tracked sine dwell, random and shock vibration testing
- Single-axis waveform replication for replay of operational conditions
- Integrates common industry standards and supports user-specific test definitions
- Fully compatible with electro-dynamic shakers and hydraulic actuators
- Expandable with extensive analysis and advanced control features



LMS Tec.Manager searches through road load data collections and derives statistics on relevant test parameters .

Road load data management

Road load data measurement projects produce mind-boggling amounts of data. Data is valuable if it is accessible to the right people at the right time. This implies that during the measurement the data is properly organized, structured and annotated, but also that data can be shared easily across team and product boundaries. LMS Tec.Manager is a web application supporting query-based data search, visualization and check-in/check-out to maximize the data capital across the organization. Another vital part of the LMS data management strategy is to provide vendor-independent access and exchange real-time data. In line with the vision as implemented at many automotive OEMs, LMS technology supports the ASAM-ODS standard to enable data exchange with software from other vendors.

About Siemens PLM Software
Siemens PLM Software, a business unit of the Siemens Industry Automation Division, is a world-leading provider of product lifecycle management (PLM) software, systems and services with nine million licensed seats and 77,000 customers worldwide. Headquartered in Plano, Texas, Siemens PLM Software helps thousands of companies make great products by optimizing their lifecycle processes, from planning and development through manufacturing and support. Our HD-PLM vision is to give everyone involved in making a product the information they need, when they need it, to make the smartest decision. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
5755 New King Court
Troy, MI 48098
USA
+1 248 952 5664

Europe
Researchpark Haasrode 1237
Interleuvenlaan 68
3001 Leuven
Belgium
+32 16 384 200

Asia-Pacific
Suites 4301-4302, 43/F
AIA Kowloon Tower,
Landmark East
100 How Ming Street
Kwun Tong, Kowloon
Hong Kong
+852 2230 3308

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