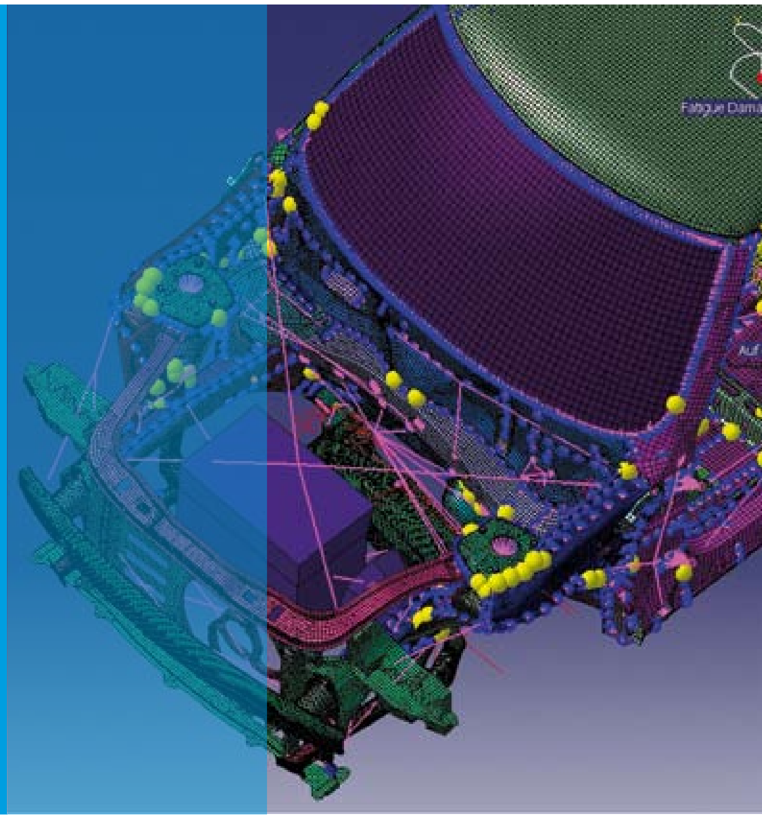
Design more cars with fewer tests

The BMW Group uses LMS lifetime prediction software to optimize vehicle durability and reduce overall weight

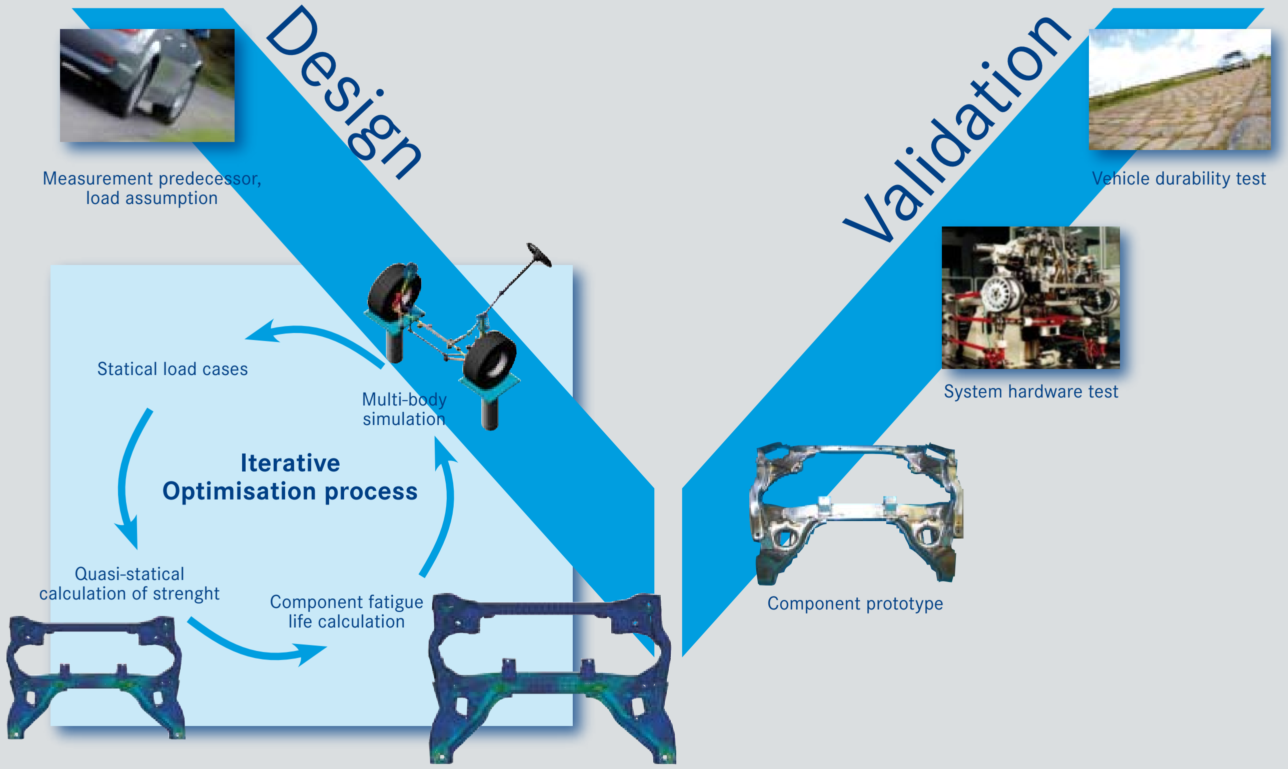


ENGINEERING INNOVATION

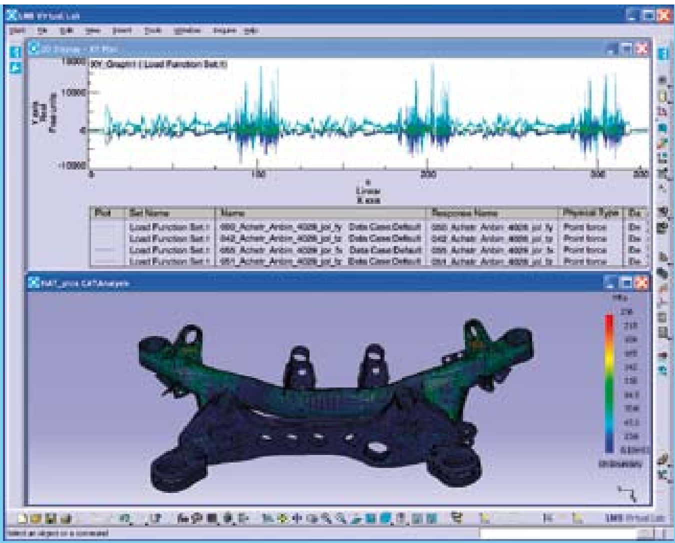
In the early and mid 1990s, car companies typically offered only a few basic models. In today's competitive market, automakers must sell a wide range of vehicles and derivative versions to suite a wide variety of changing buyer tastes and trends – all while consistently maintaining high quality and minimizing vehicle weight. Keeping up with growing numbers of new designs has stretched durability testing facilities to the limit, and the resulting bottleneck often hampers automakers in launching new designs. To solve this problem the BMW Group have integrated LMS lifetime prediction software into their core development process. The number of physical prototypes did not increase despite the fact that the range of products is continually growing. System-level durability simulation together with dedicated analysis and visualization capabilities provide an effective communication platform for collaboration between BMW Group engineering, design teams, and key suppliers. As a consequence, the BMW Group observed a shorter vehicle development time, especially for derivative versions.

Reducing the test bottleneck

Durability is of paramount importance in the competitive automotive market. Safety-related parts must not fail, of course, and overall fatigue life of parts must be sufficient to avoid customer dissatisfaction and warranty claims. Engineers must design components and systems to withstand intended operational loads and duty-cycles as well as some misuse. On the other hand, vehicles must be lightweight to lower manufacturing costs, maintain fuel economy and meet emission targets.
With these complexities and often-conflicting requirements, determining fatigue life is traditionally a time-consuming and costly process relying heavily on numerous tests of physical prototypes and mock-ups. Design changes resulting from unsatisfactory tests are translated into new hardware prototypes, which are then retested. The process is repeated until the required fatigue life is achieved. Multiple build-test-redesign loops must be performed to identify weak spots and correct designs. Generally, these are exhaustive tests, particularly when complete systems are evaluated such as axle assemblies, suspension systems, brake assemblies, or powertrain. The BMW Group offers twice the number



The BMW Group deployed a systematic approach to early fatigue life calculation for dynamically stressed parts. Using durability software, BMW Group engineers calculate the strength under cyclic load – representing the true fatigue life of their designs.



LMS Virtual.Lab Durability identifies local principal stresses and phase shifts that would likely lead to failure at two critical points on an axle carrier.

of models it did 15 years ago, with many derivative versions also available. For example, the BMW 3 Series includes cars with petrol or diesel engines, automatic and manual transmission, rear-wheel and four-wheel drive, and different body styles such as a convertible or station wagon. Each combination affects vehicle loads differently and must therefore be separately accounted for in the design. If all possible combinations were validated empirically, 25 test runs would be necessary, occupying test benches for a long time for just one model series. Fatigue life validation purely by experimental means is therefore no longer practical because test bench capacity and throughput time are simply not available to develop the various vehicle models.

A systematic approach to fatigue life prediction

Virtual simulation in combination with fatigue tests is definitely the only solution to handle the increasing diversity of vehicles, accelerate time to market and safeguard quality standards. In the past, quasi-static strength calculations in the component design phase approximated load levels parts could withstand. Only until much later in development when physical mock-ups were built and tested, precise load data could be obtained and component designs adjusted accordingly.

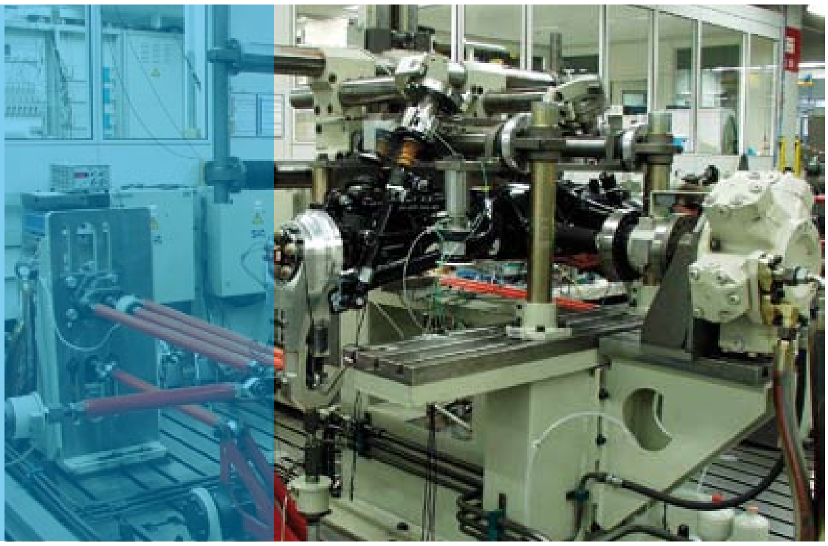
The danger of evaluating durability solely on the basis of static strength calculations is that the durability impact of cyclic loads is likely to be disregarded. To improve this situation, the BMW Group deployed a systematic approach to early fatigue-life calculation for dynamically stressed parts. Using durability software, BMW Group engineers calculate the strength under cyclic load – representing the true fatigue life of their designs. This puts them in a position to assess durability performance early in development and to deliver clear recommendations for guiding major design choices.

To more precisely predict loads early in development, BMW tested the LMS Hybrid Road approach in combination with multibody simulation. LMS Hybrid Road starts from wheel spindle loads measured on a previous model vehicle and converts these into wheel spindle displacements. The obtained spindle displacements – which are much more dependent on road surfaces than on vehicle characteristics – are used as inputs for full-vehicle multibody simulation. These dynamic motion simulations allow the cascading of vehicle excitations down to cyclic component forces and displacements acting on chassis and body parts. LMS Virtual.Lab Durability automatically multiples these cyclic loads by unit-load stresses determined by finite-element analysis. From this data and structural information such as material properties, fatigue life prediction determines accumulated damage, identifies weak areas, and provides lifetime prediction in terms of the number of duty cycles the structure can undergo.

LMS Lifetime prediction software allows engineers to identify and fix fatigue problems in a few days versus several weeks of physical testing. This

BMW 3 series	Saloon		Coupé		Convertible		Station wagon		M3
Fuel type	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol
Transmission	Automatic	Manual	Automatic	Manual	Automatic	Manual	Automatic	Manual	Manual
Traction	Rear-wheel	4-wheel	Rear-wheel		Rear-wheel		Rear-wheel	4-wheel	Rear-wheel

The model range for the BMW three series includes cars with different engines, powertrains and body styles. Empirically validating all combinations would require more then 20 separate sets of physical tests, so the company relies on lifetime prediction software to help them to develop multiple variants more quickly.



At the BMW Group, durability prototype tests are critical to confirm the accuracy of the calculations and adjust the simulation models if necessary.

compresses the process and enables what-if studies. As a result, the design is refined and most fatigue life problems are corrected before component hardware prototypes are built and assembled. So in the system validation phase, fewer iterations are required. The CAE engineer eliminates time-consuming and expensive test loops, supports consistently lightweight design and provides the required proof-of-durability for vehicles.

The new process was used extensively in the development of new BMW Group cars and showed considerable success in enabling engineers to identify and correct potential problems early. For example, fatigue-life analysis was used to simulate more than 5,000 spot welds so engineers could make design improvements to eliminate any over-stressed areas early in development.

In the future, the BMW Group plans to also use fatigue life simulation extensively in the validation phase of development. Ideally, this approach would require only two hardware prototypes: one at the end of the design process to ensure that the simulation model accurately represents the hardware, and another at the end of the validation phase for final system hardware tests.
At the BMW Group, these tests are critical to confirm the accuracy of the calculations and adjust the simulation models if necessary. In this way, testing and simulation complement one another. Intelligent use of both technologies is essential in developing all the many models and variants at the BMW Group. Moreover, empirical data and simulation models from today's vehicle programs will be valuable in developing future cars.

Simulation facilitates collaboration

The ability to predict fatigue life and other functional variables such as crash behavior and acoustics serves as a powerful communication platform for the CAE engineer to collaborate with other groups during vehicle development including designers, test engineers, management and key suppliers.
Such communication relies heavily on the ability of software to analyze and visualize results and to deliver the clear engineering insights required to eliminate durability problems.

LMS Virtual.Lab Durability, for example, shows color-coded “hot-spot” damage areas, and graphic representations can be combined with simultaneously displayed load time plots. Animated structural deformations can be displayed next to stress and/or damage results. Accumulated damage, fatigue life, maximum stress amplitudes and safety factors can all be readily displayed in graphical format.

Using such visualization and analysis capabilities, the durability CAE engineer can provide valuable feedback to the design team on improving fatigue strength by using different materials, for example. Likewise, the CAE engineer can provide the test engineer fatigue life simulation results to guide test procedures and identify areas potentially at risk to cracking, so expensive and time-consuming durability test procedures can be focused on eliminating remaining trouble areas. Fatigue life results also can be conveyed to management in a non-technical format to show, for example, the consequences of damage and its progression in the structure.
Open systems are extremely beneficial in communicating with suppliers and other external organizations, especially with the trend toward co-development partnering and greater delegation of design responsibility to subcontractors.

Enabled by the ability of simulation to quickly provide results such as fatigue life prediction, close collaboration between various groups accelerates vehicle development. More broadly, simulation-enabled collaboration facilitates the way cross-functional teams can work together synergistically in developing innovative designs of future vehicles that are the key to success for a high-end automaker such as the BMW Group. ■

LMS INTERNATIONAL
Researchpark Z1, Interleuvenlaan 68
B-3001 Leuven [Belgium]
T +32 16 384 200 | F +32 16 384 350
info@lms.be | www.lmsintl.com

LMS FRANCE	**Paris** | T +33 1 69 35 19 20 | info@lmsfrance.fr **Lyon** | T +33 4 37 49 13 25
LMS DEUTSCHLAND	**Leonberg** | T +49 7152 97 97 90 | info@lms-gmbh.de **Munich** | T +49 8954 03 43 21
LMS ITALIANA	**Novara** | T +39 0321 445 011 | info@lms.it
LMS UK	**Coventry** | T +44 2476 408120 | info@lms-uk.co.uk
LMS N. AMERICA	**Detroit** | T +1 248 952-5664 | info@lmsna.com **Los Angeles** | T +1 714 891-4205 **Washington D.C. / Baltimore** | T +1 410 203-1200
LMS JAPAN	**Yokohama** | T +81 45-478-4800 | info@lms-ja.co.jp
LMS KOREA	**Seoul** | T +82 2-571-7246 | info@lmskorea.com
LMS CHINA	**Beijing** | T +86 10 8497 6463 | info@lmschina.com **Shangai** | T +86 21 5888 8882
LMS INDIA	**CAE - Bangalore** | T +91 80 511 51 512 | info.lmsindia@lms.be **Test - Chennai** | T +91 44 281 73 711| info.lmsindia@lms.be
LMS RUSSIA	**Moscow** | T +7 095 937 84 93 | info.lmsrussia@lms.be
LMS SINGAPORE	**Singapore** | T +65 6777 3609 | info.lmssingapore@lms.be
LMS Test Division	**Leuven [Belgium]** | T +32 16 384 200 | info@lms.be **Breda [The Netherlands]** | T +31 76 573 6363 **Göttingen [Germany]** | T +49 551 50 48 50 **Brasov [Romania]** | T +40 268 414200
LMS CAE Division	**Leuven [Belgium]** | T +32 16 384 200 | info@lms.be **Kaiserslautern [Germany]** | T +49 631 30322 100 **Coralville, IA [United States]** | T +1 319 626 6700 **Brasov [Romania]** | T +40 268 414200
LMS Engineering Services Division	**Leuven [Belgium]** | T +32 16 384 200 | info@lms.be **Kaiserslautern [Germany]** | T +49 631 30322 100 **Detroit, MI [United States]** | T +1 248 952 5664 **Torino [Italy]** | T +39 011 6671 615
Worldwide	For the address of your local representative, please visit www.lmsintl.com/lmsworldwide

LMS is an engineering innovation partner for companies in the automotive, aerospace and other advanced manufacturing industries. LMS enables its customers to get better products faster to market, and to turn superior process efficiency to their strategic competitive advantage. LMS offers a unique combination of virtual simulation software, testing systems and engineering services.

LMS is focused on the mission critical performance attributes in key manufacturing industries, including structural integrity, system dynamics, handling, safety, reliability, comfort and sound quality. Through our technology, people and over 25 years of experience, LMS has become the partner of choice for most of the leading discrete manufacturing companies worldwide.

LMS is certified to ISO9001:2000 quality standards and operates through a network of subsidiaries and representatives in key locations around the world.

LMS® ENGINEERING INNOVATION