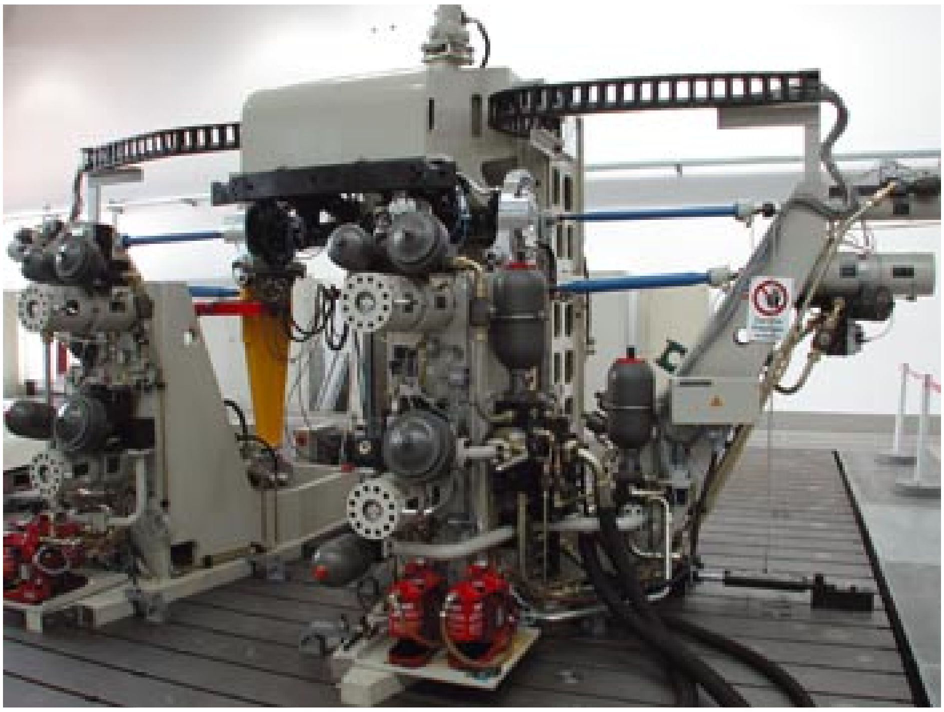
Application Case

ZF Steps Up Speed and Accuracy of Durability Testing with LMS Software

ZF Lemförder Fahrwerktechnik (Germany), Car Chassis Technology division of ZF, has improved the cost, accuracy and speed of durability engineering by introducing fatigue-life prediction at the virtual prototyping stage and by performing test track correlated rig tests on complete subassemblies. ZF Lemförder, a supplier of front and rear axle systems to car manufacturers, has become a system supplier, being encouraged by its customers to take on more design responsibility and bring its systems faster to market.



Today's ever-more competitive market circumstances put the pressure on ZF to reduce the weight and cost of its products while ensuring that they can withstand the usage scenarios defined by its customers. The company's previous fatigue-life assessment approach used stress analysis based on static load cases to develop the initial design. Durability optimization was executed based on manually configured component-based rig tests in order to match the OEM's specifications. This method was not fast enough and left room for doubt as to whether the test signals really generated the same damage as through road testing. Recently, the company has switched to a new approach in which the initial design is optimized based on fatigue-life simulations taking into account realistic loading conditions. Critical locations are accurately identified and serve as input to optimize the monitoring of component rig testing. In addition, the company invested in axle test rigs that make it possible to test complete axle assemblies. ZF introduced new tools that drastically reduce the time required to reproduce measured drive signals. They also use new methods that streamline the process of correlating test rig control signals with test track measurements.

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The challenges of moving from component to system supplier

ZF develops and supplies complete front and rear axles to automobile manufacturers. These axle systems include components such as brakes, steering, wheel heads, suspensions, and power-transmitting components such as differentials, transaxles and driveshafts. As the company moves from being a component supplier to a systems supplier, it is increasingly taking on full design responsibility for the development and production of automotive axle systems. Ensuring that axles are not excessively overdesigned and will not fail in the field are the most critical responsibilities of the system supplier. Axle design also has a major impact on vehicle ride and handling, noise and vibration and crash performance, and all of these factors need to be balanced against durability. At the same time, OEMs are encouraging their suppliers to lower the cost and weight of components while reducing the time required to get products to market.

Concerns with previous design process

The previous design process began with generating concept designs and performing stress analysis based on static load cases that did not accurately reproduce the conditions of an axle on a real vehicle. These load case assessments were based on static stress simulations gained from Finite-Element (FE) analyses. The problem is that the effects of multiple load combinations and load alternations over time are completely neglected. So, at this stage, engineers had only a rough idea of the critical areas of components in terms of durability and had to postpone optimization until the fatigue-testing phase. The next step was producing a test rig drive file designed to reproduce the multiaxial forces and loads measured by the OEM on the test track. In the past, it required years of experience and a considerable amount of intuition to generate files that matched the damage produced in road testing. Engineers had to manually generate the transfer functions needed to create the test program and run a rainflow analysis to compare the damage it produced at critical points to the original measured loads. The process was further hindered by the fact that engineers were not sure at this stage where the critical points actually were. Often many different iterations were required merely to achieve acceptable correlations.

Virtual prototyping guides rig testing

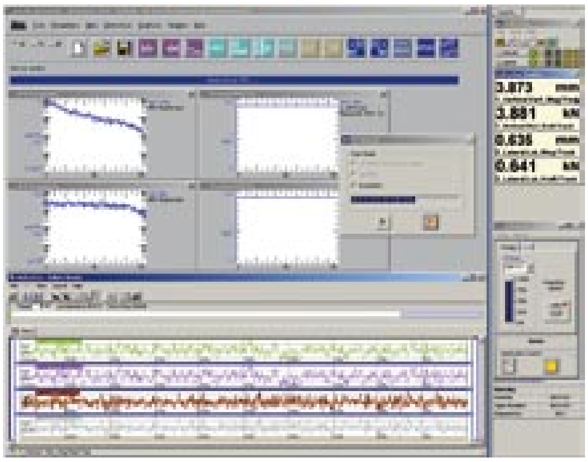
The new process begins by applying measured dynamic spindle loads to a multibody simulation model that calculates the loads on durability-critical components such as steering knuckles, control arms and subframes. These loads along with an FE mesh of the components are provided as input to LMS FALANCS durability analysis software that numerically predicts the component's critical locations, based on true dynamic loads. Having accurate predictions of the critical locations at this early phase makes it possible to carefully instrument and monitor the component at these locations during physical rig testing. Material properties are derived based on the uniform material law, which avoids the need for component testing at this stage. A detailed analysis provided by the LMS FALANCS software informs the user of the maximum stresses at critical locations. The software also computes the fatigue life of various design iterations, making it possible at this early phase to begin the process of optimizing the tradeoff between cost, weight and durability performance. The purpose of the simulation is not to predict the absolute fatigue life but to determine the relative life of various design alternatives.

An important improvement in this process has been the investment in axle test rigs that are capable of simultaneously testing 6 degrees of freedom for each wheel corner. Typically, ZF's OEM customers measure spindle forces in three axes for the left and right wheel, brake moments, steering moments and camber during field tests. ZF engineers use LMS Time Wave Replication (TWR) software, from LMS and IST, to reproduce these measured signals in the laboratory.

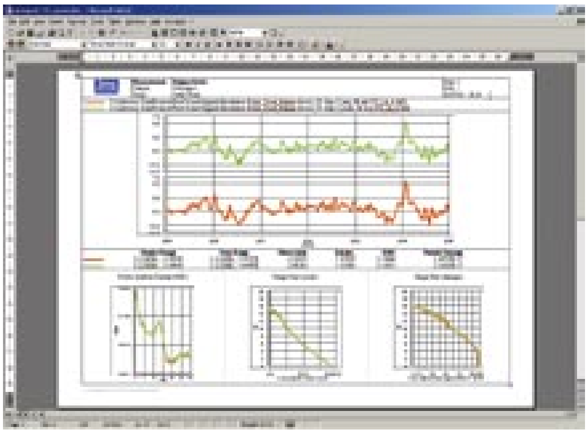
ZF supplies front and rear axle systems to automotive OEMs, including BMW.

Ensuring accurate rig testing

Rig testing accuracy depends upon defining test rig control signals for each road profile that accurately duplicate the real world. This involves applying an estimated control input to the test rig actuators, measuring the resulting force at the spindle and comparing the force measured on the test rig with the force measured on the test track. Based on the results, the control input is changed and the resulting spindle force is measured again. This iterative process is repeated until the test rig force matches the test track force, ensuring that the test rig can accurately duplicate the damage resulting from field tests. During the iterations, the LMS TWR user can easily change the setup and add or remove control channels. This flexibility makes it easy for ZF engineers to adapt to the varying requirements of their different OEM customers. LMS TWR is tightly coupled to LMS TecWare load data processing software and provides a number of different methods to compare the proving ground and test rig signals, which also helps ZF respond to different OEM requirements. ZF engineers perform the iteration steps until an excellent correlation between the road and test rig load time series is reached.



One integrated solution enables engineers to generate test rig drive files and execute durability test campaigns.



LMS/IST RS TWR and LMS TecWare execute automatic damage correlation by comparing test track and test rig measurements.

Testing the axle on full vehicle behavior

This new approach makes it possible for ZF to thoroughly and accurately evaluate the durability performance of complete assemblies on a test rig without the expense of repeated prototype testing and long before prototypes of the complete vehicle are available. In this way, ZF can further increase the quality of its products, while reducing both engineering and component costs. ZF also benefits from the fact that most of its OEM customers also use IST test rigs and LMS software so they can easily share durability test and correlation results with each other. The company has plans to further improve its fatigue design process by upgrading to LMS Virtual.Lab Durability software. This advanced solution accelerates the process of fatigue-life prediction, as it introduces new analytical models, such as seam-weld modeling, that offer higher levels of accuracy and automation. The trimming down of the development cycle is also positively affected by the interrelations between test and CAE. Component durability simulations improve testing by identifying critical areas to be more closely monitored, while testing improves simulation by developing more accurate load cases. The bottom line is that ZF can more efficiently and confidently execute system-level tests instead of field tests in order to identify and fix problems prior to the prototype stage.

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Interleuvenlaan 68
3001 Leuven - Belgium
Phone: +32 16 384 200
Fax: +32 16 384 350
e-mail: info@lms.be
http://www.lmsintl.com