BMW - Using Virtual Test Rigs for Loads Prediction

BMW Applies LMS Breakthrough in Durability Engineering

ENGINEERING INNOVATION

The “Holy Grail” for many durability engineers is to reliably predict where and when their products will break – long before the first hardware prototype is built. To do so would dramatically shorten the durability process and help engineers to get higher quality products to market faster and more cheaply. A recent break-through by LMS, working in conjunction with engineers from BMW in Germany, has made significant advances towards that ultimate goal.

For many years, CAE-based, numerical life prediction design tools such as LMS FALANCS have been increasingly accepted by the engineering community. For most applications analysts can now predict the critical-life locations and are able to compare the fatigue life of different component variants subject to a given loading.

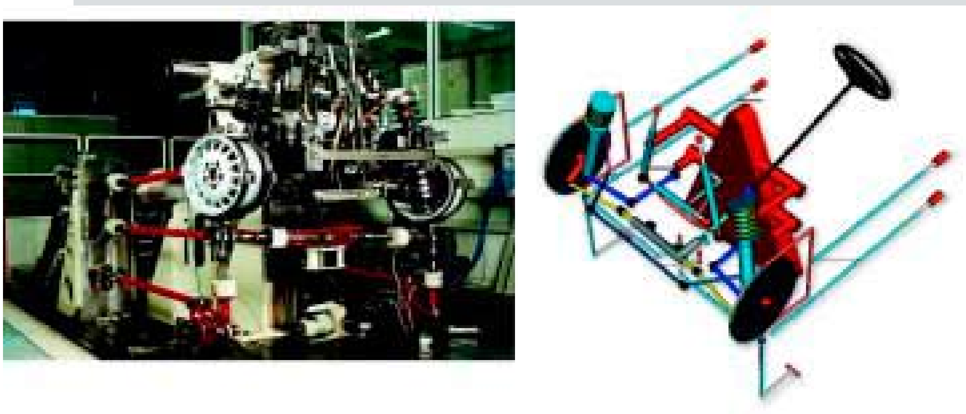
However, more is needed than just an accurate FEM-model and reliable material fatigue data for the components to be optimized -
a critical requirement is an accurate knowledge of what the loads will actually be. And it’s not so easy while the physical hardware does not exist!

In the ground vehicle industry, the traditional way is to measure representative loads on early workhorses/ mules of new car designs. Although not ideal, at least “ballpark estimates” can be made of the loads in the CAE process, which is at least better than just using a cookbook approach. Of course, having to measure representative component loads by instrumenting physical prototypes with strain gauge rosettes and load cells is time-consuming and expensive. Furthermore, it requires the instrumentation and calibration of all the suspension or body components of every variation of the vehicle. This is why the idea arose of somehow using multibody simulation (MBS) software, more typically used for ride & handling simulations, to create a virtual test rig in order to “numerically measure” the interface loads working on the different components. In theory, all that would be required was a measurement of the spindle loads with wheel force transducers, a knowledge of the system’s lumped mass, stiffnesses and damping parameters - and the forces could be computed at any location in the vehicle system. The first results proved disappointing, however. Very often, because of integration instabilities in the multibody code, the virtual vehicle would drift and even rollover.

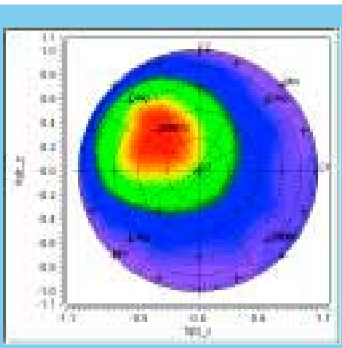
Being successful and productive with a virtual durability design process not only requires having FEM and multi-body models. Technologies, application know-how, and corresponding software tools are required to correlate these numerical models with reality (test results). Indeed the multibody models developed for handling optimization are typically not accurate enough for loads prediction because the frequency band for durability analysis is far broader. “Blind” modeling of all suspension components as flexible bodies is not a good solution either. This would require, on the one hand, unacceptable calculation times – certainly for the long loading sequences inherently linked to durability investigations. On the other hand, very complex MBS models with lots of flexible bodies do not even guarantee optimal accuracy for the loads prediction on the virtual test rigs.

So how can optimal accuracy be obtained for unconstrained and constrained suspension simulations within a virtual test rig? How can “numerical vehicle drift / rotating / roll-over” be avoided when combining measured spindle load data with MBS models that do not completely reflect the dynamic behavior of the test vehicle on which the loads have been measured? How can you eliminate a drive file generation on a physical test rig in order to make spindle loads applicable to constrained virtual test rigs? Which type of damping (modal & local) should be incorporated in MBS models? Based on years of experience with durability applications in both test and CAE projects, LMS was uniquely positioned to answer such questions and has now developed special algorithms that guarantee the optimal accuracy of loads prediction for durability evaluation.

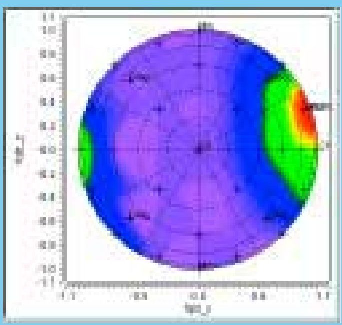
LMS had all the technology and software tools to create a virtual test rig. LMS TecWare could pre-process load



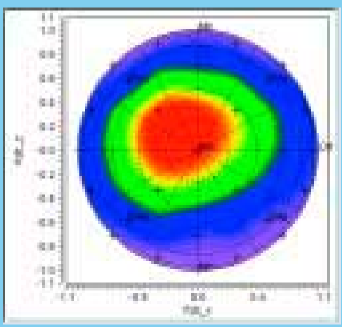
BMW Axle test rig for non-driven front suspensions (left) • BMW Virtual Axle Test Rig model (right)



Measurement



Initial MBS Model



Optimized MBS Model

Load influence sphere diagrams

sequences and synthesize customer correlated load scenarios, as well as post-process MBS generated responses. LMS DADS was proven to have the high frequency integration accuracy needed for the multi-body model-ing of virtual test rigs. It also had a unique and very efficient direct dynamics calculation integrated with LMS FALANCS. Indeed when flexible bodies are included in the DADS MBS model, the modal participation factors can be read directly into FALANCS for numerical life prediction based on the FEM-calculated stress modeshapes. This feature has important advantages both in calculation speed (eliminating the FEM-based dynamic response calculation otherwise required) and ease-of-use (no manual transfer of interface loads from

“BMW is now starting to establish true virtual durability optimization loops”

Dr. Brune, BMW

MBS to FEM-based life prediction required) and is unique in the world of MBS based numerical life prediction process. Last, but not least, LMS Time Waveform Replication (TWR) software could perform the “virtual drive file generation” to drive the virtual test rigs. Years of experience built up in controlling multiaxial, complex structural testing durability rigs is now available to derive the virtual drives needed in order to reproduce, for example, the measured spindle loads on the virtual test rig.

In addition to this tightly integrated single source solution, LMS also offers partial solutions in combination with other vendors’ products. These mixed solutions are more than just file translators just replicating time data in another format. All the above LMS tools for durability pre- and post-processing can be tightly linked into, say, an ADAMS™ software environment for MBS/virtual test rig simulations.

Loads Prediction - More than Just a Virtual Test Rig

Loads prediction with virtual test rigs always starts from measured spindle loads. However, at an early design stage of a new car ‘real-life’ loads cannot be measured because there is no physical prototype. In our experience, the solution to this lies in a hybrid approach, a so-called “Hybrid Test Track”, which can predict forces based on the measured loads available from a current production car, and MBS models of that car and the new design. The back calculation of this hybrid test track is performed using ‘virtual’ TWR technologies. In effect, the forces measured in one car can then be mapped into the new design and the loads at any component location predicted. In order to prevent the virtual model from ‘rolling’ over some dynamic constraint is required again using virtual TWR technologies.

The technologies needed to get virtual test rig to work properly lie beyond the scope of this newsletter but will be presented in papers at forthcoming technical conferences. The remainder of this article describes the usage of virtual test rigs for component loads prediction at BMW, where LMS technologies, tools & services have made it possible to deliver the integrated virtual test rig as part of their day-to-day development process for durability optimization

Loads Prediction for BMW 3 Series by means of a Virtual Axle Test Rig

BMW wants to use virtual test rigs to generate component interface loads for upfront design optimization based on numerical life prediction. These numerically generated interface loads can also be used to validate and sign off components early in the design cycle by means of single component physical tests.

LMS was asked to study, in close cooperation with BMW, the correlation of the existing ADAMS™ models made and used for handling studies with real durability test rig experiments. Our task was then to improve, update and eventually optimize these virtual test rig models for durability loads prediction, compromising between calculation/modeling effort and accuracy as needed.

The rig shown on the left tests non-driven front suspensions. All three translational loads at the wheel contact patch (on both the left and right sides) are simulated along with the steering wheel input and the inertia effects of the engine. As well as the kinematics and dynamics of all these actuators and corresponding linkages, the virtual test rig model comprises all the suspension components of the BMW 3 Series. In the initial MBS model used for handling, all these links were modeled as rigid bodies.

TecWare was intensively used in the updating process of the MBS virtual test rig models to compare the differences between multibody simulations and measured loads within a fatigue context. The multiaxial load influence spheres shown for the initial and optimized MBS model compared to the measured load data on one of the suspension links

makes clear that LMS and BMW were indeed capable of drastically improving the correlation of the initial ADAMS virtual test rig with respect to the real one.
The multiaxial load influence explains why the improvement was as drastic in amplitude (damage levels) as in phase relation between the loads (position of maximum damage on the sphere). Load influence sphere diagrams indicate the 3D load vectors. Close correlation between measurement and the final MBS can be seen.

This optimized virtual test rig was then used to generate accurate interface loads for a subsequent design optimization based on numerical life Measurement Initial MBS Model Optimized MBS Model Load influence sphere diagrams prediction with FALANCS.
“Having used LMS durability technologiesfor load data analysis and numerical fatigue life prediction for several years we are able to improve our durability engineering process substantially.
By introducing more and more CAE, we are both improving our test based capabilities and starting to establish true virtual durability optimization loops for chassis and body engineering to reduce the time and costs of the development process.” says Dr. Martin Brune, Manager Predevelopment, Methods, Calculation, BMW Group.

Conclusion

This case history shows that the LMS approach to loads prediction using a virtual test rig closely matches with reality. We would like to thank BMW for its cooperation in developing the technology - and for its permission to publish the results. Together with complete Digital Test Tracks (including LMS Advanced Tire models suited for accurate durability and ride comfort simulations) these tools are available today as loads prediction capabilities & services for full vehicles. This is a story to watch. ■

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