# Audi Moves Forward with Early Durability Predictions

## LMS Solutions are Key in Accelerating Durability Engineering Process

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Audi has achieved considerable progress in supporting the durability design of upcoming models by using a hybrid approach that effectively combines testing and simulation. This new methodology, engineered in conjunction with LMS, enables Audi to streamline its durability engineering activities. Audi has improved its ability to predict and adapt the durability of key components with the LMS FALANCS solver, even before the start of the physical prototyping phase. Dynamic simulations put Audi in a position to adapt the spindle forces measured on existing models more reliably in order to confidently use these modified forces throughout the development process of a new vehicle. The new approach contributes to substantial time and cost savings.

Audi and LMS pioneered a new approach that involves converting measured spindle loads from an earlier model vehicle into spindle displacements. Converting between spindle loads and spindle displacements is an innovative process that accounts for the differences between the two vehicles. Audi applies these displacements to a MultiBody Simulation (MBS) of the new vehicle that calculates load histories for the car's individual components. The load histories are, in combination with Finite Element (FE) models and material properties, then used in LMS Virtual.Lab Durability, which predicts the fatigue life of each component. This approach makes it possible for Audi engineers to address durability problems in the design phase, when they can be solved much less expensively and without delaying the development cycle.

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## Physical prototypes are indispensable in hardware-oriented approach

Ensuring that each component can meet fatigue and durability requirements is one of the critical aspects of the development process. For a number of years automobile manufacturers have used software, such as LMS FALANCS, to support estimates of the components' durability. But this software requires reliable information on the loading environment faced by individual components. The traditional approach of collecting this information requires prototype vehicles or mules to be available. Several of the chassis components must be instrumented individually, often adding up to more than 100 strain gauges and other sensors. This approach, however, means that reliable load data are known relatively late in the design process. At this point, major changes would be expensive because the changes often affect many other components and subassemblies. Furthermore, marked changes of the suspension setup that may occur during the design and development process would, in principle, require new measurements.

## Need to combine test results with virtual prototyping

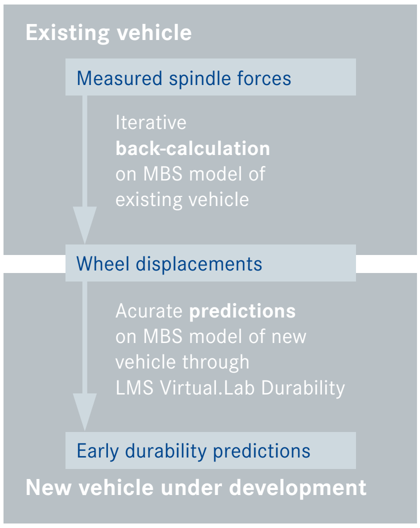
In recent years, the automobile industry has made increasing use of virtual prototyping to simulate the operating of vehicles and subsystems prior to as well as during the prototyping phase. For this reason, previous attempts to predict component loads prior to prototyping have generally focused on road testing a previous model vehicle, measuring loads at the wheel spindles and re-using these loads for the development of a new vehicle. The problem with this approach is that the loads are highly dependent on the vehicle's mass, spring and damper characteristics and other factors, with the result that the accuracy achieved by this method is highly questionable, even when a scaling factor is introduced to account for differences in the weight of the old and new vehicles.

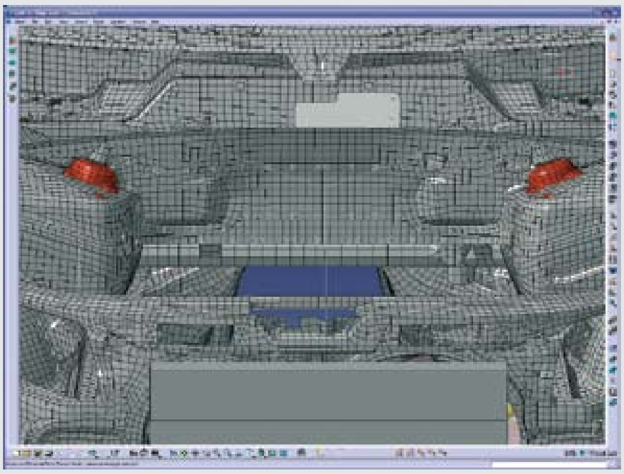
The new approach, pioneered by Audi and LMS, overcomes these problems by better transforming wheel spindle loads measured on the previous model vehicle into wheel spindle displacements that are much less vehicle-dependent because they are based on the road surface rather than the vehicle characteristics.

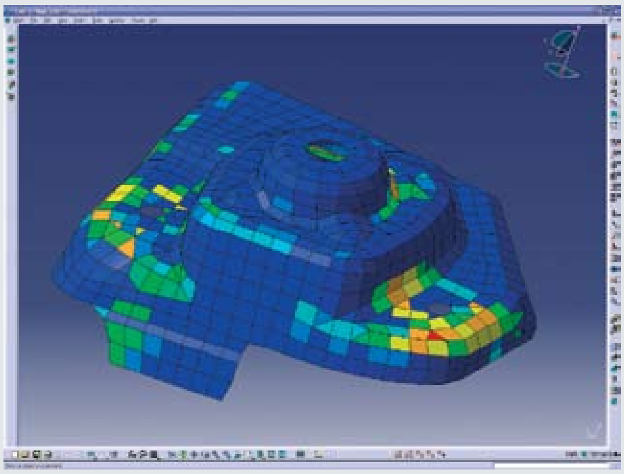
## Generating spindle displacements for MultiBody Simulation (MBS)

The goal is to generate displacement signals to accurately drive the MBS model of the new design. The vertical spindle forces and moments measured on the previous model vehicle are first applied to an MBS model of the previous vehicle, while constraining its body. The MBS model is then run to generate initial estimates of the spindle displacements.

The accuracy of the initial estimates is increased by using LMS Time Waveform Replication (TWR) software to determine accurate spindle displacements based on the virtual forces for the old model vehicle that were determined through multibody simulation and the rough





Damage result display in LMS Virtual.Lab Durability of the front strut mount.

displacement estimates. Through an iterative process, TWR moves to the point that the measured and simulated vertical forces match, continually improving accuracy in the process.
A similar iterative process is used to back-calculate the tire contact-patch displacements, which provide an alternative measurement that serves to validate the results. TWR was originally created to produce drive signals for durability testing on complex multiaxial test rigs, where it is typically used to back-calculate actuator displacements from spindle loads. In the application presented here, TWR automatically calculates the synthetic displacement drive signals that are shaped to the road profile on which the earlier model vehicle was tested.

## Calculating component loads and fatigue life

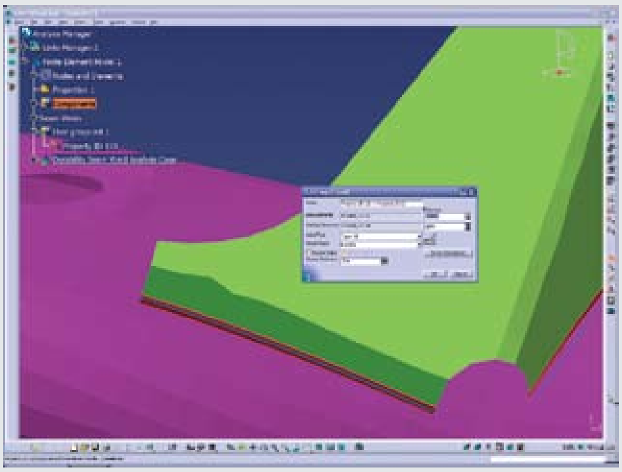
The resulting loads and displacements are then applied to an MBS model of the new vehicle. The load histories generated by the model are fed into the fatigue life solver FALANCS of LMS Virtual.Lab Durability. In addition, engineers enter material properties and geometry information and unit-load stress results from FE component models. The local-strain and critical-plane approaches are used to generate life predictions for the base material of the body in white and suspension components. The local-strain approach is based on linear elastic-stress analysis and includes an elastoplastic correction. The critical-plane approach examines several potential crack-initiation planes and determines the one with the biggest damage.

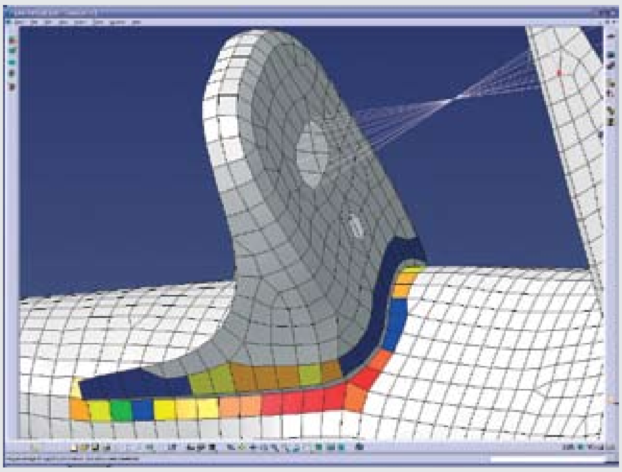
## Saving time in checking weld durability

The seam weld modeling option of LMS Virtual.Lab is used to assess the durability of seam welds. It automatically detects the connections between sheets and classifies the different types of seam welds, identifying local stress concentrations based on all possible combinations of local load conditions.
The two-step approach used by the software eliminates the need for the user to create a detailed three-dimensional FE model of the weld. The forces around the welded joint are calculated using a global FE model in the first step. In the second step, the local stresses at the critical locations of the seam weld are calculated and evaluated for fatigue life by using a detailed model, which is available in the database of LMS Virtual.Lab Durability.
The new technology identifies the local stress concentrations, based on all possible combinations of (local) load conditions of the welded detail. To model the spot welds, the Rupp approach is used with shell elements and beams.
The calculated forces are converted into radial stresses and the damage caused by these stress histories is evaluated using a stress-life curve that had earlier been back-calculated from coupon test results.

## Changing designs long before physical prototypes are made

Within a pilot study of a new model, durability problems were identified in the initial designs of several components, including the seam welds in a front subframe and specific details of a wheel carrier. Audi engineers made design changes to address these problems, then repeated the analysis process to ensure that the re-designed components met the durability specifications.
Thus numerical durability analyses successfully contributed to reach viable solutions within narrow time and cost constraints. Therefore Audi management has endorsed the concept of system-level durability prediction and plans to use these methods in future vehicle design programs.





Damage results at seam welds of the suspension subframe.

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