How John Deere utility tractors earn farmers' respect

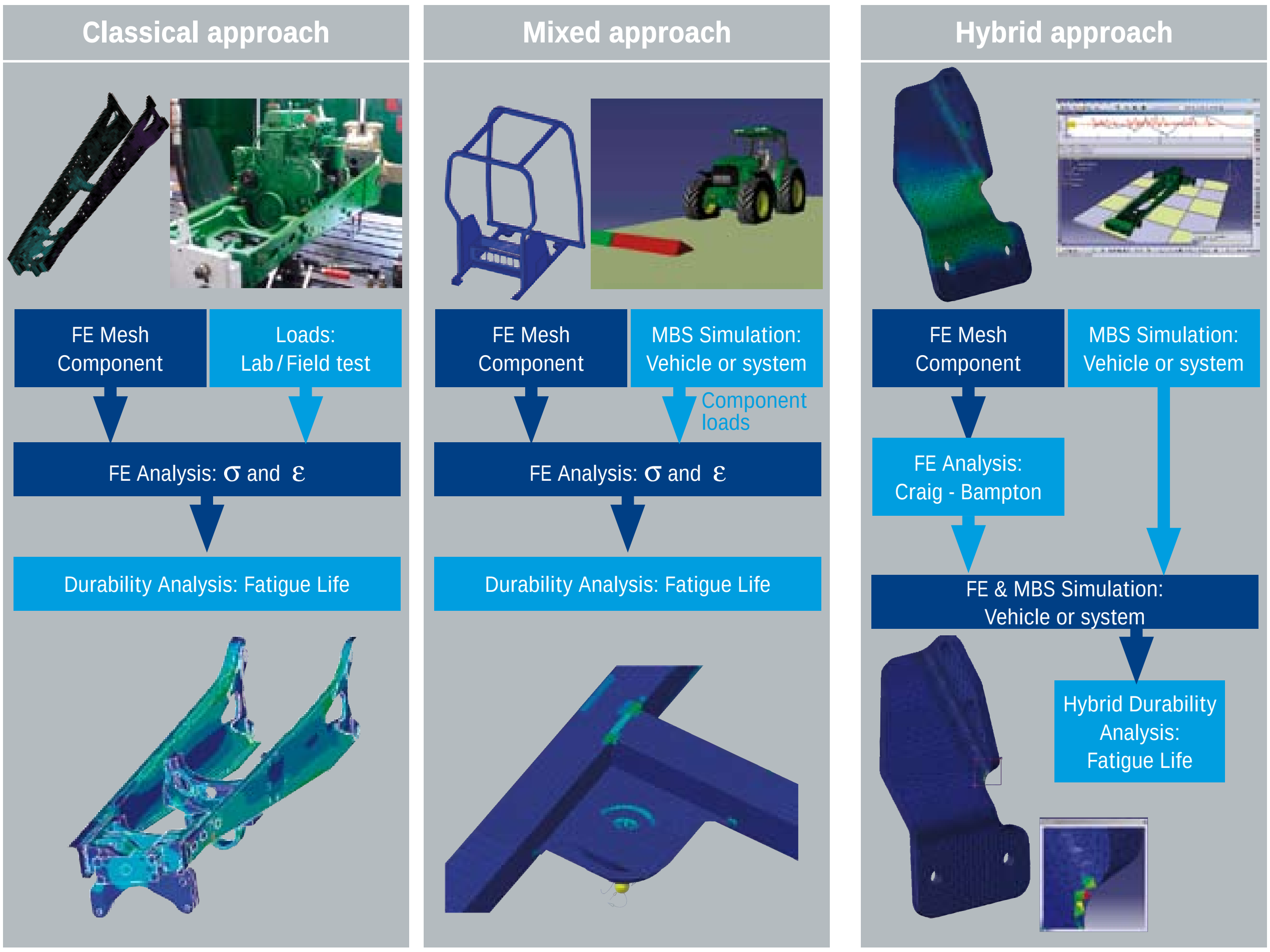
John Deere Werke Mannheim increases tractor endurance through early-process simulations using LMS Virtual.Lab Motion and Durability

ENGINEERING INNOVATION

Since high risk and tight margins rule international agriculture, farmers opt for equipment that offer versatile features in combination with the endurance required to make it through peak harvesting periods. To further increase the quality and reliability of new tractor models, engineers at John Deere Werke Mannheim, Germany, frontload virtual simulation into the development process of John Deere 5000 and 6000-series utility tractors. The application of complimentary simulation strategies, founded on LMS Virtual.Lab Motion and Durability, provide valuable insight into how design variations influence tractor quality and reliability. Virtual simulation helps John Deere compress tractor development cycles, while delivering better performance, flexibility, comfort and economy at comparable cost.

The typical green frame and yellow rims

The tractor of a farmer is like a referee's whistle or a hunter's rifle. If there is one thing from which a farmer expects firm guarantees, it is definitely the reliability of his tractor, the money-making machine on which he spends a good part of his life. Under any circumstances, John Deere tractors must withstand the rigors of agriculture: providing sufficient hydraulic power to lift and drive various implements connected to the tractor, and offering the ability to work their way through different soil and weather conditions while pushing / pulling implements. During hectic harvesting periods in particular, the farmer counts on his John Deere to run long days for many weeks. Needless to say that a major tractor breakdown in this period would potentially put the turnover of the farmer's business at risk. Tractor quality and reliability are among the critical aspects that set a John Deere aside from other tractors. For the largest part, John Deere's mid-size and large-size utility tractors are designed, developed and manufactured at John Deere Werke Mannheim, Germany. Every year, about 40,000 tractors, all with the typical green color and yellow rims, leave this location to be shipped to customers worldwide.



Instead of a single fit-for-all solution, John Deere engineers created a toolbox with multiple durability simulation approaches, each offering specific predictive capabilities and setting different constraints in terms of timing and effort.

This number consists of all John Deere 6000 and most 5000-series tractors, each offering a unique combination of option list items and implement assembly choices. These utility tractors typically offer a high degree of versatility in combination with time-saving features you would expect on larger tractors. Christian von Holst, Senior Engineer at John Deere Werke Mannheim, commented “Over the last 10 years, John Deere engineers succeeded in substantially reducing the required development time for these tractors, while steadily enhancing product performance characteristics and keeping sales prices relatively constant.”

Frontloading durability simulation into the design process

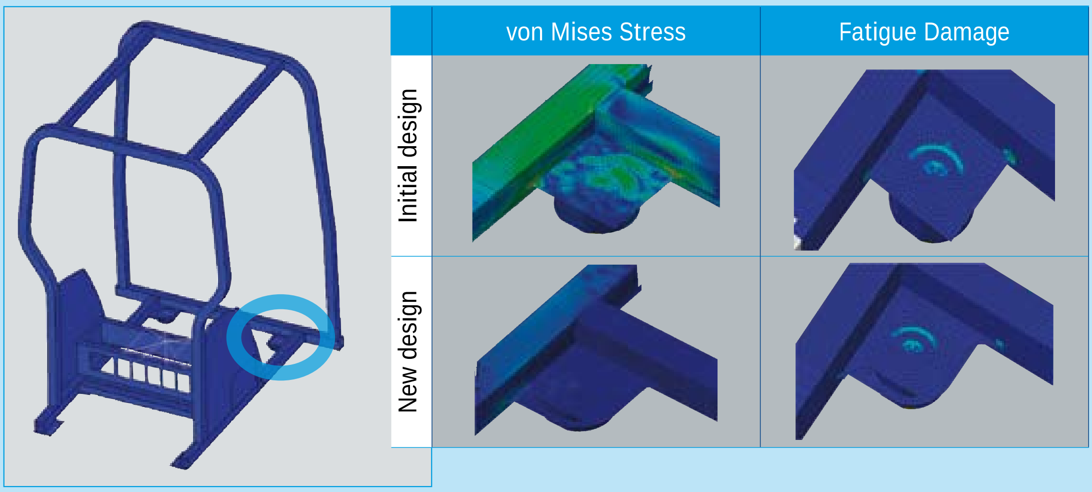
At John Deere, a development process typically starts with an idea phase, during which concerns, ideas, requests, suggestions and remarks are translated into more concrete product requirements. In the subsequent concept phase, ideas are fltered, concepts are proofed and the technical feasibility of suggested approaches are evaluated, all to shape the technical strategy to be followed. After further elaborating on the most promising concepts, the pre-design phase starts and the frst premature designs go into successive mock-up, mule and different kinds of prototype states. In the design phase, engineers consistently use insights and results acquired during physical testing to gradually enhance the performance of the new tractor design. Further iterations are executed until the new design fulflls the original product demands, which for tractors are predominantly driven by durability-related considerations.

Over the last decade, John Deere accelerated the use of virtual simulation in development processes that used to be entirely driven by physical testing. “By frontloading durability simulations into our tractor design processes, we are better positioned to evaluate the technical feasibility of design modifcations and to anticipate the consequences of making more radical design changes,” stated Christian von Holst. “Acquiring concrete information in the initial design stages enables us to steer elaborate design efforts into directions that will more likely and more effciently deliver the targeted product requirements. The selection and application of suitable combinations of virtual simulation and physical testing are essential in simulating the impact of potential design changes, such as for example a modifed suspended cab design or a more powerful tractor engine.”

A durability simulation toolbox driven by LMS Virtual.Lab

Instead of a single ft-for-all solution, John Deere engineers created a toolbox with multiple durability simulation approaches, each offering specifc predictive capabilities and setting different constraints in terms of timing and effort. The so-called classical approach is a component fatigue-life prediction method that runs on LMS Virtual.Lab and starts off on the basis of measured load data. In addition to this approach, they introduced the mixed and a hybrid simulation approaches, two methods that integrate the combined use of LMS Virtual.Lab Motion and Durability. Compared to the classical approach, the mixed approach is capable of simulating the impact of more profound tractor design changes, as it generates input loads through dynamic motion simulations performed on the tractor design under development. The third approach, named the hybrid approach, focuses on the structural fexibility of tractor parts and its effect on dynamic motion and tractor durability.

The classical approach can be illustrated by durability investigations performed on a tractor cabin frame, which faces the loading of a ride on a bumpy circular test track. While driving at constant velocity, the forces acting on the cabin’s



The classical LMS Virtual.Lab-driven simulation approach indicates that the use of round-edged cabin mounts offers superior fatigue-life performance compared to square-edged mounts. In case John Deere engineers need to evaluate more profound design changes, they retrieve the required cabin loads using system-level simulations in LMS Virtual.Lab Motion instead of gaining the data through measurement.

coupling points with the tractor frame are measured in addition to specifc cabin point displacements and accelerations. The obtained dynamic loads are then applied to the Finite-Element (FE) model of the cabin frame, which after simulation, provide the stresses and strains that are present in the cabin structure. On the basis of these results, engineers run simulations in LMS Virtual.Lab Durability to obtain the fatigue-life performance of the cabin design and assess the impact of suggested cabin modifcations. Simulations performed on round-edged and square-edged cabin mounts enabled engineers to extend the fatigue life of the cabin frame's most damaged location beyond the targeted value, while reducing maximum stress both in the base material and the seam weld. Although the classical approach is capable of dealing with non-linear FE models, its validity is restricted to relatively small changes on the level of the investigated part. As a consequence, this classical durability simulation method cannot be used to predict the effect of more drastic part modifcations or changes made to mount properties and locations.

More profound design changes and the fexibility of parts

John Deere engineers introduced the mixed approach to extend durability simulation capabilities beyond what the classical approach has to offer. Instead of running physical tests to generate the load data, LMS Virtual.Lab Motion is used to model tractor subassemblies, tie them together and perform full-tractor dynamic motion simulations. By having realistically modeled tractor designs run over dedicated virtual tracks, engineers are able to retrieve the resulting tractor load data as well as the resulting internal forces in the tractor assembly. The acquired load data then serve as input in subsequent FE and durability simulation steps that are identical to the classical durability simulation approach. Christian von Holst commented, "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 modifed 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 fexibly and realistically model full-tractor designs. Although the modeling of a new tractor design requires considerable effort as well as in-depth CAE expertise, we are able to use these models in support of multiple simulation purposes, including durability, ride and handling, control mechanism and tractor-implement interaction."

The third approach in the durability simulation toolbox is what John Deere refers to as the hybrid approach. A key beneft of this method is its ability to consider the structural fexibility of specifc tractor components, such as suspension parts, cabin mounts and wheel cover brackets. The FE modeling of fexible parts is performed according to the requirements of a Craig-Bampton analysis, which can be automatically initiated and driven from within LMS Virtual.Lab. During full-tractor simulations, LMS Virtual.Lab Motion calculates modal participation factors to characterize the deformations of the fexible bodies and

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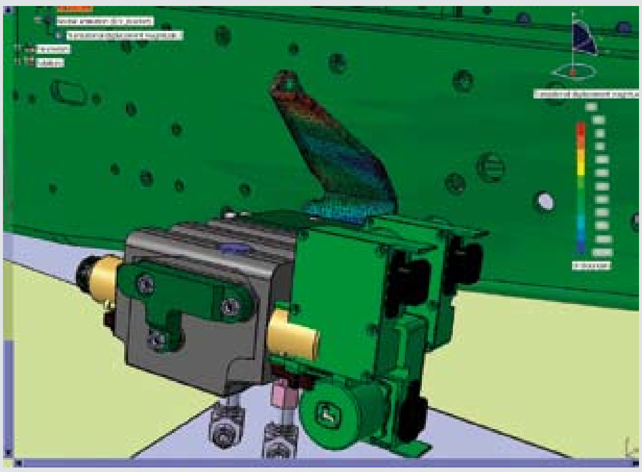
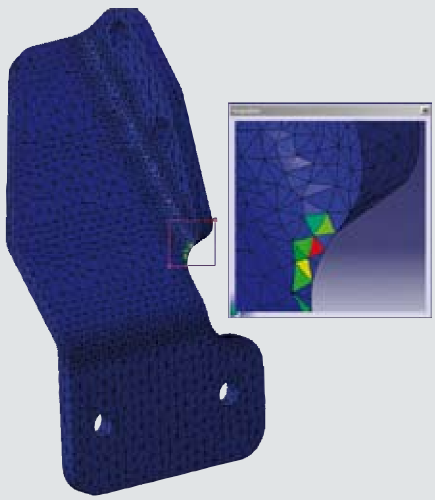


Since actuator assembly brackets connected to the tractor frame are rather thin parts that operate while carrying many times their own weight, it is necessary to model such components as fexible bodies.



The transient stress and strain history results of the motion simulations are used as input for the subsequent analysis in LMS Virtual.Lab Durability, which detects the weakest spots of the fexible parts being evaluated.

ultimately to retrieve the reaction forces that apply to these parts. The transient stress and strain history results of the motion simulations are used as input for the subsequent durability analysis, which detects the weakest spots of the fexible parts being evaluated.

Higher tractor reliability with fewer physical prototypes

“A typical component that is investigated by means of the hybrid approach is an actuator assembly bracket that is connected to the tractor frame,” Christian von Holst explained. “Since these rather thin brackets operate while carrying many times their own weight, it is necessary to model such components as fexible bodies. The deformation of the bracket and the excitation of its natural frequencies lead to altered mechanism motion, unwanted system vibrations and signifcant changes in internal loads. This hybrid approach, which tightly integrates multibody simulation with fexible-body analysis and fatigue-life prediction, allows us to evaluate the durability of the bracket in context of realistic full-tractor performance before completing the design process. With LMS Virtual.Lab’s graphic post-processing features, we are able to zoom in on specifc durability hot spots of tractor components and gain insight into the underlying root causes. The identifed hot spots also make it possible to organize more detailed physical tests later on that more specifcally focus on the critical areas detected on the virtual prototype. In many situations, the capabilities of the hybrid durability simulation approach overcompensate for the additional processing power that is required and the method’s restriction to linear FE investigations.”

Over recent years, virtual simulation has evolved into a more accepted and trustworthy source of information that is already applicable from the early conceptual design stages onwards. “The introduction of Virtual.Lab Durability in the early design stages – when there is still plenty of design freedom – positively impacts tractor reliability and reduces the number of required prototype tests,” Christian von Holst stated. “The added value of LMS Virtual.Lab on virtual durability investigations performed at John Deere is signifcant, as it serves as the critical backbone of the hybrid approach and increases the effciency of the mixed approach. In this way, LMS Virtual.Lab helps John Deere strengthen its capability to provide compelling reasons for farmers to buy new tractors, by offering better performance, fexibility, comfort, economy and secured reliability.” ■

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