

Industrial machinery and heavy equipment

John Deere

Agricultural machinery manufacturer addresses NVH issues early in the product development process with the help of LMS

Product

LMS

Business challenges

Identify best way to quiet cabs at higher operating speeds

Develop simulation models to predict booming cab noises

Enable farmers to remain comfortable during a long day

Keys to success

Use a combination of experimental and numerical acoustic analysis techniques

Use LMS Engineering services and LMS software to identify and resolve issues

Leverage the strong collaboration opportunities between organizations

Results

Developed approach for addressing acoustic issues early in the development process

Quickly and efficiently identified effects that lead to loud cab noise

Enabled better understanding of the complex acoustic system



Siemens PLM Software products and services enable John Deere to resolve excessive cab noise

Quiet cabs fight fatigue

Using acoustic simulation software and clever detective work, LMS™ Engineering services helped John Deere spot a resonance from an unexpected source, giving one of the world's leading agricultural equipment manufacturers the tools and insight to further improve the acoustic quality in its next-generation of products.

Today, farmers feed the world faster than ever before: the average farmer produces 12 times more agricultural output per hour than in the 1950s. This is due to improved agriculture techniques and

high-performance equipment, such as tractors with global positioning system (GPS) precision guidance, intelligent power management systems, powerful engines, high-torque transmissions and other advanced technologies.

A major part of this increased productivity results from enabling farmers to stay in the cab most of the day to complete large-scale field applications, such as row-cropping and large livestock operations. With days that start before the sun rises and end after sunset, fatigue is a key concern. Comfortable and quiet cabs loaded with numerous features help farmers get the tough field work done as quickly and efficiently as possible.

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Dr. Ing. Christian von Holst
Group Leader
Suspension Systems
John Deere Werke Mannheim

John Deere, a leading global manufacturer in the \$70 billion agricultural equipment market, offers a ComfortGard premium cab with advanced filtration air conditioning, built-in refrigerator and air-suspension upholstered seats with dual armrests. Cabs are mounted on rubber isolation mounts with acoustic trim to reduce interior sound levels to 70 decibels (dB). A computer-controlled command center displays tractor performance and allows farmers to quickly and easily make adjustments to the hitch, hydraulic, transmission and other systems via a single on-screen user interface.

To boost productivity even further, many premium tractors can be driven at higher speeds on public roads, a necessity in many European countries where the farmers need to access separate fields and remote areas of the farms.

Figuring out the source

This faster operation brings about a noise, vibration and harshness (NVH) problem that is widespread throughout the agricultural industry: a booming noise in the cab

at high speeds. Typically found in only a narrow range of frequencies, these noise levels are generally not addressed in the coarse overall NVH limits set by legal sound-emission standards established by groups such as the Organization for Economic Cooperation and Development (OECD), European Economic Community (EEC) and the Occupational Safety and Health Administration (OSHA) standards.

Traditionally, tractors have easily met these standards. Nevertheless, the noise poses a challenge for tractor designers. Farmers who are accustomed to a rather quiet cab during normal operation become distracted and annoyed with sudden sound level spikes, or booming as the tractor accelerates on the road.

The booming noise was in the 100 to 110 hertz (Hz) frequency range with sound levels increasing by as much as 8 dB while driving at speeds greater than 48 kilometers per hour (km/h) on hard flat road surfaces. John Deere took a number of measurements that showed that a

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combination of factors amplified the problem, including resonant vibration modes defined by the cab size and shape, cab modal frequencies and associated large sheet-metal parts, and the contribution of different panels to structural sound transmission.

However, no single effect could be identified as dominant. The primary source of the problem remained a mystery, even after months of rigorous testing. Moreover, traditional sound-reduction methods like acoustic insulation proved to be ineffective at diminishing the booming noise. Typically, sound-absorbing acoustic insulation works well in abating sound above the 500 Hz frequency level, but not with the low 110 Hz frequency range of booming noise.

Unfortunately, the cab consisted of huge acoustically transparent areas of glass and steel that could not be modified. John Deere tried design variations for the cab-mounted exhaust system as well as the windshield and roof hatch. These had little effect on lowering the noise.

Finding the root cause

To get to the bottom of this booming noise and determine how best to quiet cabs at higher operating speeds, John Deere Werke Mannheim (Germany) collaborated with LMS Engineering on a project to develop simulation models to predict cab booming noises.

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more efficiently through our cooperation with LMS Engineering services,” says Dr. Ing. Christian von Holst, group leader of suspension systems at John Deere Werke Mannheim. “The Siemens PLM Software staff and test facilities showed an unexpected flexibility to deal with our more exotic and less automotive-like vehicle and problem.”

Digging into the data

The first step in the study was to measure tractor acoustics on a chassis dynamometer in a semi-anechoic room using LMS Test.Lab™ software from Siemens PLM Software. Sound levels were recorded inside and outside the cab at different driving speeds and the measurements were correlated with test track measurements. This verified what the John Deere engineers had already encountered: the noise depended on driving speed rather than engine speed, number of cylinders or gear ratio. More specifically, the engineers found that the noise depended most heavily on the tires. The excitation frequency equaled wheel rotational speed times the number of wheel lugs.

For the particular tractor and tire type in the study, wheels with 44 lugs on a tractor traveling at 50 km/hr produced an

excitation frequency of 108 Hz, almost exactly the same as when the booming noise was apparent. LMS engineers reasoned that the wheel lugs acted as rotating fan blades, producing aerodynamic pulses that excited the cabin interior to resonant vibration.

Determining the sound transfer path

To gain insight into the path of the wheel lug vibration into the cab, LMS engineers used a simulation approach to represent the acoustic behavior of the tractor. Geometry data from John Deere’s computer-aided design (CAD) system was transferred to LMS Virtual.Lab™ software from Siemens PLM Software to create a boundary element model (BEM) of the cabin, wheel and fender. This model was then used with LMS Virtual.Lab™ Acoustics software from Siemens PLM Software to predict sound pressure levels around that area of the tractor. The predictions were then correlated with actual sound measurements to validate the model.

Graphical output from the acoustic simulation indicated a hot spot of sound pressure with structure-born vibrations transferring the energy into the cab, producing the booming noise. To test this theory, researchers removed cab parts and found

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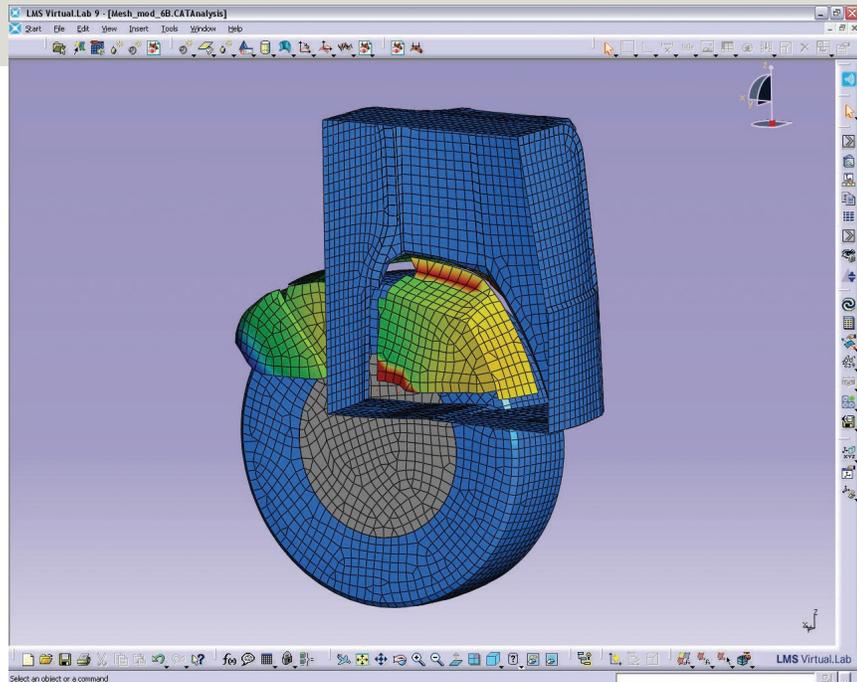
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Customer's primary business

John Deere is one of the largest manufacturers of agricultural machinery in the world, and is committed to the success of customers whose work is linked to the land – those who cultivate, harvest, transform, enrich and build upon the land to meet the world's dramatically increasing need for food, fuel, shelter and infrastructure.
www.johndeere.com

Customer location

Moline, Illinois
United States



that cab noise dropped by 7 dB, virtually eliminating the booming sound. The acoustic model was then modified and simulations were repeated to evaluate the noise effect of different fender sizes, shapes and clearances.

"The deep experience of Siemens PLM Software in these kinds of NVH problems and the way the engineers think out-of-the-box brought us a significant step forward," says von Holst. "The results of the analysis together with our in-house experience on the machine allowed us to quickly identify possibilities to enhance the cab acoustics."

Shifting NVH optimization upfront

Working with LMS Engineering, John Deere engineers gained additional valuable insight into the combined application of experimental and numerical acoustic analysis techniques. More broadly, thanks to the knowledge transfer from LMS Engineering, John Deere engineers now have a proven approach using LMS Virtual.Lab Acoustics to address acoustic effects earlier in the product development process.

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