Cleaning out noise early in design at Miele

LMS Virtual.Lab Acoustics is used by consulting firm Novicos in helping appliance manufacturer Miele launch new washing machines faster while maintaining high quality.

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Instead of damping some of the noise with hit-or-miss changes and numerous prototype tests late in development, engineers now have a proven process for designing quietness into their products up front in the cycle. This predictive capability radically compresses development time and is a key part of the company's strategy to deeply penetrate new markets with a broad range of machines soon to hit showroom floors around the world.

On the outside, a washing machine is a deceptively simple metal box. But dynamic assemblies and subsystems are packed tightly inside: more potential sound sources than any other home appliance. So designing these machines to run quietly is an engineering challenge, especially in trying to limit noise during the spin-dry cycle when high-speed drum rotation can set up intense vibrations that resonate throughout the structure.

Nobody knows more about minimizing this type of noise than Miele and Company KG, the largest family-owned and operated appliance company in the world. The Germany-based manufacturer is known across Europe for top quality appliances and takes pride in the intensive work devoted to developing its high-end products. In plans to deeply penetrate global markets in the US and Asia, Miele needs to quickly develop new models while maintaining the strong reputation for quality standards.

To accomplish this aggressive business goal, Miele is moving beyond the time-consuming development methods traditionally used throughout the appliance industry, where companies typically go through numerous physical prototype test cycles and make hurried hit-or-miss engineering changes late in design to damp out some of the noise. Instead, Miele is working with consulting firm Novicos in using virtual prototyping to predict radiated sound levels with LMS Virtual.Lab Acoustics. This allows engineers to readily determine noise levels early on so they can use their expertise in quickly modifying washing machine dynamics to more effectively reduce sound levels up front in development.

Critical Element of Competitive Strategy

Acoustic simulation technology is a critical element of this competitive strategy. Dr. Eduard Sailer, Managing Director at Miele, cites the important role of virtual prototyping in the company's plans for future business development.

"To build a strong presence in the global market, we absolutely must develop new models of appliances as quickly as possible while maintaining the same top quality standards that has set us apart from competitors for over 100 years," explains Sailer. "The use of advanced technology is key to this strategy, with acoustic simulation, for example, enabling our engineers to effectively design quietness into our new washing machine models through the use of virtual prototypes and computer analysis early in the development process."

According to Sailer, these tools leverage the tremendous expertise of the company's technical professionals, with Miele having more experience than almost any other appliance manufacturer in taking washing machines to the highest level of quietness, reliability and convenience. "Use of advanced technology demonstrates our technological leadership position in the appliance industry and our continuing commitment to our traditional high standards of quality and customer satisfaction," says Sailer.

Process for Noise Prediction

To assist in its acoustic simulation work, Miele has partnered with Novicos GmbH, a consulting firm specializing in noise and vibration for a wide range of clients including Airbus, BMW, DaimlerChrysler and Volkswagen. The goal was to develop and benchmark a process that could be used systematically in Miele's

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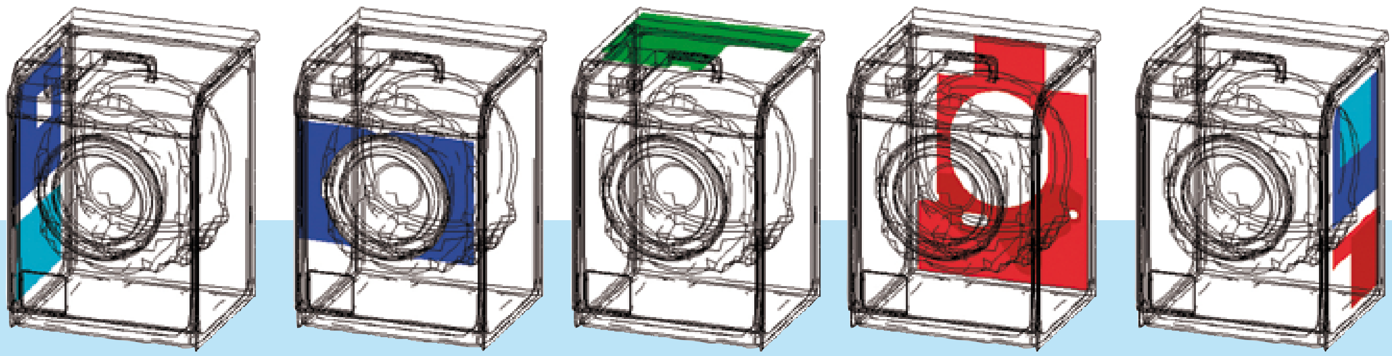


The acoustic simulation included studying the effects of sound-absorbing cotton fleece mats of various thicknesses placed in different positions on the side and rear panels.

development cycle to accurately predict sound levels early in the design of new washing machines.

In the first step of the process the project team has devised, static displacements and structural vibration modes of individual components such as the motor and pump are computed with finite-element analysis (FEA). Next, these results from FEA are transferred to nodes on a flexible multi-body dynamics (MBD) model, which accounts for imbalanced masses in the machine, centers of gravity, rigid body momentum, motor characteristics, the run-up profile and characteristic curves of springs, dampers, supports and door seals. This MBD analysis provides data on resonant vibration modes and transient structural response in the form of modal coordinates, thus representing the overall dynamic behavior of entire machine

Output from this coupled FEA/MBD analysis is transferred to a MATLAB script and FORTRAN programs written by Novicos. This custom interface translates the data into a form for direct transfer of Eigenvectors and surface velocity amplitudes onto the acoustic mesh in LMS Virtual.Lab Acoustics. The software uses an indirect boundary element method (IBEM), which in contrast to conventional direct BEM techniques, can perform a sound field analysis in unlimited areas on structures with free edges as well as branched surfaces. In this manner, Novicos engineers use LMS Virtual. Lab Acoustics to accurately predict sound pressure levels surrounding the washing machine, with output displayed in a variety of graphic formats including sound pressure distribution surrounding the machine at a given frequency, plots of sound amplitude at specified locations for a range of frequencies, or color maps showing major noise contributors by amplitude and frequency.

Verification of Results

To verify the accuracy of the process, Miele and Novicos worked on an initial project where they simulated sound levels for an existing washing machine and checked results against noise measurements. Sound levels from the machine operating at several spin-dry speeds were measured by Miele by recording sound levels from six time-series microphones and analyzing the signals to determine characteristic features of the acoustic emission.

Hans-Walter Beckmann, a senior mechanical engineer at Miele in charge of the project with Novicos, relates that Novicos computations from LMS Virtual. Lab Acoustics compared very favorably with measurements taken on the washing machine, thus verifying the accuracy of the approach. “We have demonstrated the feasibility for simulating sound levels early in design and validated that such a process can support us in reliably predicting noise emissions of new washing machines,” explains Beckmann.

Beckmann explains that even though Miele strongly believes in the potential of virtual prototyping, empirical testing of hardware prototypes remains an important part of development. “The LMS test system has given us years of excellent service and will continue in its vital role of verifying that new designs meet Miele’s high quality standards. We definitely consider acoustic simulation as a technology that can enable us to better direct our efforts in investigating noise issues with fewer tests that are more focused.”

Benefits of Early Acoustic Simulation

According to Beckmann, acoustic simulation has provided considerable insight into noise sources and how the sound is transmitted throughout the structure. One significant revelation for both Novicos and Miele engineers was discovering that the side panels transmitted more sound to the outside air than was previously thought, leading to further studies on placement of sound-absorbing materials. “We have been working with these machines for decades, yet the acoustic analysis showed us aspects of noise radiation we were not aware of before,” says Beckmann.

“Acoustic simulation can be extremely valuable in our product development cycle in predicting radiated noise and allowing us to easily make changes to reduce sound levels,” says Beckmann. “Modifying the design and running a new simulation is orders of magnitude faster than building and testing physical prototypes. This can undoubtedly compress the product development cycle and thereby enable our engineering staff to develop many more new high-quality appliance models in far less time.”

For competitive reasons, Miele justifiably guards exact details on time savings. However, in an industry where top-of-the line washing machines may undergo five or six prototype testing cycles that each take weeks, it is not unreasonable to assume that an appliance maker able to cut the number of cycles at least in half could shave several months of precious time from its development process.

LMS Virtual.Lab Acoustics unquestionably is of immense value for us as a service provider for our customers, who reap the benefits of radically compressing the time to develop quiet, innovative, high-quality products

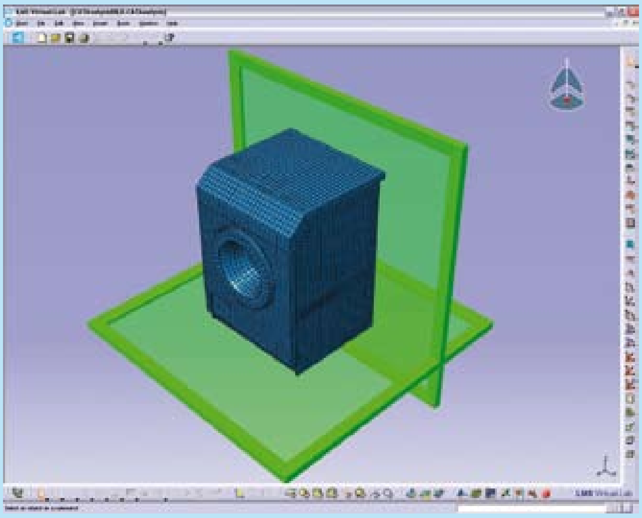
Leading-Edge Technology

Olgierd Zaleski, the chief executive offcer at Novicos who jointly with Dr. Marian Markiewicz spearheaded the acoustic simulation work for Miele, explains the advantages of using LMS Virtual.Lab Acoustic software in such an approach. “Optimization features are some of the most valuable capabilities of LMS Virtual. Lab Acoustics in working on the Miele designs,” he says. “This technology allows us to minimize sound levels by exploring the impact of various factors such as mount stiffnesses, wall thicknesses, motor placement, the gap between the frame and sidewalls, or location of sound-damping feece mats.”

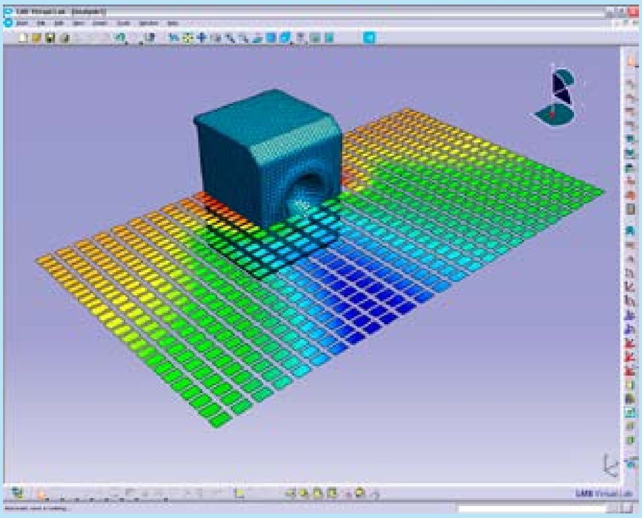
Zaleski cites the ease and power of automated features in LMS Virtual.Lab Acoustics for setting boundary conditions with a single mouse click instead of having to perform multiple separate operations to defne the envelope of the model, free edges, junctions and other conditions. “Automation of these tasks speeds up the process, ensures that boundary conditions are properly set, and guarantees that none are forgotten,” notes Zaleski.

“We see similar benefts in using tools such as skinning the mesh and wrapping the mesh for more easily preparing the acoustic mesh based on geometry obtained from the FE model,” he explains. “This type of functionality enables us to create a high-quality mesh in a few hours instead of several days. In some cases, without these automated capabilities, building an accurate mesh representation would not be possible because of the extremely large number of elements required for some detailed parts of the model.”

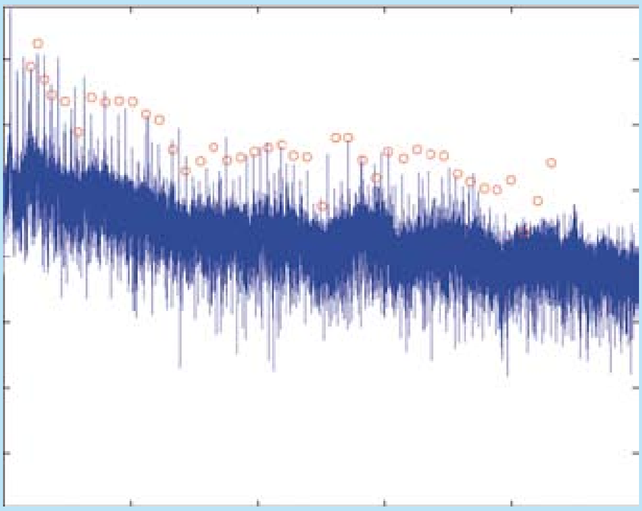
“From a purely engineering standpoint, having this broad range of analytical functionality in a single suite of integrated software enables us do the best possible job of predicting noise levels early in development and helping Miele quickly arrive at an optimally quiet design,” explains Zaleski. “From a business perspective, LMS Virtual.Lab Acoustics unquestionably is of immense value for us as a service provider for our customers, who reap the benefts of radically compressing the time to develop quiet, innovative, high-quality products that reinforce brand value and drive top-line revenue growth.”



Acoustic model of washing machine includes representations of the frame and interior components such as the drum, drive unit, detergent dispenser. Exterior acoustic surface mesh incorporates reverberant rear wall and foor that must be taken into account.



LMS Virtual.Lab Acoustics predicted the sound pressure distribution at a frequency of 240Hz in the region surrounding the washing machine.



Spectral responses computations from LMS Virtual.Lab Acoustics indicated distinctive noise-level peaks that matched favorably with measurements, thus verifying the accuracy of the approach.

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