SIEMENS

AUTOMOTIVE AND TRANSPORTATION

Mazda Motor Corporation,
Mazda Engineering and Technology

Perfecting in-vehicle audio with model-based development and full-vehicle simulation

Product

Simcenter

Business challenges

Reduce vehicle tuning and development time

Reduce the number of required physical prototypes

Develop and validate simulation methods that accurately predict physical performance

Keys to success

Use Simcenter 3D for model-based development

Integrate Simcenter HEEDS to speed up optimization

Simulate frequencies across full human audible range

Results

Reduced speaker grill simulation from 2.5 days to 4 hours

Created reusable models that reduce complete speaker analysis to 2 hours

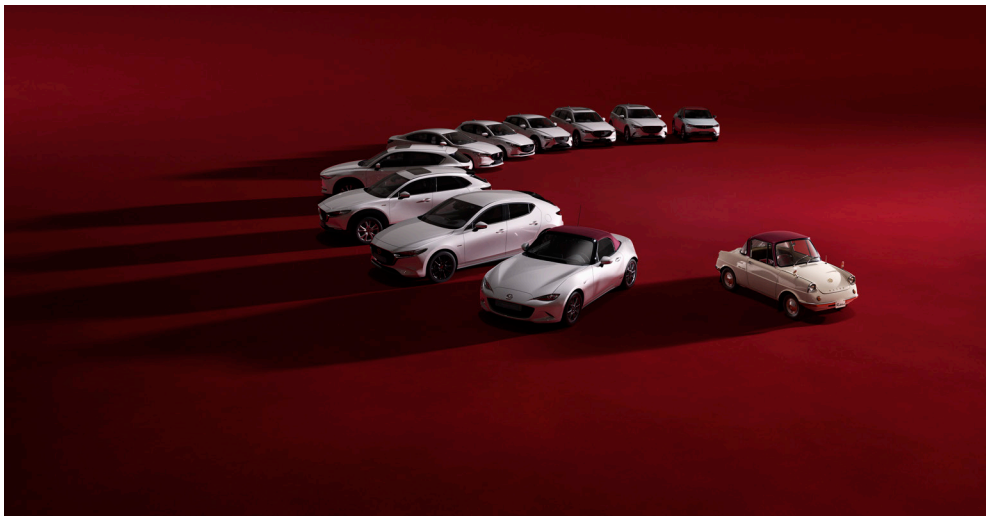
Simulated full-vehicle interior acoustics for the frequency and time domain using Simcenter 3D ray acoustics

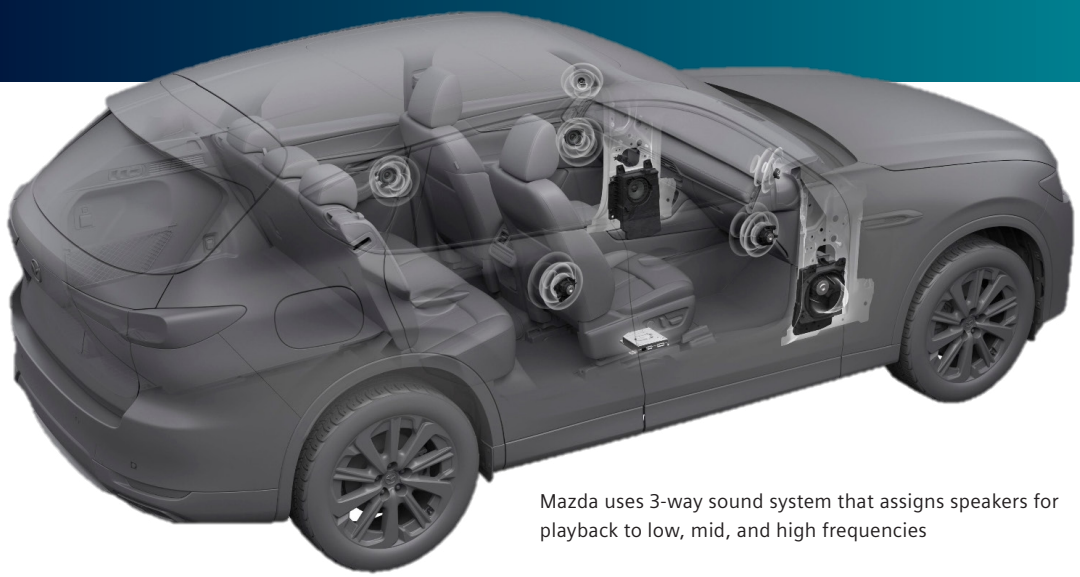
Mazda uses Simcenter 3D and Simcenter HEEDS to optimize audio acoustic performance and reduce simulation from 2.5 days to 4 hours

For almost 100 years, the Mazda Motor Corporation (Mazda) has strived to build the best, safest, most comfortable and most enjoyable vehicles for its customers. Over time, as standards and expectations steadily increased, the company regularly invested in expert engineers and the latest technology to stay ahead of the competition.

Mazda Engineering & Technology Co., LTD. (Mazda E&T) is an affiliate company 100 percent owned by Mazda. Mazda E&T is a comprehensive engineering company specializing in developing and manufacturing small-volume, special-use vehicles, such as training vehicles and welfare vehicles. As a member of Mazda, they are taking on new challenges every day to carve out the future of the motorized vehicle industry.

No modern vehicle is complete without an audio system. For Mazda, this is much more than an afterthought. The best vehicles need the best audio experience; however, it has become increasingly challenging to improve audio systems and tune them to each vehicle, ensuring optimal performance. To shorten development time, Mazda E&T is searching for ways to reduce the number of engineering hours spent working with physical full-vehicle prototypes and speed up the audio tuning process.





Mazda uses 3-way sound system that assigns speakers for playback to low, mid, and high frequencies

"Previously, when simulating acoustic-vibration coupling, we had to spend time checking the availability of Simcenter NASTRAN solvers and repeating calculations. Thanks to Simcenter 3D, we can carry out these calculations immediately."

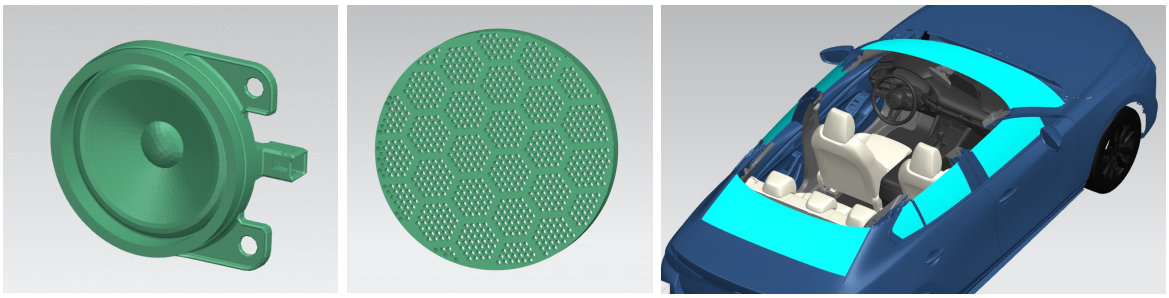
Masaaki Sakiyama
Deputy Staff Manager,
Model Base Development Division, CAE Technology Development Office
Mazda E&T

To accomplish this, the company turned to Siemens Digital Industries Software and used Simcenter™ 3D software and Simcenter HEEDS™ software, which are part of the Siemens Xcelerator business platform of software, hardware and services.

Focusing on complete audio acoustic analysis

To deliver the highest quality sound, Mazda developed a three-way audio system with separate speakers for low, mid and high frequencies, from hertz (Hz) to kilohertz (kHz). "The entire range of human hearing is extremely wide, from 20 Hz to 20 kHz, making it incredibly resource and time-intensive to analyze acoustic performance," says Masaaki Sakiyama, the deputy staff manager of the model base development division, CAE technology development office at Mazda E&T. "We must consider all frequencies within this range when analyzing performance, and to produce the top quality, it's also important to analyze sound reverberation inside the car's cabin."

To create an optimal design, companies need to analyze three key areas: the speaker, the speaker's grill and the vehicle's interior acoustics. In the past, building and running simulations for the speaker and grill typically took several days. This made it impractical to build a simulation for analyzing the vehicle's interior acoustics at the relevant frequencies because finite element-based methods would take too long to model and simulate.



Mazda analyzes the car audio energy flow from the speaker, through the grill and then cabin interior.

"Our goal is to reduce the number of prototypes in the vehicle development process by using simulation to analyze and optimize audio designs before manufacturing vehicles," says Koji Wakamatsu, technical leader of the integrated control system development division in the electrical and electronics performance development department at Mazda. "To do this, we needed to find a new solution that enables model-based development."

Using Simcenter 3D for model-based development

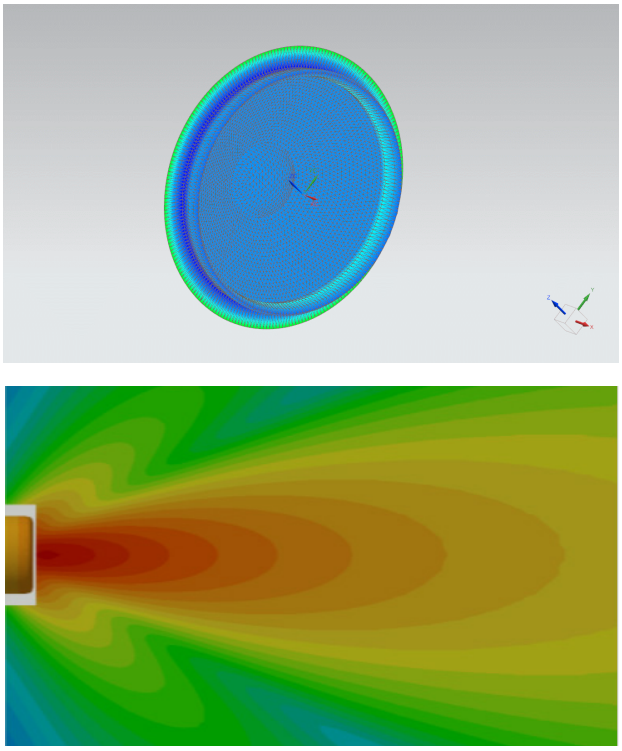
By adopting model-based development, which reuses models in repeated simulations, Mazda E&T significantly improved and sped up the performance analysis of its audio systems.

Using Simcenter 3D, the team builds separate models for each key area. The first model reproduces the directional characteristics of each speaker to reveal how the speaker's construction and material choice alter its sound radiation at different frequencies. To validate the fidelity of these models, the engineers take physical measurements of the sound pressure directivity every 10 degrees in front of the speaker. This way, they can compare them against the vibroacoustic simulation results of the speaker model in Simcenter 3D.

Using Simcenter HEEDS to optimize speaker materials

After creating the speaker model, the engineers must answer two questions. First, does the model accurately identify the correct speaker material properties? Second, are measurements taken from the model as accurate as physical test measurements?

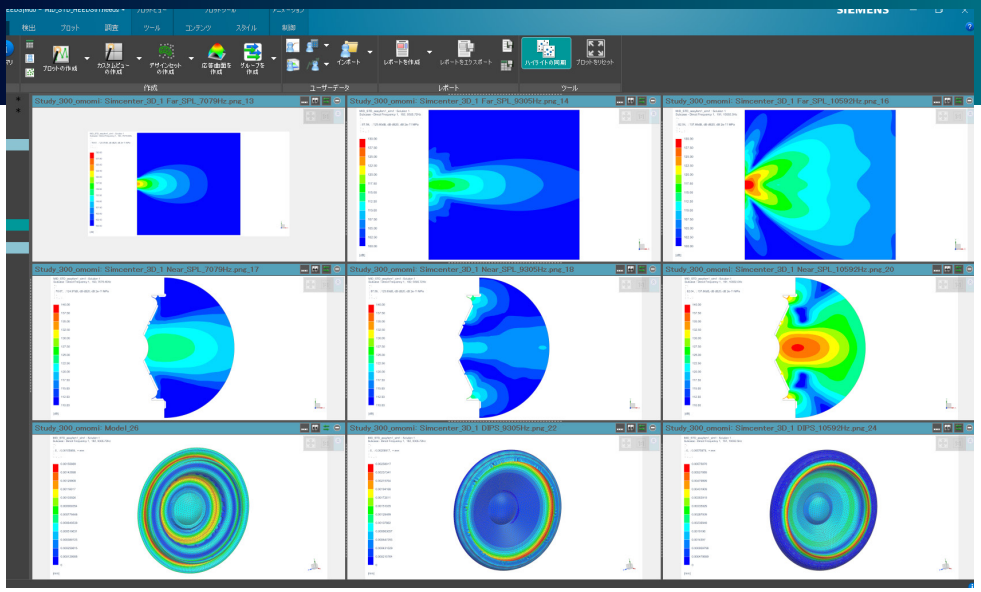
To do this, the engineers use Simcenter HEEDS to drive the simulation model in Simcenter 3D and determine the material properties that will ensure the simulation results match the physical measurements. "Using Simcenter HEEDS, we can leverage the extraction capability for result images, which was not available in other



Speaker movement and frequency changes influence directional characteristics.

"The Simcenter HEEDS and Simcenter 3D support teams worked well together, which was vital for achieving our goals."

Masaaki Sakiyama
Deputy Staff Manager, Model Base Development Division, CAE Technology Development Office
Mazda E&T



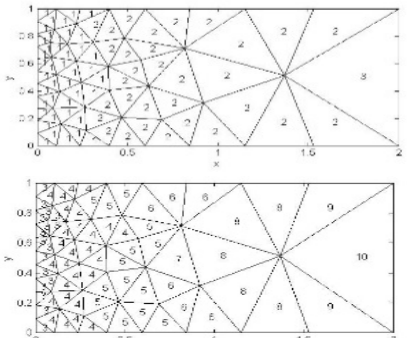
Simcenter HEEDS was used to determine the optimum speaker material properties to match measured results.

optimization tools," says Sakiyama. "Rather than switch to a new visualization method to examine the results, we continued using the approach we knew already worked and then pulled the results together in Simcenter HEEDS."

By using Simcenter HEEDS, Mazda E&T could closely predict the same material properties they used in the physical model and found the simulation results correlated with physical measurements more precisely than previous methods for predicting speaker performance. With this exercise, the company proved that simulation can accurately predict speaker performance, meaning Mazda E&T can speed up development using simulation instead of physical models.

Leveraging the FEMAO model

Next, the engineers looked at the speaker grill and how the depth, diameter and positioning of its holes affect the radiation pattern. Using standard finite element (FE) models, calculating across the audible frequency range takes too long. Thus, the team used Simcenter 3D FE method adaptive order (FEMAO) technology to speed up the vibration-acoustic coupled analysis without needing to simplify the grill model.



Simcenter 3D Acoustics FEMAO uses a single mesh and changes the order for each frequency for a more efficient process.

Top: f=100Hz

Bottom: f=1000Hz

"

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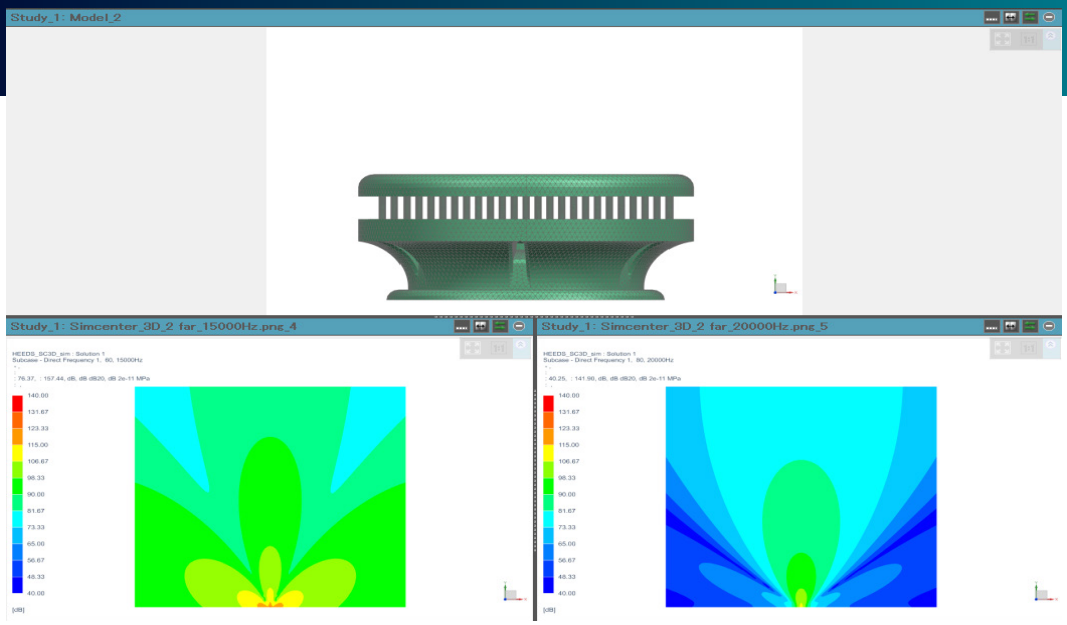

Speaker grill hole depth and diameter impacts sound scattering characteristics.

Using FEMAO provides more accurate results and faster solve times by adapting the model size to the complexity of the analysis. This means that the engineer only needs to create a single FE mesh. Then the solver automatically reduces the element order (lower number of degrees of freedom per element) at low frequencies and increases the element order (higher number of degrees of freedom per element) at high frequencies, based on each element's size. This significantly reduces calculation time since engineers need one FE model rather than manually recreating models for various frequency ranges.

Additionally, Mazda E&T used Simcenter NASTRAN software, which is also part of the Siemens Xcelerator business platform. Sakiyama notes that the integration between Simcenter 3D and Simcenter NASTRAN helped save them time. "Previously, when simulating acoustic-vibration coupling, we had to spend time checking the availability of Simcenter NASTRAN solvers and repeating calculations," says Sakiyama. "Thanks to Simcenter 3D, we can carry out these calculations immediately."

Using this new process, the team reduced the speaker grill analysis time from 2.5 days to 4 hours, enabling greater optimization in a shorter timeframe.

Achieving full-vehicle interior acoustics

To understand the audio experience for occupants in a vehicle, Mazda E&T previously tuned the audio system using vehicle prototypes, which could take several weeks. The company wanted a way to virtually tune an entire vehicle using simulation. However, creating a full-vehicle FE simulation model takes too long, and calculating the results for a large FE model was even less feasible.

Alternatively, Mazda E&T started using Simcenter 3D ray acoustics, which efficiently solves high-frequency acoustic models. For a car's cabin, the typical applicable frequency range is between 500 Hz and 20 kHz. When the acoustic wavelength is small compared to the acoustic environment, engineers assume that the acoustic energy propagates similarly to light rays.

This means that engineers do not have to create a large, detailed, finely meshed vehicle model. Instead, they need to create

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Development Office
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Customer's primary business

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mazda.com

Customer location

Fuchū, Hiroshima
Japan

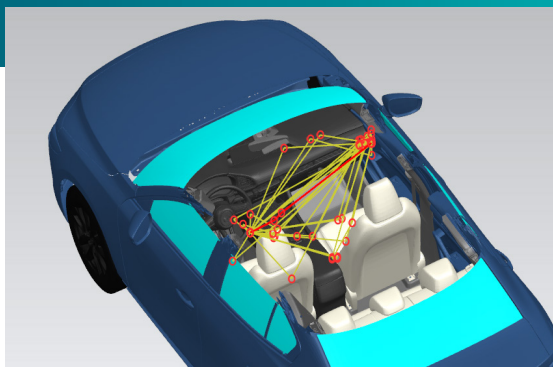
a coarse representation of the vehicle's interior using surface discretization. As a result, it takes an engineer three man-days to convert the computer-aided design (CAD) model to a computer-aided engineering (CAE) model for ray acoustics.

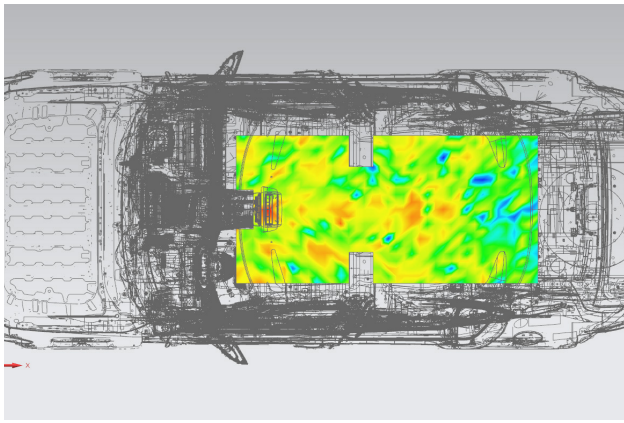
Once the initial model is complete, engineers can analyze the frequency and time domains without requiring a high-quality mesh for the FE method and boundary element method (BEM) wave analysis. Additionally, they can reuse the models with various parameters repeatedly to reach full optimization. The result is engineers completing a full analysis of eight speaker models over 0 to 20,000 Hz, which the software calculates in 1 Hz steps, in just 2 hours.

Optimizing with the best tools and support

Thanks to these Siemens solutions, Mazda E&T made advancements in developing audio systems; however, integrating new software was only part of the solution. "The Simcenter HEEDS and Simcenter 3D support teams worked well together, which was vital for achieving our goals," says Sakiyama. "Using these solutions helped us avoid making mistakes early in the process, meaning we could realize the full benefits of the technology much sooner."

The advent of quieter electric powertrains that no longer mask audio sound quality issues, wind noise or road noise presents further opportunities for the Mazda E&T research team to extend their work and demonstrate its value. Additionally, Wakamatsu believes they can apply similar simulation methods to improve other noise, vibration and harshness (NVH) issues in vehicle development, helping Mazda deliver an even more comfortable experience to its customers in the future.





Simcenter 3D Ray Acoustics helps Mazda perform analysis on the scale of a vehicle model in two hours.

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