DESIGNING TOMORROW'S VEHICLE HVAC SYSTEMS

Challenge:
BMW needed to design a vehicle HVAC system that balanced acoustic comfort with effective performance.

Solution:
BMW used SIMULIA PowerFLOW to investigate how noise levels could be lowered without sacrificing defrost performance.

Benefits:
Using PowerFLOW, BMW demonstrated a successful method of optimizing both acoustics and design performance, achieving a 6 to 13 db(A) Overall Sound Pressure Level improvement.

When designing a car, manufacturers and engineers need to consider multiple factors. Safety, obviously, is paramount, but drivers universally want a pleasant driving experience as well, and that includes a quiet cabin. Some noise sources on a typical drive are impossible to prevent—the noise of other traffic, for example – but within the car itself, a significant amount of noise comes from areas such as wind, tires, and the HVAC system. These are the areas of opportunity for engineers to focus on, reducing noise as much as possible in order to create a satisfactorily quiet driving experience.

HVAC—THE PRIMARY CULPRIT IN VEHICLE NOISE

Wind noise can be mitigated by carefully designing the aerodynamics or improving the acoustic packaging of a vehicle, and advancements in tire design have allowed for much quieter tires. HVAC, therefore, is a primary concern in design, even more so when the vehicle is stopped.

Dr. Jan Biermann, Expert for the Development of Overall Vehicle Noise, Vibration and Harshness at BMW, is an authority on reducing noise in automobiles. According to Dr. Biermann, HVAC noise is "the predominant driver for overall acoustic comfort in the car."

A vehicle's HVAC system must provide heating, air conditioning and defrosting to the cabin and windshield, but doing so can trigger different noise generation mechanisms. The balance of thermal comfort or defrost performance, and noise, must be perfected early in the design process, often before a prototype is available. This is complicated because multiple other factors must be balanced, such as airflow, effective heating and cooling, and a fast, thorough defrosting system.

"You cannot solely design a system just to create a mass flow or a certain airflow in the cabin without dealing with these acoustic effects right from the beginning," says Dr. Biermann. "Because otherwise you have literally no chance to fix this. That's why you have to take [them] into account in a very early design stage."

These challenges grow even more difficult when it comes to electric vehicles, which are naturally quieter because their electric engines make far less noise than their internal combustion counterparts. Without that engine noise, other noise sources become much more pronounced.

A COMPLEX CHALLENGE IN NOISE REDUCTION

The Rolls Royce Phantom VIII is not an electric car, but it is touted as the quietest car on the road currently. Reducing HVAC noise was a major challenge in designing this car. Obstacles included the limited under-the-hood and dashboard package space, difficulty in identifying noise sources in the internal flow system, short development cycles, and, as Dr. Biermann pointed out, the fact that substantial improvements were only possible in the very early stages of design.

Virtual reality exploration in the 7 series HVAC, on the **3D**EXPERIENCE platform.

"Package space and the fight for it is a very real and important point," says Dr. Biermann. "Because, first of all, we have... more room with the car. It's more like an open space, the cabin. So, you lose room, let's say under the dashboard. And that's where all the action is for the HVAC. Secondly, we have more and more functions that also claim package space under the dashboard; you want to have all your big screens and head up display and whatnot. Package space is shrinking to begin with, and so that's probably the most valuable asset when it comes to building a car, plus some design issues."

Therefore, he continues, engineers must be highly "accurate and sharp" in identifying their needs. They must identify the single most problematic part in an HVAC system, and a BMW design trend study pinpointed it as the defrost mechanism. SIMULIA's Find Contributions are useful for identifying the predominant noise sources in a vehicle system and ranking them based on their impact on the consumer; the defrost is an obvious example. Not only is it the noisiest mode of a heating and cooling system, it is also the most important and complex, as it must pass certain defrost regulations.

"We were looking for a simulation tool to help us with the analysis of the HVAC system," he says. "And so we came across SIMULIA PowerFLOW, and it was the only tool that could provide us with a solution in the timeframe we had....PowerFLOW was the only viable solution."

—Dr. Jan Biermann, Expert for the Development of Overall Vehicle Noise, Vibration and Harshness, BMW

BALANCING DEFROST EFFECTIVENESS AND ACOUSTIC COMFORT

Defrost legislation ensures safe driving, so meeting its requirements is an obvious priority. These regulations demand a defrost mechanism that can clear a windshield quickly, usually assessed in early design through indirect metrics such as skin friction. As the study determined, skin friction and noise reduction were competing objectives. Anyone who has ever turned their defrost on full-blast on a wintry morning can understand this, so it was a challenge well worth taking on.

Using SIMULIA's PowerFLOW, a fluids/CFD simulation solution capable of capturing aeroacoustic and transient thermal performance, the study attempted to identify key design trends that reduced noise levels whilst meeting defrost regulation. Instead of relying on indirect metrics such as skin friction, the study showed that the exact homologation test for defrost performance could be replicated in simulation accurately, providing exact information about the presence of ice on the windshield as a function of time. Using this methodology, designs that lowered the noise level in the cabin, and provided the same defrost experience and safety as from noisier designs, could be identified. BMW was ultimately able to successfully demonstrate a method of optimizing both the acoustics and defrost performance, achieving a 6 to 13 db(A) Overall Sound Pressure Level improvement.

This study zeroed in on balancing defrost effectiveness and acoustics, but in a real design scenario, those would be only two factors that would have to be considered. Optimizing HVAC in a small package space would also have to be simulated, and, according to Dr. Biermann, SIMULIA solutions have proved extremely valuable in assessing all of these factors.

FINDING A SOLUTION WITH POWERFLOW

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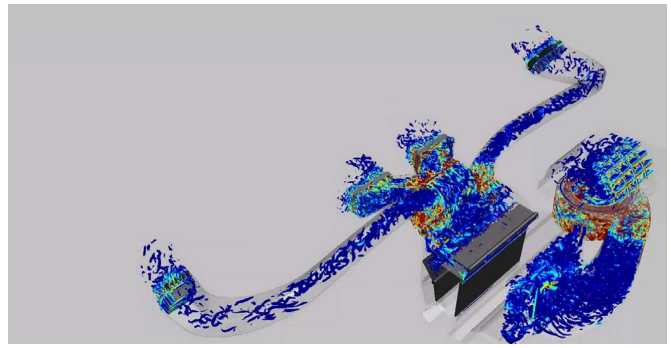
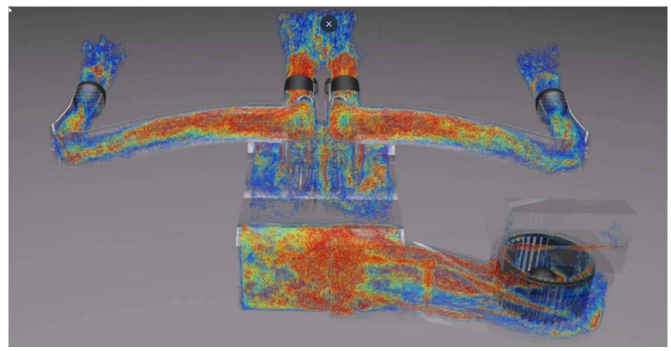
PowerFLOW does so while retaining all of the geometrical details of the HVAC and simulating real rotating geometry driving the flow. It also allows the representation of functional aspects such as thermal comfort and defrost efficiency, replacing homologation tests for defrost and doing so in a fast, accurate manner while replicating any real world environmental conditions, or physiologies.

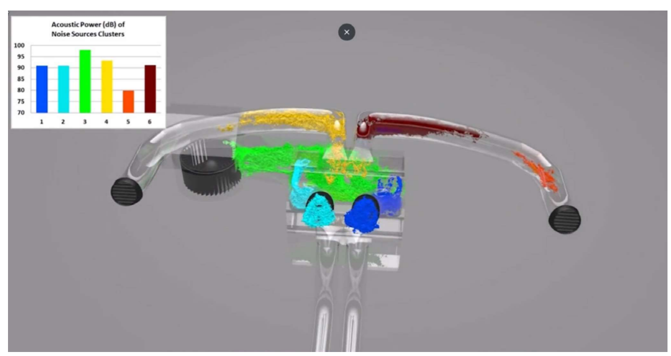
"Something we do have is a lot of computation resources," Dr. Biermann continues. "But in order to benefit from that your code has to scale pretty well. And PowerFLOW did and we gained results and information about a problematic system up to a frequency range that we have not been able to, with an accuracy that we would have not gotten with another software."



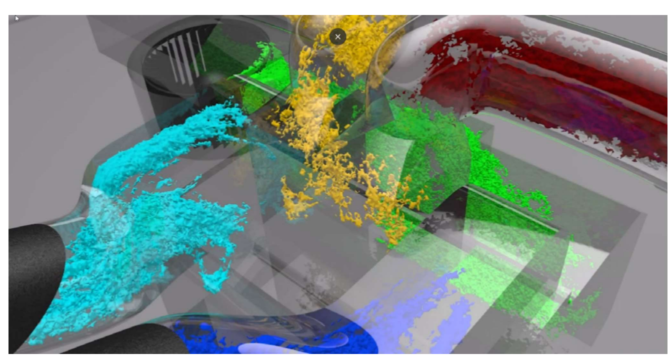
Turbulent flow structures in the HVAC.



Volume Visualization of noise sources in the HVAC.



Ranking of the acoustic power of each cluster for a broad frequency band.



Clustered noise sources colored by amplitude.

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Dr. Biermann expects that simulation is going to continue to play a major role in automobile design. In the earlier days of automotive manufacturing, he says, acoustics was less important than it is now, as consumers now expect more out of their vehicles. Energy efficiency is also a significant factor, as OEMs strive to make their products as green as possible. This means reducing weight and optimizing aerodynamics, both of which are time-consuming and costly processes without simulation.

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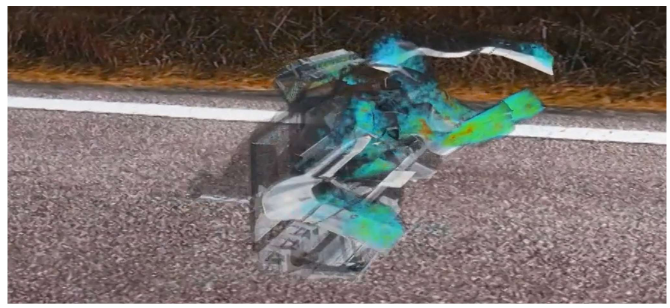
THE IMPORTANCE OF SIMULATION IN HVAC DESIGN

In such a competitive automotive market, with more and more options for customization, manufacturers must optimize everything about their vehicles. Even without considering the ever-stricter regulations for aspects such as energy efficiency and safety, OEMs are beholden to customers who expect the best that manufacturing technology has to offer— and simulation enables those manufacturers to achieve the best, all while reducing their own cost, time and effort.

"Simulation is going to play the predominant role, especially for HVAC because there are so many multi-physics aspects," says Dr. Biermann. "[There are] classical fluid dynamics to begin with, but then HVAC acoustic has so many other, important parts, acoustic effects or phenomena like acoustic transmission, but then also vibro-acoustics and we have different noise paths.

Turbulent flow structures in the 7 series HVAC.



Volume Visualization of regions of high acoustic contribution to the driver ear in the 7 series HVAC.

"And so, it is highly complex. And to control all these aspects, I think, there is hardly any way to handle this without simulation. Ninety to eighty percent of the work is already done in the early designs stage...I think there are certain aspects that we still have to measure, but I guess ninety to ninety-five percent of the overall work will be just simulation-based."

That's good news for the environment as well as consumers, as much less physical material will be required to create numerous prototypes of cars. Nearly everything can be done digitally, allowing engineers to make both large changes and small tweaks with the mere click of a button. Now is an exciting time for both automotive manufacturers and consumers—and simulation is, in large part, to thank for that.

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