

Behr Innovates Thermal-management Solutions with LMS Test and Simulation Technologies



A world on the move demands vehicle transportation with comfort in the cockpit and reliability under the hood. “Made by Behr” represents innovative thermal management solutions, which are increasingly adopted by the world’s leading automotive and other ground vehicle OEMs. Behr has truly established a climate of innovation, by resolutely exploiting the power of virtual simulations and test-based validations and making them standard practice in its worldwide organization. LMS solutions are used by Behr to obtain faster and more accurate optimizations of their engine-cooling and climate-control systems for multiple attributes, including durability and NVH (Noise, Vibration and Harshness.)

Introducing a system integrator

Behr is a world leader in designing and manufacturing climate-control and engine-cooling systems. Behr primarily targets automotive OEMs by offering innovative solutions for vehicles ranging from compact to luxury cars as well as commercial trucks. With its cooling systems, Behr is also active in the aerospace sector, other ground-transportation markets, and industrial markets. Over the years, Behr has evolved from a local German technology leader into a global development partner. Behr positions itself as a supplier of components and modules and as a system integrator, taking responsibility from development to production-line delivery. With 16,200 employees working in distributed development, production, test and service centers, Behr is present in all key markets.



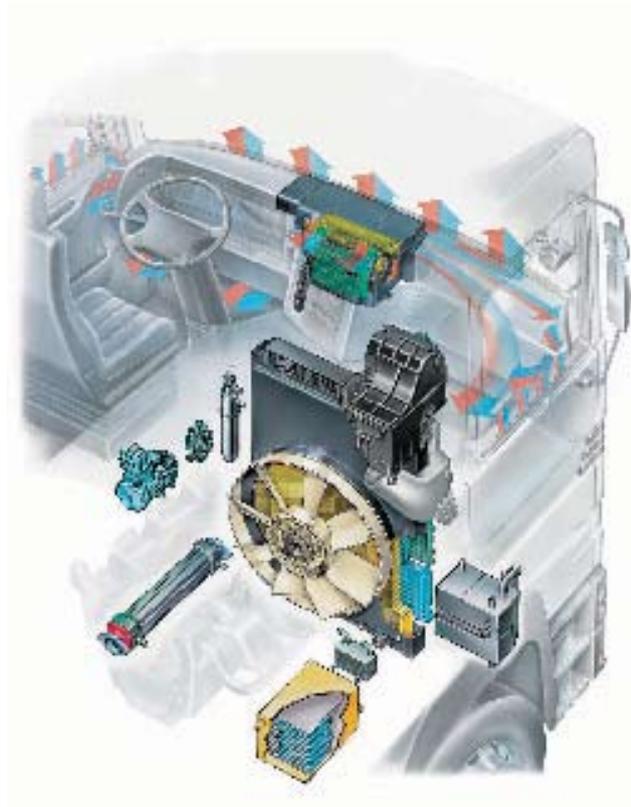
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Adapting to an increased pace

Major car and truck producers increasingly ask suppliers to take on additional levels of engineering responsibility for the parts and assemblies they manufacture. Behr receives more and more requests to design complete modules and entire thermal-management solutions to meet the unique demands of specific vehicles. Air-conditioning systems from Behr improve occupant comfort, ergonomics, user-friendliness, safety and total thermal performance of the vehicle. The engine-cooling systems provide a stable, temperature-controlled environment for high-performance engine efficiency, and resulting fuel and emission levels. Behr leverages the values of its customers' brands by continuously introducing new innovations, including hybrid cross-bar beams, four-zone climate control systems, monoblock radiator systems and the use of environmentally-friendly carbon dioxide as a refrigerant.

Behr's challenging future

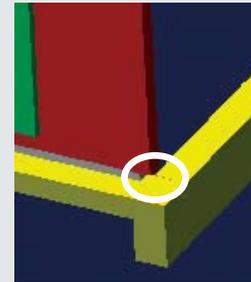
With the target specifications of the OEM at hand, Behr initiates the task of developing a tailor-made air-conditioning and/or engine-cooling system, while facing several challenges. Firstly, the dedicated vehicle space assigned to Behr's systems is precisely specified and is often very limited, as room must also be reserved for the glove compartment, airbags, engines, actuators, turbo components, etc. Next, the Behr package is held against strict weight limits and outstanding cooling and heating performance characteristics. Then, Behr solutions in operation must meet very tight NVH restrictions to keep overall interior noise levels down. Reliability is another key issue, as the performance of the cooling system is critical to the reliability of the car itself.



Case example

Proving ground failure

A vehicle durability test performed on one type of truck produced a leaking radiator. The truck was instrumented and Behr engineers discovered acceleration spikes, which indicated interference in between parts. They determined that the cooling module and the frame components repeatedly collided during the test drives. Behr created a model in LMS DADS and performed motion simulations in order to reproduce the contact events. These motion insights also enabled Behr to eliminate the contacts by establishing optimal clearances with adjacent truck components.



Turning smart processes into product innovations

Behr believes that innovative product design starts with innovative development processes. This vision is put into practice by installing effective and reliable design processes through the introduction of virtual design simulations in all steps of the development. To utilize simulation in the early concept phase, Behr sets up preliminary geometry models and builds the basic system models. Results gained from motion simulations, followed by acoustic simulations and durability assessments, already provide valuable insights into the conceptually-developed system models. This allows Behr to narrow down the scope of successive and extensive simulations in later design phases. LMS solutions support Behr in optimizing the performance of the thermal management systems before the sign-off to physical prototype testing.

Combining CAE with test-based validations

At Behr, new products are effectively and accurately designed by finding the right combination of vigorous virtual simulations and test-based validations. This has made Behr's engineering process not only faster and less expensive but also more accurate and robust. The role of testing is changing from a product-development tool towards a design-validation tool and a means to correlate virtual simulation models. Test systems at Behr include LMS SCADAS II and III, LMS Roadrunner multichannel data acquisition hardware and corresponding LMS CADA-X test software. In addition, the new-generation LMS Test.Lab software suite is currently being rolled out.

To increase the performance of simulations and to bring direct added value to commercial projects, Behr

continuously dedicates resources to basic investigation projects. Behr Stuttgart (D) and Behr Charleston (US) initiated three of these joint investigation projects that focus on dynamic cooling-module and air-conditioning unit simulations. Results and expertise gained in these projects are shared with the entire Behr organization through global guidelines and standards. One major project achievement was a modal analysis study on cooling modules, performed with LMS GATEWAY and LMS CADA-X, which successfully correlated experimental test results with Finite Element Analysis (FEA) results. Other efforts focus on the characterization of higher temperature loads, new materials or smart metal-plastic connections.

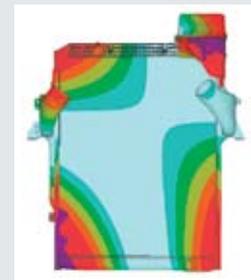
Starting with dynamic load cases

Behr starts with experimental load series that result from extensive vehicle tests performed on their customers' test tracks. They collect and evaluate dynamic load series, which will be added to Behr's recently established worldwide loads database. Feeding these load data into dynamic motion studies represents the start of the virtual design process. From motion simulations, predictions of dynamic reaction loads acting on the individual components are retrieved. Motion studies take real-world conditions and material flexibility into account and the internal system forces obtained form the reliable basis for other, more specific analyses, such as NVH and durability. Behr simultaneously engineers their designs for different attributes, and is therefore able to balance the overall design by establishing the most beneficial attribute trade-offs. LMS TecWare is used for evaluating experimental load cases and LMS DADS / LMS Virtual.Lab Motion and LMS CADA-X for dynamic simulations at the system level.

Case example

Test correlation of engine cooling system

Throughout the design process of engine cooling systems, Behr performs three-dimensional NVH simulations. Frequency-response analyses performed on cooling modules can be used to detect critical areas in components such as supports, brackets and connecting parts. These results are used as a basis for further fatigue predictions. Behr uses LMS GATEWAY to correlate vibration behavior and gain damping factors of the cooling module. Correlated analysis models are the key for accurate results, as well as the basis for reliable fatigue evaluations and a future flexible-body database for dynamic LMS Virtual.Lab simulations.



Refining air flow, noise and vibration

Since silent operation of systems such as air-conditioning is required by car drivers as one of the key values for comfort, OEMs impose ever-more-stringent NVH levels on most of their suppliers. Behr anticipated this by performing intensive acoustics and CFD (Computation Fluid Dynamics) studies to further reduce the noise levels and improve the performance of the thermal-management systems. For example, Behr uses parametric cabin models to simulate how the air flow of the systems in operation will be perceived by the passengers in the car. Sources of undesired noises and disturbing vibrations are also traced and different design variations are evaluated to optimize the acoustic transfer functions of air-conditioning systems. Controlling NVH is very complex due to the numerous potential areas of concern, such as the flaps regulating cold and warm airflows, the interconnections between components, as well as the stiffness of the material itself. Behr uses LMS GATEWAY to verify modal analysis results to gain a valid basis for response simulations. Behr also makes extensive use of LMS SYSNOISE to simulate, evaluate and optimize the acoustics performance of its designs.

Taking control of system durability

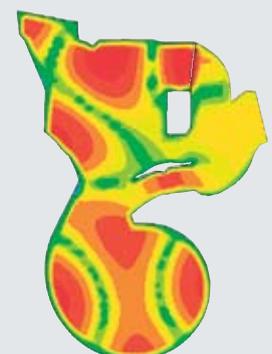
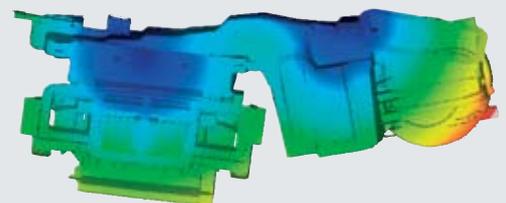
Behr's products are exposed to severe, mostly coupled operating conditions such as vibrations, or to transient temperature and pressure loads. For this reason, assessing system durability by combining experimentally-gathered material and component fatigue data with numerical analysis tools is one of the most challenging goals for the company. This task becomes even more complex when the lifetime of components is also influenced by exposure to aggressive substances like refrigerants, fuels, or oils.

For straightforward fatigue problems with known failure locations, Behr performs static FE analyses and compares the stress result with Wöhler curves, gained

Case example

NVH simulations on climate control units

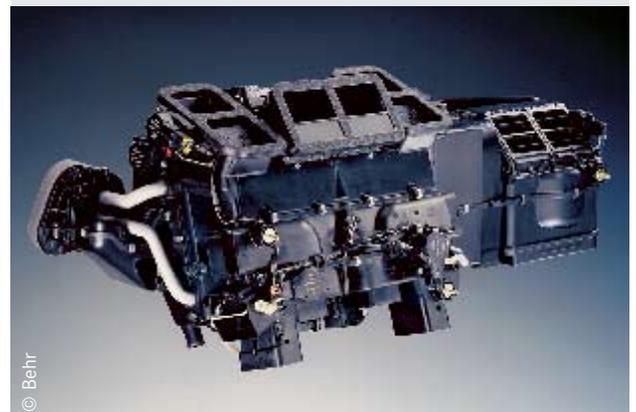
Behr also performs NVH simulations on climate-control units. The unit displayed on the left and center graphic is of the asymmetrical type and will be integrated in passenger cars crosswise below the dashboard panel. The unit on the right graphic is of the symmetrical type and will be placed in mid-position below the dashboard panel, adjacent to the center console. The design type of a concept is chosen to fit in the car space that is assigned to the Behr system. Behr uses LMS SYSNOISE (see right graphic) to gain the necessary acoustic insights needed to meet the OEM's noise targets. Test correlations using LMS GATEWAY (see center graphic) are performed to improve the dynamic FEA analyses and to fulfil the OEM's requirements concerning vibration behavior and durability.



from destructive tests, to predict the fatigue life. To solve more complex, dynamic fatigue problems, Behr invested in the LMS TecWare/LMS FALANCS fatigue-analysis solution and an interface to its PERMAS FEA solver. Depending on the frequency content of the dynamic loading, Behr uses either a quasi-static or a modal superposition approach. In both cases, LMS FALANCS combines FE analysis results with load-time histories to calculate the product's fatigue life. Reliable stress and durability insights enable Behr to deliver customer-specific systems that meet very tight cost, weight and endurance specifications.

Capturing simulation processes

To further strengthen its highly competitive position in its market place, Behr needs to deliver world-class thermal management solutions, which comply with stringent, multiattribute requirements. By re-designing its product development processes by integrating virtual simulations in every process step and by efficiently complementing simulations with physical testing, Behr will achieve these targets. At Behr, virtual prototyping is a standard practice. The company already experiences the leveraging of specialist expertise and the control over the characteristics of products that it will offer in the near future. Early insights and virtual design explorations speed up the design process and deliver heightened degrees of innovation. In the Behr development process of thermal-management solutions, the simulation and test solutions from LMS make a big difference.



An engine cooling module (above) and an air-conditioning module (below).



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LMS is an engineering innovation partner for companies in the automotive, aerospace and other advanced manufacturing industries. LMS enables its customers to get better products faster to market, and to turn superior process efficiency to their strategic competitive advantage. LMS offers a unique combination of virtual simulation software, testing systems and engineering services.

LMS is focused on the mission critical performance attributes in key manufacturing industries, including structural integrity, system dynamics, handling, safety, reliability, comfort and sound quality. Through our technology, people and over 25 years of experience, LMS has become the partner of choice for most of the leading discrete manufacturing companies worldwide.

LMS is certified to ISO9001:2000 quality standards and operates through a network of subsidiaries and representatives in key locations around the world.

