Automotive and transportation

Samsung R&D Institute

Using STAR-CCM+ and Battery Design Studio helps research organization deliver safer, more efficient lithium-ion battery packs

Product

Simcenter

Business challenges

Produce a battery with higher energy density and durability

Increase battery life by enhancing thermal management system

Keys to success

Use CFD to examine tradeoffs between pressure loss in coolant systems and temperature uniformity

Use simulation to help batteries remain in a narrow temperature range

Results

Delivered safer, more efficient lithium-ion battery packs

Enhanced feasibility of electric vehicles

Designed novel liquid-coolant-based thermal system

Predicted sensitivity of thermal performance to contact resistance

Reduced thermal variation inside battery pack

Siemens PLM Software solutions enable Samsung R&D Institute to enhance feasibility of electric vehicles

Developing a better thermal management system

The use of lithium-ion (Li-ion) batteries has made the electric vehicle a reality, so we could see the widespread acceptance of electric mobility in the not-too-distant future. However, there have been more than a few incidents of Li-ion batteries in electric vehicles catching fire due to faulty thermal management systems (TMS) or rough-driving abuse. This underscores the importance of finding new methods for effectively and accurately designing TMS that control temperature and optimize the performance of Li-ion batteries.

To address these challenges, the Samsung R&D Institute in Bangalore, India, in collaboration with the Samsung Advanced Institute of Technology, Korea, recently presented a novel, liquid-coolant-based TMS for large Li-ion battery packs. They constructed a coupled 3D electrochemical/thermal model of the proposed battery pack. The simulation revealed that contact resistance had the greatest impact on the pack's thermal performance.

The role of computational fluid dynamics

Considering the three-dimensional nature of the flow around the cells in a battery pack and the spatial variance involved in heat generation, the practice of simulating battery packs using computational fluid dynamics (CFD) has evolved to become an effective design and optimization tool to address thermal management problems.

For the large battery packs that operate at the high discharge rates typically used in electric vehicles (EVs) and hybrid electric vehicles (HEVs), CFD studies have shown that liquid cooling is more effective than air cooling, enabling the design of more compact and efficient batteries.

Pack geometry and experimental setup

In the Li-ion battery pack presented in figure 1, a commercially available 18,650-cell Li-NCA/C battery was used. Elements made of highly conductive metal transferred heat from the cylindrical cells to the coolant channel and, finally, to the coolant liquid (in this case, water). A test pack of 30 cells was fabricated, with six cells in series and five cells in parallel (see figure 1).

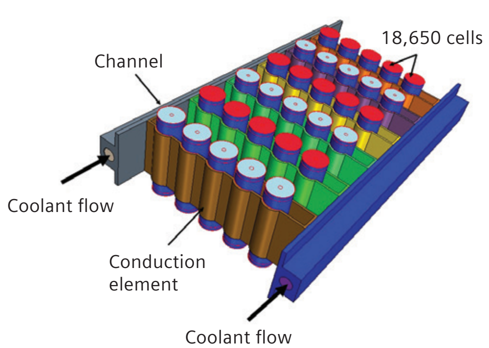

Figure 1: Geometry of the pack and the thermal management system.

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3D CFD model

A complete characterization of heat generation was obtained by constructing a 3D CFD-based electrochemical model of the battery that could be validated against experimental results, then used to simulate and evaluate the performance of the TMS under various operating conditions.

This project used two Siemens PLM Software products: STAR-CCM+® software and Battery Design Studio™ software. STAR-CCM+ was used to simulate flow and conjugate heat transfer, while Battery Design Studio was used to obtain electrochemical input data. This combination was used to simulate the performance of the battery pack.

Accurate temperature predictions from a single cell

The 3D TMS model was used to compute the performance of the representative battery pack. It was found the average temperature difference between the hottest and coldest cells was only .5 Kelvin (°K). Observing a clear pattern in the temperature rise, the authors realized that a properly defined temperature coefficient could predict the temperature of other cells based on the temperature of just one cell.

Coolant flow rate is critical

In electric vehicles, power for operating the TMS comes from energy extracted from the battery. Reducing the energy requirement for the TMS reduces its drain on the battery, thereby optimizing coolant flow rate, which is essential. The STAR-CCM+ model revealed that more heat is stored in the battery pack in lower coolant flow velocity conditions, indicating that at lower flow velocities, less heat is transferred into the coolant.

In most battery packs, maximum temperature variation is limited to 3 °K along the direction of the flow stream. The experimental model easily met the 3 °K limit and could effectively cool the pack even at low-flow velocities.

Materials such as graphene are used in compact TMS, which is a novel but expensive material. The results in figure 2 show the temperature rise in the battery pack using the experimental TMS are on the same order as those reported in research literature that used graphene as a phase

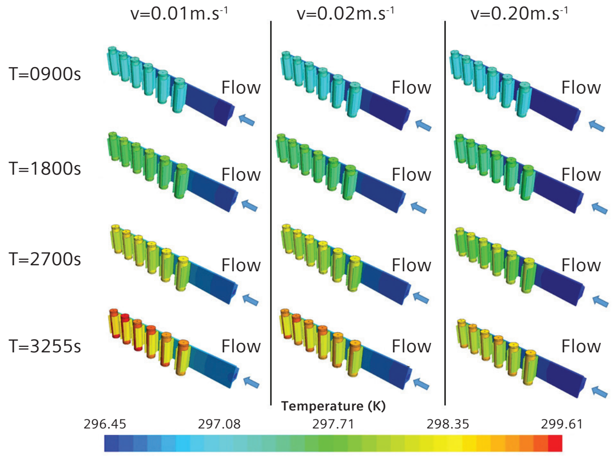

Figure 2: The temperature rise in the first set of series cells in the pack is a function of the .9 Celsius (°C) discharge rate and contact resistance of .0025 (m2.°K)/W.

The simulation revealed that contact resistance had the greatest impact on the pack's thermal performance.

change material (PCM) based thermal management system. Although such PCM-based TMS are compact, this new TMS does not require use of such novel materials and can therefore be produced at lower cost.

Conclusion

By using the CFD-based TMS functional model created with STAR-CCM+ and Battery Design Studio, the results of simulations and experimental measurements were in agreement, validating the model against the experiment with greater than 90 percent accuracy. Representative battery packs constructed using the symmetry of the total pack were successfully simulated, together with the TMS, to lower the computational cost.

Since the TMS worked effectively and safely under stringent conditions, it is a suitable candidate for large Li-ion battery packs that are used in electric vehicles.

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Solutions/Services

STAR-CCM+
https://mdx.plm.automation.siemens.com

Battery Design Studio
http://mdx2.plm.automation.siemens.com/products/battery-design-studio%C2%AE

Customer's primary business

Samsung emphasizes innovation and research and development (R&D) because it is essential to its business. In order to infuse a culture of global and local innovation, the Samsung Research Institute has a number of R&D centers strategically spread across the globe, including three in India: Bangalore, Delhi and Noida. Samsung R&D Bangalore is Samsung Electronics' largest overseas R&D center.
www.samsung.com/in/aboutsamsung/samsungelectronics/india/rnd

Customer location

Bangalore
India

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