Flow, Thermal and Electrochemistry Simulation of Batteries

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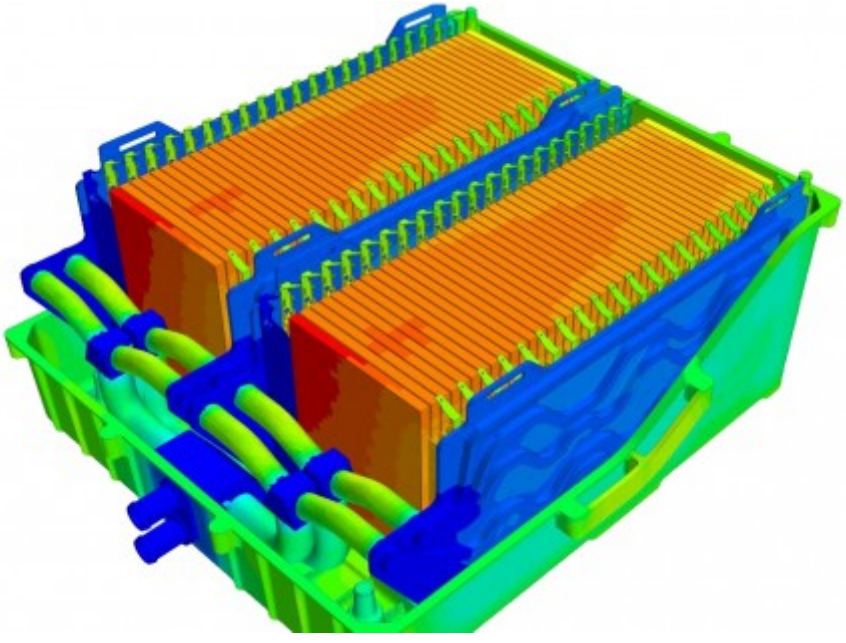
Driven by the twin demands of evolving customer expectations and increasing emissions regulation, the global automotive industry is in a race to deliver a sustainable compliment (if not replacement) to the Internal Combustion Engine. For now, propulsion systems based partially, or entirely, around electricity seem like the most credible prospect for providing the greatest reduction in CO2 emissions, within a reasonable timescale.

However, compared to gasoline engines, the cost of electrified power trains remains high, mainly due to the high cost of the batteries required to store and deliver the electrical power needed to drive such vehicles. Both Automotive OEMs and battery manufacturers are investing heavily in battery technology, with the aim of extending battery life, achieving higher energy densities and faster charging times, while improving both safety and reliability. A lot of this investment focuses on the efficient thermal control of battery cells.



[1]

Simulation is an important tool in this changing industry. In order to deliver credible

performance over a reasonable life span (and to prevent potential thermal runaway), current automotive battery technology requires elaborate monitoring, balancing and cooling to carefully control the electrochemical release of energy. The technological challenge is further complicated by the need to predict the performance of a battery system over a wide range of vehicle operating conditions, typically minus 30 deg C to plus 50 deg C.

It should be immediately clear that an accurate prediction of electrical and thermal performance is only possible when all the physics of the system (flow, thermal & electrochemistry) are considered concurrently. Battery modeling (if done properly) is a perfect example of "simulating systems" and highlights why the traditional approach of modeling particular physics in discrete, but different tools, will limit overall accuracy.

The image above shows STAR-CCM+'s flow, thermal and electrochemistry solver in action to predict the overall system behavior of this off road vehicle battery pack.

The pack supplements the vehicles traditional drive train providing high power bursts of energy and accepting similarly high power regenerative pulses. This mode of operation requires the cooling system to manage the considerable waste heat generated throughout such electrical bursts as local temperature differences will effect each battery cells performance.

The computation model accounts for numerous solid and fluid materials and simulates convective, conductive and radiative heat transfer as well as the electrical performance of the cells under the time varying load. This later component uses a complex numerical model to capture the temperature and state of charge dependent response of each cell and links them together as in the physical case to predict overall electrical response of the pack. In one simulation environment an engineer can see thermal and electrical systems performance.

The final result shown is a detailed, transient understanding of the entire system over the complete test cycle or drive cycle. Armed with this analysis design engineers can asses what further modifications are required to achieve the overall systems performance and ultimately the engineering success of the system.

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