The Thermal Management of Li-ion Battery Packs

For both operational and safety reasons, it's crucial to keep the batteries in electric and hybrid vehicles within a certain temperature range. To find the optimal cooling method quickly and efficiently, researchers at Fiat are turning to modeling.

MICHELE GOSSO AND ANTONIO FIUMARA, FIAT RESEARCH CENTER, ORBASSANO, ITALY

Given the long development cycle for vehicles, automobile manufacturers must plan their upcoming lines far in advance. And with growing emission regulations and the rising cost for gas, we can expect full electric and hybrid vehicles to become more attractive and grow in market share.

At the Fiat Research Center in Orbassano (near Turin), our group is focusing on the development of electric and hybrid vehicles using lithium and lead-acid batteries as well as supercapacitors. Fiat currently has several light trucks that run on electric drives, and the next application will be an electric version of the Fiat 500, which has been announced for the US market.

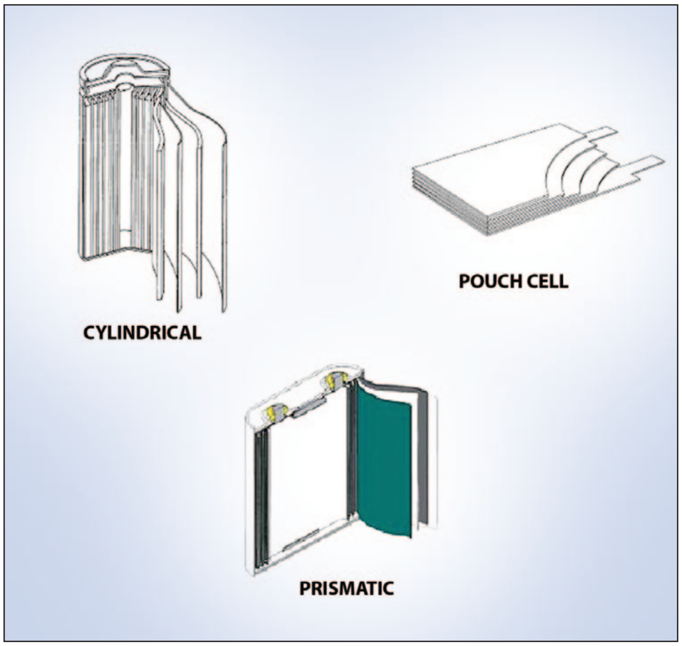

Figure 1: Three types of lithium-ion batteries. Fiat uses a series of 100 or so of the pouch cells to power their vehicles.

Cooling Multiple Battery Pouch Cells

We do not manufacture the individual lithium-ion battery pouch cells (Figure 1), but we are responsible for combining as many as 100 of them into battery packs that generate the 350V that is needed. Here, we must also provide sufficient cooling while keeping the packs as small and light as possible. Because the cells are wired in series, if one cell doesn't work well due to problems with heat, then it has a negative impact on the entire pack.

It is important that the maximum temperature differential among all the cells in a pack does not exceed 5 °C. Further, if the temperature of the pack as a whole is too low, it limits the charge you can extract from a pack; if it is too high, then you can run the risk of thermal runaway, which can mean a jump directly to electrolyte emission, smoke, or in the worst case, fire.

In these batteries, heat is produced through both Joule heating and chemical reactions, which we determine from an expression dependent on the current density. In our designs we prefer convection air cooling and we are using COMSOL Multiphysics to study the surface distribution because of this.

Our model (Figure 2) divides each surface of the pouch cell into nine areas, which correspond to the thermocouples on the cell itself. We examine the temperature distribution at several charge/discharge rates and verify that the model is consistent with reality, as measured by thermocouples and infrared heat cameras (Figure 3). Here, we found that the results were within 1 °C of the measurements (Figure 4).

With this information and confidence in the model, we can find hot spots on

"In our designs we prefer convection air cooling and we are using COMSOL Multiphysics to study the surface distribution because of this."

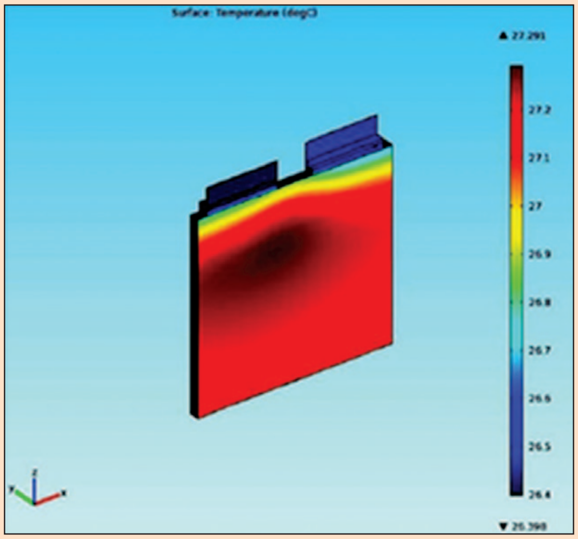

Figure 2: Surface heat of a lithium-ion battery pack — the uniform heat distribution is an important parameter.

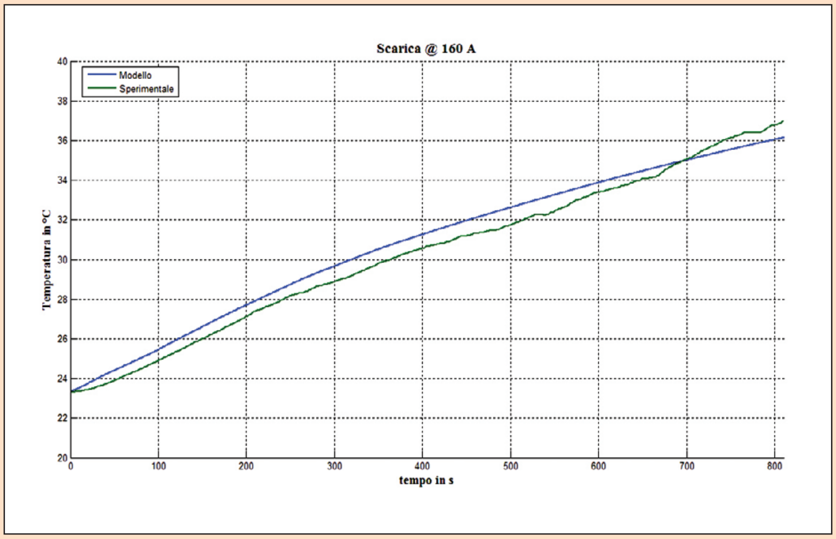

Figure 4: A comparison of model and experimental results at one of the thermocouples on the surface of the lithium cell. The results show a maximum difference of 1 °C between the two.

the cell and also investigate its internal temperature distribution. This provides invaluable information that cannot be achieved in other ways due to the difficulty of embedding thermocouples in battery pouches and attaining reliable results from them.

Smaller, Lighter Packs

With the knowledge we have gained from the model, we have been able to reduce the physical channels between the cells, which not only reduces space but also cuts weight because a smaller frame can be used. This makes it easier to insert the battery pack in a larger variety of vehicles, which is important because we are trying to adapt battery powertrains to vehicles already on the market.

In addition, we determined that a less powerful fan was required, which helped reduce costs. With the help of the model, we were able to cut our design time by 70%; we estimate that instead of needing 1,000 hours for the design of a battery pack, we could cut it down to roughly 300 hours.

> "With the help of the model, we were able to cut our design time by 70%."

A future project will also look at the other extreme conditions for these battery packs, namely at temperatures below freezing. In these situations, it can be difficult to charge these types of batteries. But by leveraging the Joule heating effect and through innovative design, we believe that will also be able to solve this problem. ■

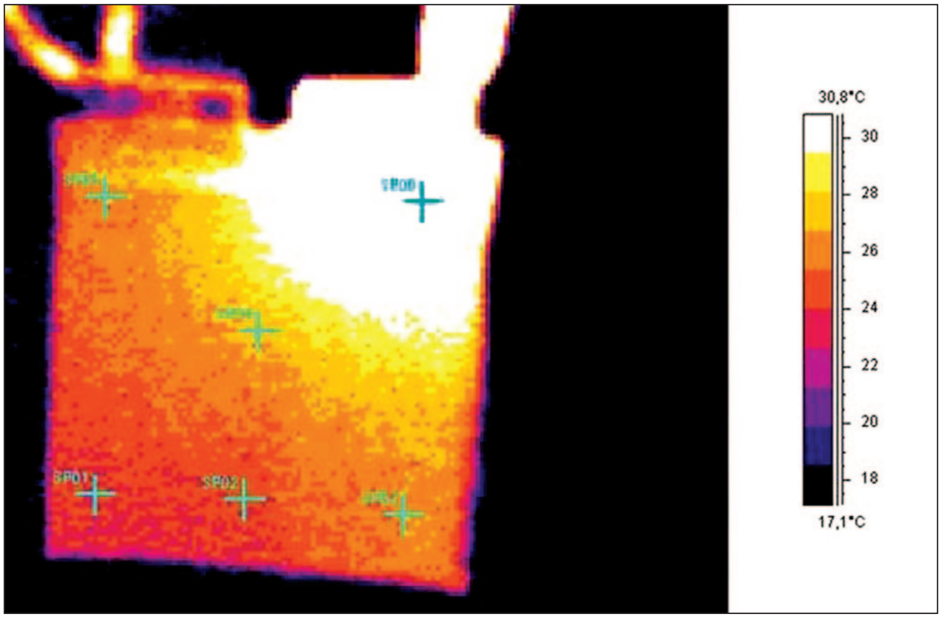

Figure 3: Result from using an infrared camera and thermocouples to measure the heat on the surface of a pouch cell.

About the Authors

Michele Gosso is a Senior Research Engineer at the Fiat Central Research Center in Orbassano , Italy, where he is in charge of the development of power for electric and hybrid vehicles. Antonio Fiumara is the group's coordinator.