Crash-testing lithium-ion batteries

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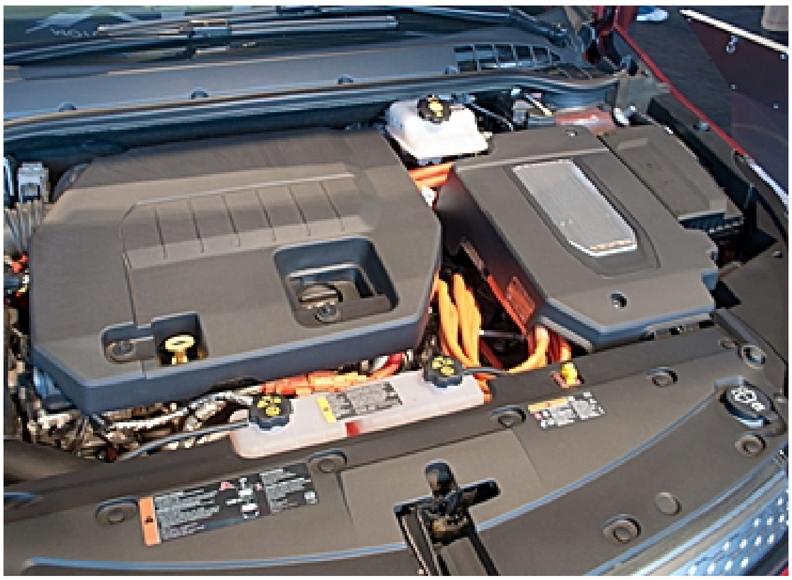

Credit: FLICKR.COM/INSAPPHOWETRUST

Lithium-ion batteries are lightweight, fully rechargeable, and can pack a lot of energy into a small volume—making them attractive as power sources for hybrid and electric vehicles.

However, there's a significant downside: Overheating and collisions may cause the batteries to short-circuit and burst into flames. Engineers have worked to improve the safety of lithium-ion batteries, largely by designing elaborate systems to cool and protect battery packs.

But Tomasz Wierzbicki, a professor of applied mechanics and director of MIT's Impact and Crashworthiness Laboratory, says there may be ways to make batteries themselves more resilient—an improvement that could reduce the bulk of protective housing, in turn reducing fuel costs.

First, though, Wierzbicki says engineers need to understand the mechanical properties and physical limits of existing batteries.

Now he and MIT postdoc Elham Sahraei have studied the resilience of cylindrical lithium-ion batteries similar to those used to power the Tesla Roadster and other electric vehicles. The team subjected individual cells to forces mimicking frontal, rear and side collisions. Using data from these experiments, the researchers developed a computer model that accurately simulates how a battery can deform and short-circuit under various crash scenarios.

Among their observations, the researchers found that a battery's shell casing—an outer lining of aluminum or steel—may contribute differently to overall resilience, depending on the scenario. Making shell casings more ductile or flexible, the team says, may be one way to improve the safety of lithium-ion batteries.

Wierzbicki says the team's model may be used to design new batteries, as well as to test existing batteries. The model may also be incorporated into whole-vehicle simulations to predict a battery pack's risk of "thermal runaway," a term engineers use to describe cases of catastrophic fire and smoke.

"We are developing computational tools to redesign batteries so the new generation is more resilient," Wierzbicki says. "These batteries may be able to take much higher loads without getting into the thermal runaway that everyone's afraid of."

The team has published its results this month in the *Journal of Power*

Sources.

Crushing a jellyroll

Wierzbicki says that in order to know how a battery will deform in a crash, it's important to "start from the smallest building block." In the case of lithium-ion battery packs, that building block is the "jellyroll": a single battery's interior, which is made up of alternating anode and cathode layers, and a separating layer, all rolled up and encased in a protective tube of aluminum or steel.

The batteries work when lithium ions travel across each separating layer, creating a current. But when the separator is compromised by the forces generated by an impact, a battery can short-circuit, and possibly catch fire.

To test a battery's resilience, the team crushed batteries between metal plates in various orientations, and used metal spheres and rods to dent and deform individual cells. The tests were designed to mimic certain repercussions of a crash: batteries crushing each other, or parts of a battery pack piercing the individual batteries inside.

To prevent "catastrophic thermal runaway," the researchers ran each test on batteries that were 90 percent discharged; the remaining 10 percent charge still allowed measurement of sudden drops in voltage. In addition to voltage, Wierzbicki and Sahraei monitored battery temperature and structural deformation after impact.

Keeping ahead of thermal runaway

The researchers used their data to develop a computational model for how a single cylindrical lithium-ion battery deforms under various crash scenarios. The model, which the researchers validated with further experimental tests, accurately predicted battery indentation under a certain load or force.

"With the knowledge of how a battery reacts in a crash, you can design your battery pack to resist damage," Sahraei says. "When you have a better understanding of how the cells react, you may find you could reduce the weight of the battery pack by reducing the excessive protective structures around it."

Sahraei, Wierzbicki and their colleagues are continuing to study the physical limits of cylindrical lithium-ion batteries, as well as the pouch and prismatic batteries that are used to power vehicles like the Chevrolet Volt. Ultimately, the group hopes to scale up experiments to test the integrity of whole battery packs, and incorporate battery models into whole-vehicle simulations. To further explore new and safer designs, Wierzbicki is forming a battery consortium that will include lithium-ion battery manufacturers and car companies.

While it's virtually impossible to design lithium-ion batteries to be risk-free, Wierzbicki says that models like his can help to reduce catastrophic outcomes in accidents involving electric vehicles.

"There's a certain critical velocity at which bad things happen," Wierzbicki says. "Right now, thermal runaway might occur during a 20-mph side collision. We'd like to increase that threshold to maybe 40 mph. By doing this, maybe 95 percent of accidents would be safe from the point of view of a battery exploding. But there will always be some collision—for example, a very fast car hits a tree or a post—and that's not a survivable accident for people and also for batteries. So you cannot have absolute safety. But we can increase this safety."

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