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I.C Computer-Aided Engineering for Batteries (CAEBAT)

I.C.6 Advanced Tool for Computer Aided Battery Engineering (SNL)

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Project Introduction

This project aims to provide experimental support, including support for validation and parameterization, for mechanical failure modeling work as part of DOE's Computer Aided Engineering for Electric-Drive Vehicle Batteries (CAEBAT) program. This work involves mechanical deformation testing on both charged and discharged cells, including abusive mechanical testing leading to battery failure. The mechanical data generated is provided to the modeling teams to provide empirical parameterization as well as validation for newly developed models. Testing fully charged cells and packs (abusive battery testing) also allows for a better understanding of what conditions are most likely to lead to a potentially hazardous thermal runaway event.

Objectives

Experimental determination of mechanical properties of lithium ion batteries and materials
Experimentally validate simulation tools used to predict thermal runaway events caused by crash induced crush. This includes rate-dependent mechanical failure and properties of individual cells as well battery packs. Provide collected data to the consortium to aid in model development. Partner with the USCAR Crash Safety Work Group to obtain feedback on experimental methods as well as develop new tests that may be of relevance to crash safety engineers.

Approach

Sandia's Battery Abuse Test Laboratory was used to perform mechanical testing on full cells and packs for this project. This facility can contain and withstand thermal runaway of lithium ion cells and packs of up to 1 kWh of total energy. Mechanical test capabilities include a 100 klbf large crush fixture and a 10 klbf nail penetration and small-scale crush fixture. Recording capabilities include force, displacement, temperature and voltage measurements at rates of up to 1 kHz. Data recording rates varied depending on duration of testing.

Mechanical deformation results collected at Sandia have been provided to NREL and the technical working groups. This has also included collaboration and information sharing with the USCAR Crash Safety Working Group, with the ultimate goal of understanding what hazards lithium ion batteries may pose during extreme mechanical deformation events, such as an auto collision. Quarterly meetings also provide information sharing and collaboration with the broader consortium, including NREL, ANL, SNL and Purdue University, as well as members of the ORNL consortium.

Results

Mechanical/electrochemical/thermal abuse

Sandia National Laboratories developed and performed mechanical abuse testing to support CAEBAT modeling efforts to provide both parameterization and validation of mechanical abuse models. Current work focuses on understanding of the mechanical response of cells at elevated temperatures and the development of dynamic impact testing.

Figure 1 below shows the impact of temperature on fully charged 5 AH pouch cells. Previous work has shown little change in the mechanical behavior of these cells when evaluated at temperatures within typical operating ranges of lithium ion batteries. This new work evaluated cells above normal operating temperatures. The cells were compressed at a rate of 0.1 mm/sec with a 24.4 mm radius cylindrical impactor. Cells were tested at both 100% SOC and 0% SOC. 100% SOC cells were compressed until thermal runaway was observed, while cells at 0% SOC were compressed to the average deformation required to create thermal runaway. The current results show little change in the overall mechanical behavior of the cells up to 100 °C, however at 120 °C we observed a significant reduction in the force required to deform the battery. We also observed a slightly higher displacement before thermal runaway occurred at elevated temperatures.

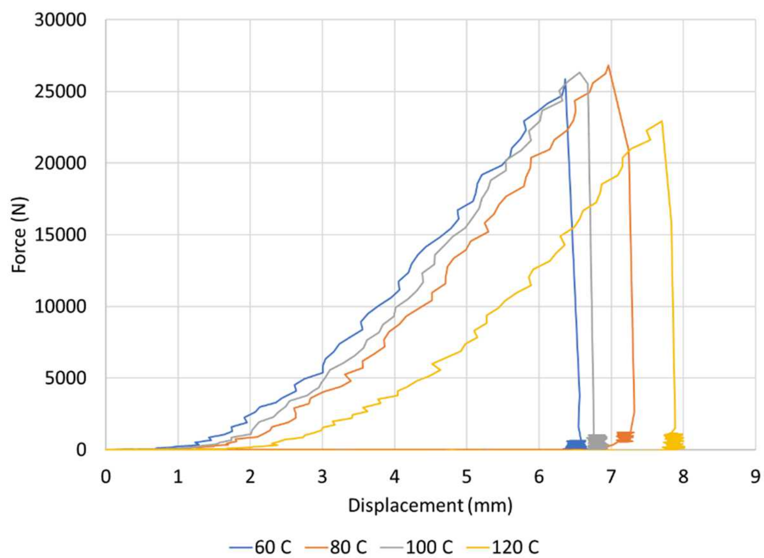

Figure 1 Force vs displacement of fully charged 5 AH pouch cells. Little changed is observed up to 60 °C, however a dramatic softening of the cell is observed at 120 °C

The observations here suggest that temperature would have minimal impact on the resilience of cells to mechanical deformation at more moderate temperatures. This and previously collected data show little apparent change in the behaviors at lower temperatures suggesting that until 120 °C we wouldn't expect the susceptibility to mechanical crush to change significantly. On-going testing is looking at this elevated temperature testing at different rates and orientations to provide a complete picture on this susceptibility.

Figure 2 Drop tower commissioning

Figure 2 shows the commissioning progress on the drop tower to perform dynamic impact testing on cells and packs. The final deliverables pursued for this project in FY19 will be to perform drop tower testing on relevant cells and packs to provide parameterization and validation of behaviors under dynamic conditions.

Information sharing with NREL continues as well. Propagation testing data collected as part of this and other projects have been shared and developed into a publication detailing the behavior of cell to cell thermal runaway. Figure 3 shows a sample of the data that has been provided. The intent is to provide sufficient data to further the analysis and understanding of multi-cell thermal runaway, particularly that introduced through mechanical failure.

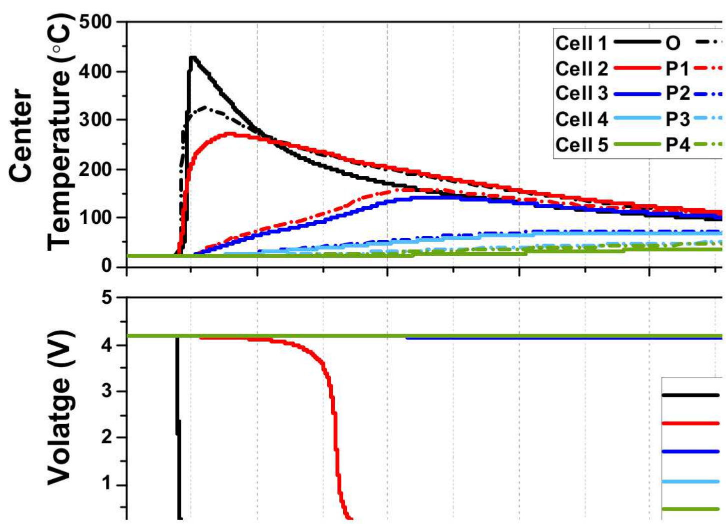

Figure 3 Example propagation data provided to NREL for multi-cell modeling activities.

Conclusions

Sandia continues to provide experimental validation results to the NREL consortium as well as providing a broader understanding of the conditions likely to cause a potentially dangerous thermal runaway event in lithium ion batteries. The current work shows that mechanical compression events continue to be the most likely to cause a thermal runaway event. There was little observed dependence on temperature with cell mechanical behavior up to 100 °C. However, at elevated temperatures a the cell was observed to require less force to drive the cell into thermal runaway suggesting softening of the constituent materials at that temperature. Sandia also continues to participate in information sharing with NREL partners as well as the USCAR Crash Safety Work Group.

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