Safety Assessment

Thermal Runaway

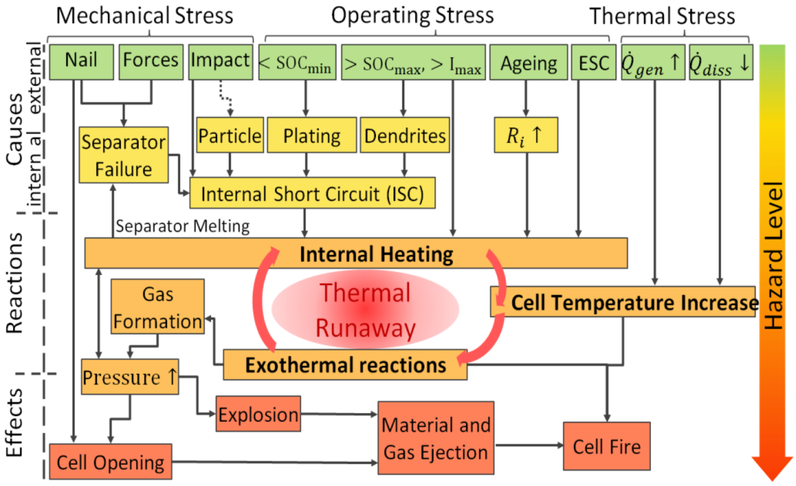

Figure 1. Causes and effects of thermal runaway in electrochemical cells during normal use, abuse or accidents.

The development of safe battery cells and packs is of the outmost importance for a breakthrough in the electrification of transport and for using batteries in stationary storage. This is because an uncontrollable increase in temperature of the entire battery system (so-called thermal runaway) can cause an ignition or even explosion of the cell with simultaneous release of toxic gases. The causes and effects of a thermal runaway can be very diverse and complex (Figure 1). Either internal or external mechanical, operating or thermal stress leads to an internal heating of the cell that initiate different exothermal reactions, which lead to a further temperature and pressure increase. The final effects can be classified by the Hazard Level (1-7). Cell designs, component integrity, and manufacturing processes all have critical influence on the safety of Li-ion batteries [1]. To avoid thermal runaway, the system must be designed optimally on material, cell, pack and system level. In addition the battery and thermal management systems must be optimally designed for the technical and commercial requirements.

Importance of safety

Safety is a crucial selection criterion for electrochemical devices. The technologies that will win widespread adoption will win it partly on their safety argument. This may require sacrificing some energy or power density, because safety issues have a major influence on consumers' willingness to adopt electrochemical energy storage systems.

Safety research also necessitates joint investigation of the effects of temperature and pressure increase, internal and external short circuits, overcharge and over discharge. Safety boundary conditions for cells in regular use, abuse and during accidents have to be investigated with specific equipment (calorimeters, hot boxes, nail penetration testers (Figure 2) and crush testers). Consequently, uniform and standardized measurements and tests as well as pre-normative work must be done to receive reliable data. One major focus is the development of common standards and protocols in cell, battery and supercapacitor safety assessment.

Figure 2. Nail penetration test on Lithium-ion pouch cell.

Safety testing on all levels of the value chain

This task focuses on mapping of the different facilities for safety testing that are available to the partners in the JPES SP1 on different levels of the value chain. It will be mostly aimed at identifying strong and weak areas of coverage and at experimentally validating the complementarity of the existing facilities.

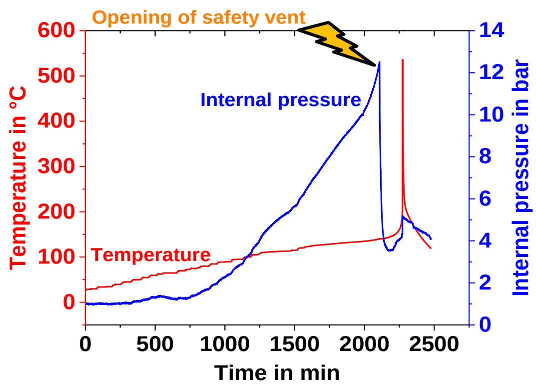

Figure 3. Temperature and internal pressure variation during thermal abuse of an 18650 cell [2].

Abuse testing is aimed at characterizing energy storage systems in off-normal or severe operating conditions/environments. The test program for abuse testing has the main objective of identifying, through controlled simulation testing, all possible risks conditions. These conditions are analysed to define mitigation measures to be used in design, control and usage of such storage systems. The results will be crucial input data for designing thermal and battery management systems. The safety assessment will be performed on all levels of the value chain:

- Materials level: differential scanning calorimeter, thermo-gravimetric analyzer, laser flash analyzers, flammability test;
- Cell level: accelerating rate calorimeter (ARC), isothermal calorimeter, hotbox, nail penetration tester, crush tester, shock tester, vacuum chamber;
- Pack level: nail penetration tester, crush tester, shaker;
- Battery level: large-scale nail penetration tester, large-scale crush tester;
- System level: EV crash test, home-storage or microgrid testing facility.

Figure 4. Two accelerating rate calorimeters (ARC) for safety testing of cells and packs.

Potential, barriers and challenges

Solving the safety issues of current electrochemical energy storages (EES) has the potential to pave the way for their large-scale adoption. In addition, improved and better standardised safety tests will help to increase quality and safety standards of cell and pack manufacturers and battery and system distributors.

For example Figure 3 clearly shows that during the thermal abuse of an 18650 cell in an ARC (Figure 4) a pressure increase occurs much earlier than self-heating [2]. Thus the internal pressure could be used for the early prediction of processes leading to thermal runaway. Practically a pressure sensor is applied to the cell or the pack.

One of the main barriers is a lack of common safety testing standards on the cell, pack and battery level [3]. Furthermore access to the relevant data is difficult due to IP protection rules. The influence of aging on the safety of the cells is a very critical factor for their commercial use, especially in view of 2nd life applications such as the adaptation of used EV batteries for stationary storage.

According to a recent presentation by the JRC in Petten a challenging and timely topic is the development of a reliable thermal propagation test method [4]. Especially for EV's it is of utmost importance to allow enough time (5 min) to egress the vehicle in case of a battery accident. Thus this WP supports the development of new standards with experimental pre-normative research, which will define and validate test procedures for safety characterization of current and novel electrochemical storage systems on the cell, pack and battery levels in close cooperation with JRC and other stakeholders from academia and industry. Specifically, it provides access to relevant data as well as written guidelines.

Potential

- Paving the way for large-scale adoption of EES by reducing safety issues
- Improving the quality and safety standards of manufacturers and distributors
- Guidelines for the development of intrinsically safe materials such as solid-state electrolytes

Barriers

- Clear classification of thermal runaway rates is missing
- Different safety standards in different applications, markets and countries
- Difficult access to relevant data
- Long experiments needed for assessment of ageing effects on safety (2nd life option)

Challenges

- Development of common safety standards
- Ensuring access to relevant data
- Development of thermal propagation test method with higher reliability

References

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[2] B. Lei, W. Zhao, C. Ziebert, A. Melcher, M. Rohde, H.J. Seifert, Experimental analysis of thermal runaway in 18650 cylindrical cells using an accelerating rate calorimeter, Batteries 3 (2017) 14, doi:10.3390/batteries3020014.

[3] V. Ruiz, A. Pfrang, A. Kriston, N. Omar, P. Van den Bosche, L. Boon-Brett, A review of international abuse testing standards and regulations for lithium ion batteries in electric and hybrid electric vehicles, Renewable and Sustainable Energy Reviews 81 (2018) 1427–1452 doi: 10.1016/j.rser.2017.05.195.

[4] V. Ruiz, A. Pfrang, A. Kriston, N. Omar, P. Van den Bosche, L. Boon-Brett, Safety testing of lithium ion traction batteries; identifying gaps and shortcomings, Advanced Battery Power, Münster, 10-04-2018, https://www.researchgate.net/publication/324942334

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