Physics-based Modeling of Ageing Phenomena in Commercial Li-ion Pouch Cells

Evelina Wikner[a], Torbjörn Thiringer[a, b], Johan Scheers[b]

[a]*Electric Power Eng, Chalmers University of Technology, SE-41296 Gothenburg*
[b]*Propulsion Energy Systems, Volvo Car Corporation, SE-40531 Gothenburg*

E-mail: evelina.wikner@chalmers.se

There is a strong trend for vehicle manufacturers to electrify their vehicles using Lithium-ion batteries (LiBs) as the energy storage unit. The requirements on LiB life, safety and performance are high, since the battery is the most expensive component. These properties are strongly influenced by the conditions of use and to compete with combustion vehicles it is important to utilize the LiBs with the largest possible operation window. Being able to correlate load cycles to a specific type of ageing will improve the understanding how to better utilize the LiBs - improving lifetime predictions and extending the LiB lifetime in the vehicle.

A physics-based model has been used to simulate ageing of a commercial Li-ion pouch cell with a graphite anode and a blended LMO/NMC cathode. The model, based on the Newman theory [1] and implemented in COMSOL, relate to previous results in [2-6] and is a direct continuation of the work in [6]. The model has been tuned with respect to experimental test data and shows how the SEI growth can be implemented and mathematically linked to a change in active material porosity by reducing the volume of electrolyte in the electrode. The resulting effect on the cell resistance and capacity during various test conditions is determined for different ageing parameter values.

The experimental tests were performed using synthetic load cycles for various C-rates, at different Depth of Discharge (DOD) and at different State of Charge (SOC). The results show an expected increased ageing with C-rate, but more surprising is the ageing pattern seen for small DOD, at various SOC intervals, which does not follow the trend observed for LiBs with LFP cathodes [7]. The LiB tested here degrade most strongly at high SOC (>60%), in accordance with previous research, while at SOC < 30% ageing is impressively slow. The tests in SOC < 30% are still not close to reach end of life (EOL), even after 3x longer test period compared to the tests in high SOC. The developed ageing model can successfully capture the difference in capacity loss due to larger SEI growth at high SOC.

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