Degradation Characterisation of Lithium-ion Batteries using Non-Destructive Ultrasonic Inspection

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Abstract

Lithium-ion batteries are extensively utilized in many applications ranging from smartphones to electric vehicles. Battery degradation deprives the performance of energy storage systems so monitoring it is important. Destructive methods are mainly used to observe the mechanisms that lead to battery degradation. This methods do not allow for battery degradation to be analysed along the lifetime of a battery.

The aim of this project was to use Non-Destructive Testing (NDT) to monitor the degradation process for a Lithium-ion battery throughout its lifetime. Monitoring was performed via the use of an ultrasonic transducer attached to the external surface of a Lithium-ion cell. The cell was cycled, and ultrasonic inspections every 50 cycles showed correlation between ultrasonic amplitude and number of cycles.

Motivation

- Ultrasonic inspection can run in real time allowing for structural changes in the battery to be observed both during a single cycle and throughout its lifetime.
- What properties of the reflected echo signal can give valuable information about the cell's state of health?
- What is the dependency of the ultrasonic inspection results on the cell's state of charge?
- Study the effect of different cell chemistries on the NDT results during the degradation process

Methods

- Three different types of cells were used:
  - NMC 622 with five layers.
  - NMC 811 with five layers.
  - LFP with ten layers.
- Test rigs were designed and created via the use of laser cutting, 3D printing and manual machining.
- The cells were cycled at 1C while monitoring their state of health.
- Every 50 cycles, cells underwent the NDT procedure using a 5MHz transducer.
- NDT was performed at 100%, 75%, 50%, 25%, 0% State of Charge
- NDT data was converted to unsigned and smoothed using a Savitzky-Golay filter of second polynomial order.

NDT results for LFP cell

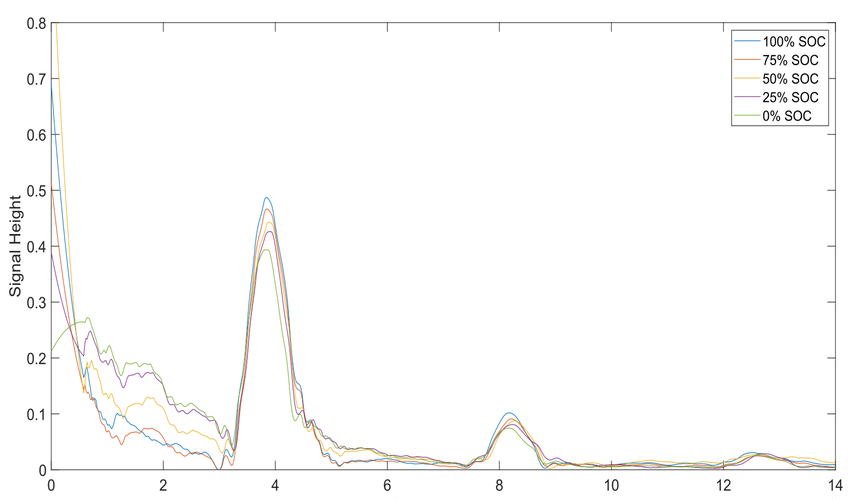

Figure 1: NDT results for the LFP cell at the cell's beginning of life for the five SOC values

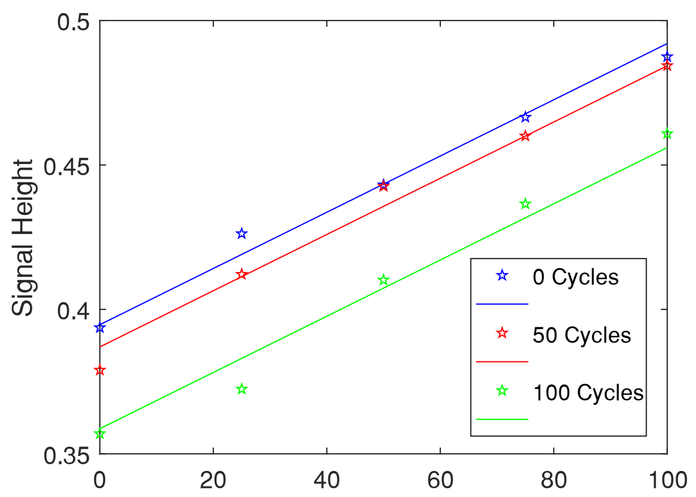

Figure 2: Ultrasonic amplitude for the LFP cell determined from the first-reflected echo signal

NDT results for NMC 811 cell

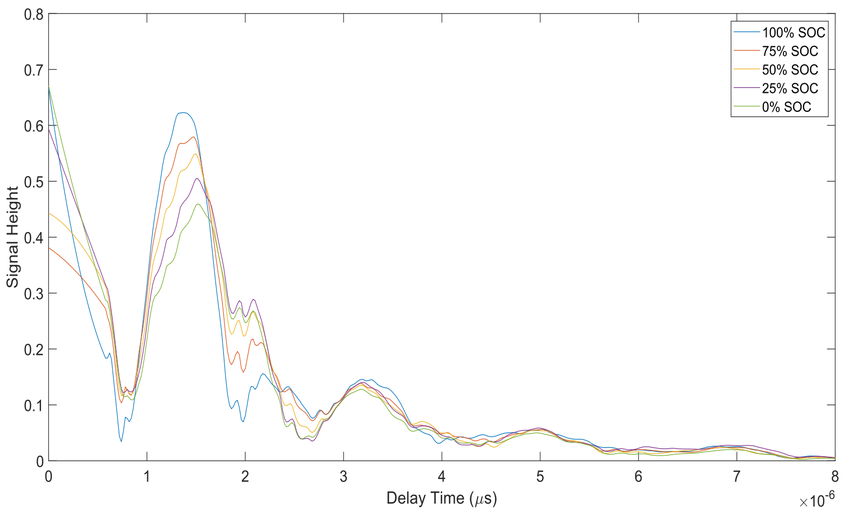

Figure 3: NDT results for the NMC 811 cell at the cell's beginning of life for the five SOC values

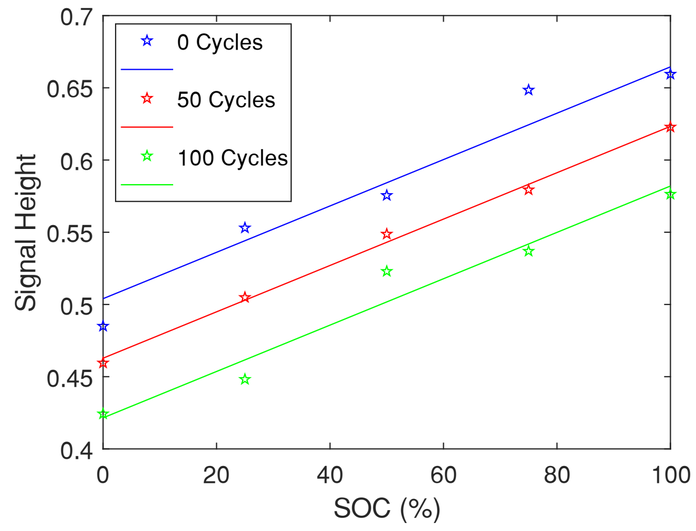

Figure 4: Ultrasonic amplitude for the NMC 811 cell determined from the first-reflected echo signal

NDT results for NMC 622 cell

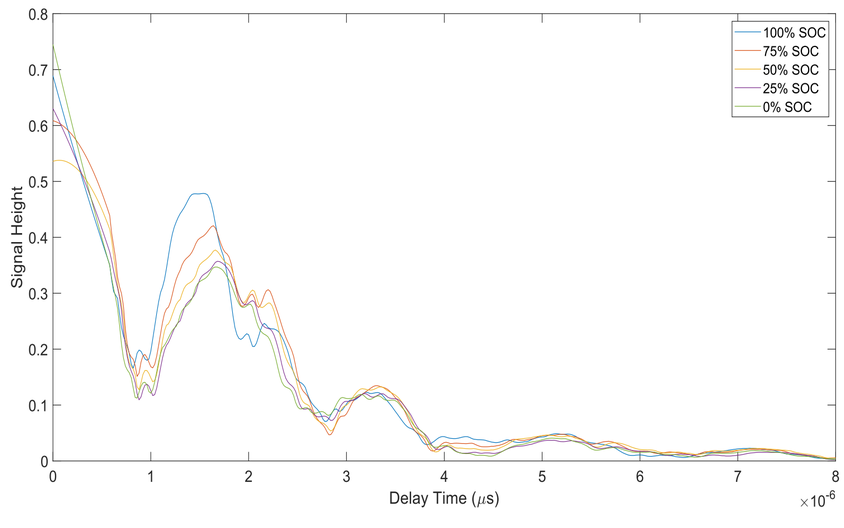

Figure 5: NDT results for the NMC 622 cell at the cell's beginning of life for the five SOC values

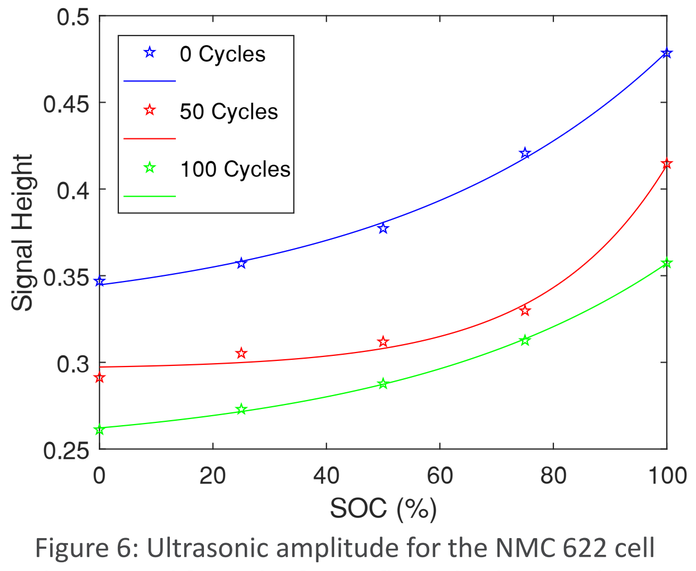

Figure 6: Ultrasonic amplitude for the NMC 622 cell determined from the first-reflected echo signal

Conclusions

- Three Lithium-ion cells with different chemistries were tested over 100 cycles at 50 cycle intervals
- The results for all three cells showed correlation between the amplitude of the first-reflected echo signal and the number of cycles. The ultrasonic amplitude drops as the cells are aging for all three cell chemistries
- The results for all three cells showed strong correlation between the amplitude of the first-reflected echo signal and the sate of charge. This relation changes with the chemistry of the cell as the NMC 622 offers an exponential relation while NMC 811 and LFP cells offer a linear relation

Impact / Next steps

- The work done demonstrated that ultrasonic inspection can provide some meaningful information about a battery's state of health
- This technology can be integrated to the battery management system providing real-time measurements to update the degradation model
- Further experiments are required to improve the quality of results by:
  - Conducting the ultrasonic inspections until the cell reaches its end of life
  - Increasing the number of cells to find the repeatability of the results

Intern bio

Nikolas Loizou is entering the 4th and final year of his MEng Mechanical and Electrical Engineering degree at the University of Bristol. He has strong interest in renewable energy and Lithium-ion batteries, especially in the automotive sector. He is particularly passionate with lab-based research where work is hands-on and innovative ways to overcome difficulties are required.

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