Impact of ageing at different C-rates on battery performance

Using Galvanostatic Intermittent Titration Technique

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Abstract

- The need to move towards a more electrical future and the subsequent increase in demand for Li ion batteries (LIBs) has increased research into improving the efficiency, safety and capacity of LIBs.
- This is especially important in the automotive industry, where electric vehicles require batteries with long range, long cycle lives, and fast charging times. Advancements are often countered by increases in resistance and battery capacity fade.
- In this study, Galvanostatic Intermittent Titration Technique (GITT) is used over the course of 160 ageing cycles at various C-rates to explore resistance-based issues.

Motivations

- **Key issue**: degradation, i.e. resistance and capacity fade, increases with faster charging. This issue is exacerbated as the cell ages. Therefore, creating safe and efficient fast-charging EVs has been a great challenge in the automotive industry.
- **Key question**: How do we improve the performance of batteries so that EVs are as convenient for everyday use as petrol/diesel?

Theory

GITT test: a type of electrochemical test. A cell is supplied with alternating periods of rest and positive (charging)/negative (discharging) current pulses. The evolution of voltage and current over time is measured.

- Several tests at different C-rates* (0.5C and 1C) were carried out over 160 ageing cycles to calculate the battery's ohmic resistance, according to equation [1]:

$$R_i = \frac{|E_{max} - E_{eq}|}{I_{applied}} \quad [1]$$

➢ GITT tests from 0-100% state-of-charge (SOC)* without ageing and after 160 cycles of ageing at both 0.5C & 1C

An analogous test is the HPPC test. This supplying a cell with rapid discharging and regeneration pulses from 0-100% SOC*. The evolution of voltage and current over time is measured.

Both the GITT and HPC test were researched however the GITT test was chosen for this study as it is more efficient for the internship timescale and provides more datapoints across state of charge.

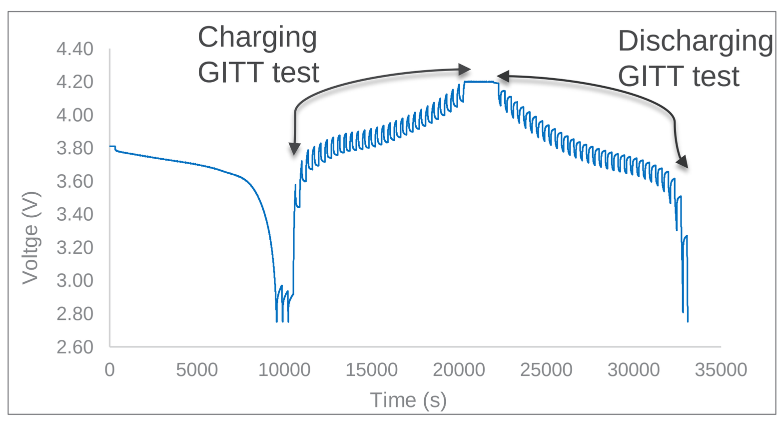

Figure 1 – example GITT profile

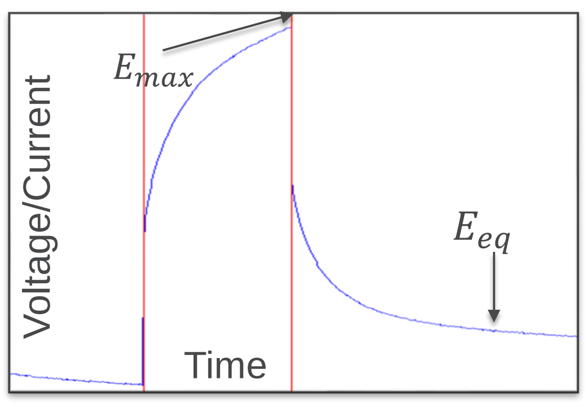

Figure 2 – a single GITT pulse

C-rate = charging rate of the battery. 1C = full charge within an hour; 0.5C = full charge in 2 hours

Methods

Figure 3 – Image of an example pouch cell used in this study

1. Ageing cycles

- 1C C-rate → 1300mA of current supplied
- 0.5C C-rate → 650mA of current supplied
- 20 ageing cycles (full battery charge and discharge) at either 1C or 0.5C.

2. GITT test

- Current pulse period: 2-minute pulses of 650mA.
- Rest period: 4-minute period of zero current.
- Pulse and rest periods repeated from 0-70% SOC. The tests were not taken up to 100% SOC as this study was focussed on providing data for electric vehicles which often don't exceed 70% during rapid charge.

3. **Repeat** up to 160 ageing cycles

BTLab was used to program the parameter settings and cell characteristics.

GITT results and observations

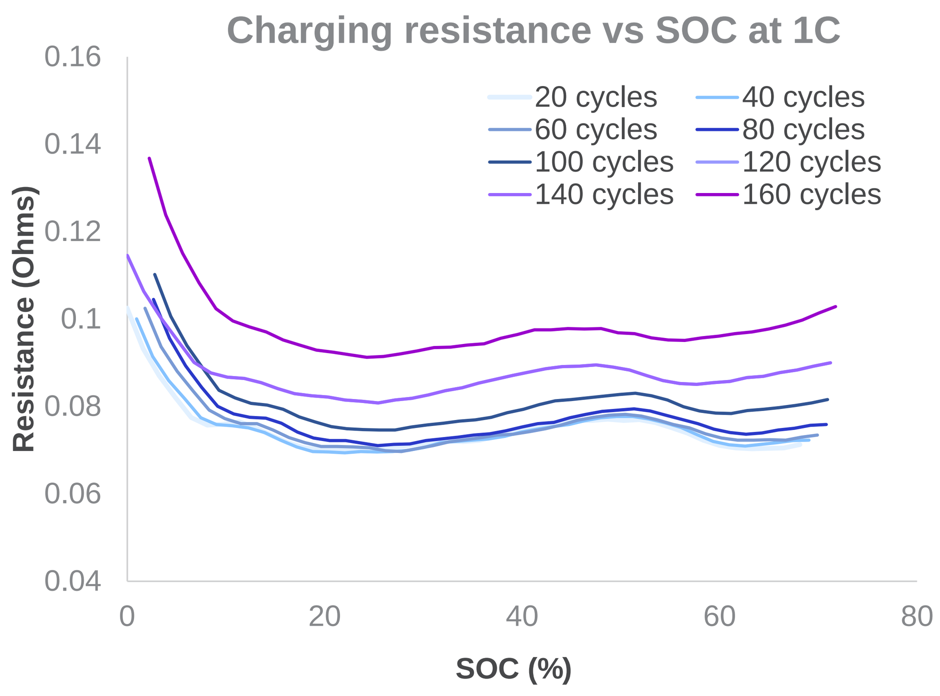

Figure 4 – Charging resistance vs time after 160 cycles 1C ageing

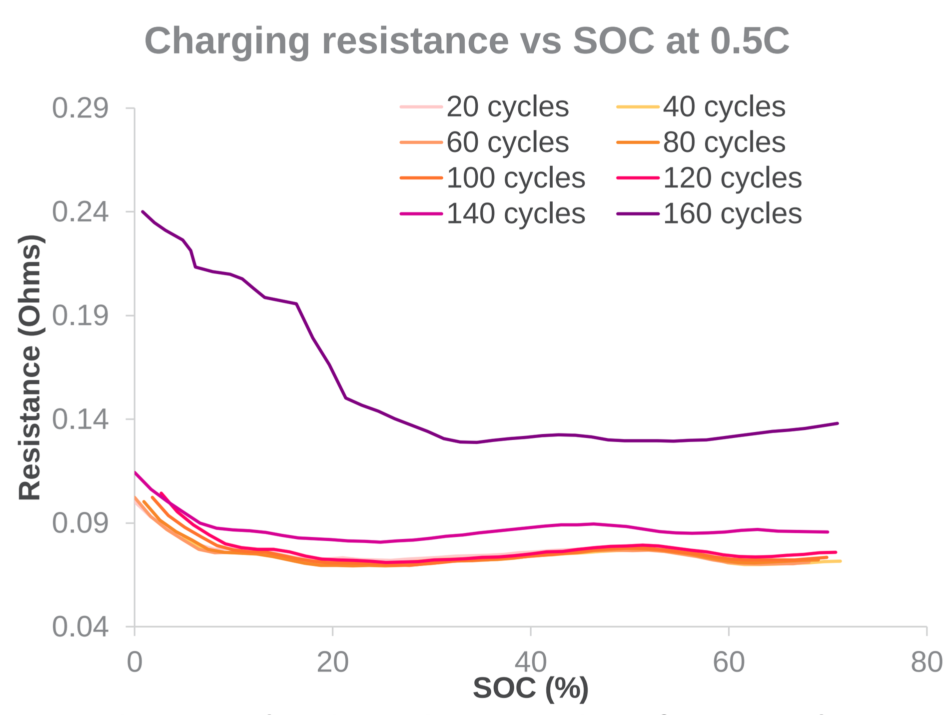

Figure 5 – Charging resistance vs time after 160 cycles 0.5C ageing

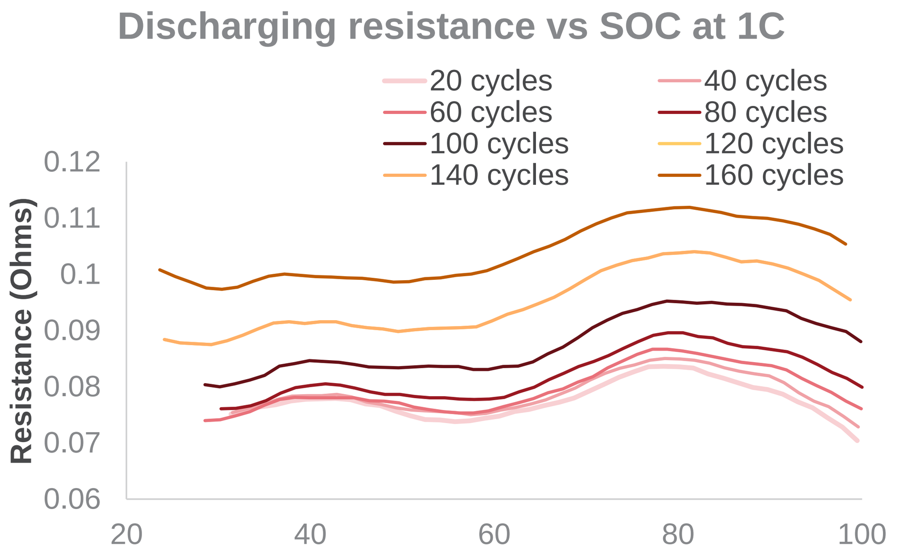

Figure 6 – Discharging resistance vs time after 160 cycles 1C ageing

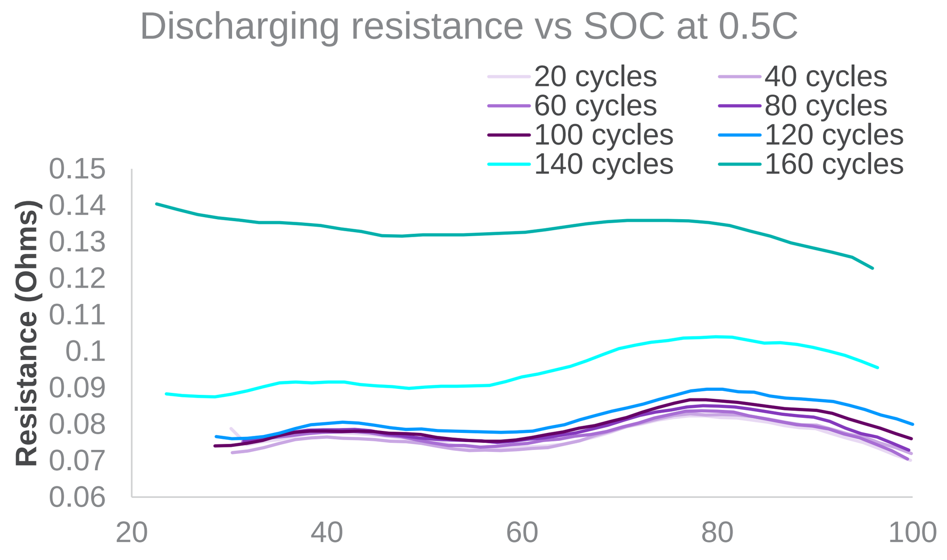

Figure 7 – Discharging resistance vs time after 160 cycles 0.5C ageing

- Resistance is higher at 1C than 0.5C
- The increase in resistance between ageing cycles is faster at 1C than at 0.5C
- Charging resistance is greater than discharging resistance
- During charging, resistance is high at low SOC and high SOC
- During discharging, resistance is high at high SOC
- At 0.5C there is a larger increase from 120-140 and 140-160 cycles than at 1C

***discharging tests were not taken to 0% SOC to prevent over-discharging*

Conclusions and next steps

➢ ***Observation:* *increasing resistance with cycle number***

- **Interpretation: degradation at the anode → development of the SEI (solid electrolyte interface) and non-SEI due to reductive electrolyte decomposition (1). Results in decreased contact between the anode and the electrolyte and hence reduced conductivity.**
- **Interpretation: degradation at the cathode → Binder decomposition, corrosion of the current collector, oxidation of the conductive agent**

➢ ***Observation:* *high resistance at low SOC***

- **Interpretation: corrosion of current collectors**

➢ ***Observation:* *high resistance at high SOC***

- **Interpretation: enhanced electrolyte decomposition and SEI formation**

Next steps:

- **Use statistical tests (such as the Chi-squared test) to assess whether there is any statistically significant difference between resistance after 1C and 0.5C ageing.**
- **Calculate resistance and pulse power capability using hybrid pulse power characterization (HPPC)**
- **Monitor how resistance changes with ageing when using 4.2C (~5600mA)**

References

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Intern bio

Chloe Wills is a student studying Natural Sciences at the University of Cambridge. She is about to enter her 3rd year, hoping to specialise in electrochemistry and surface chemistry.
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