

LFP battery aging study: selecting batteries for reuse in a second life

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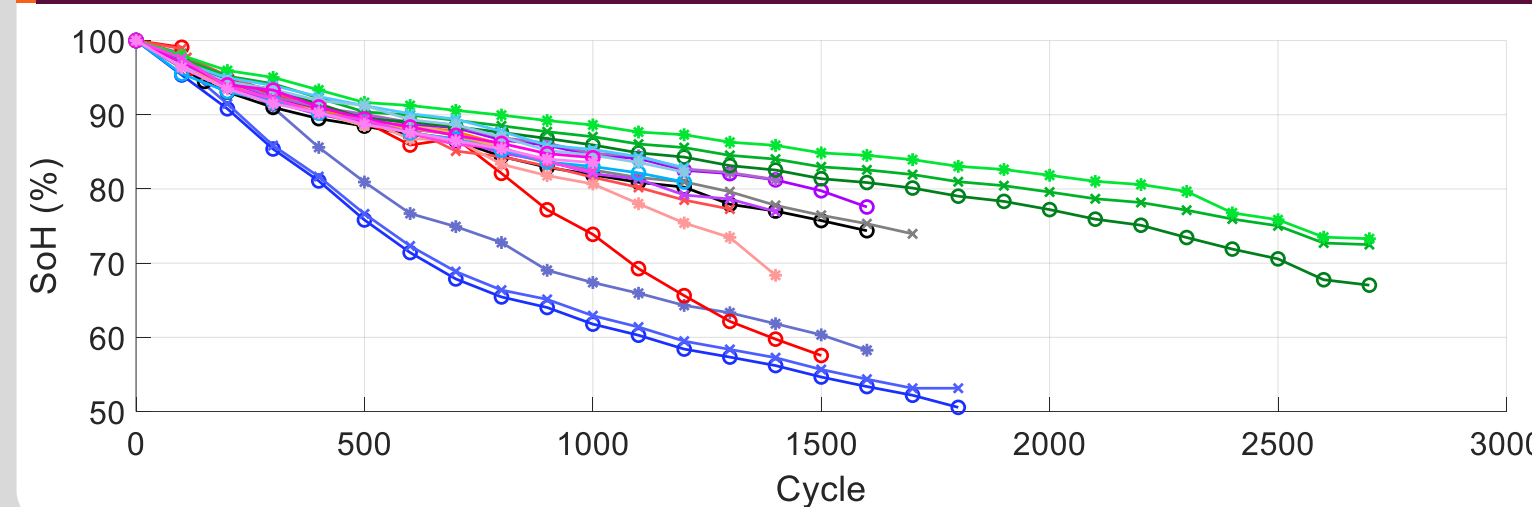
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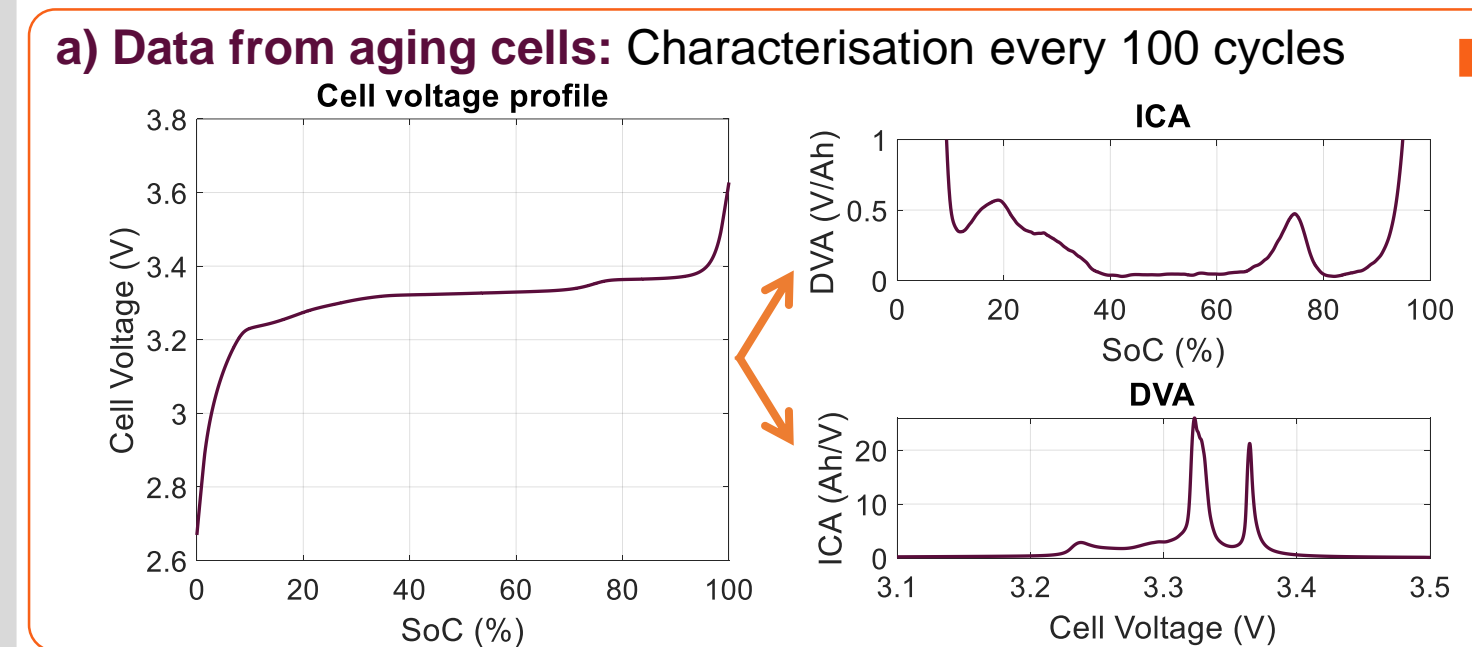
1. INTRODUCTION

A battery sorting process is a milestone in achieving and ensuring reliability of batteries in a **second life**. Batteries from **specific electric vehicles** age differently due to different parameters such as design, use and environment. Second life batteries recomposed from first-life elements must be **guaranteed** for a specified time and use. In some cases a **sudden shift in cell aging** may appear: capacity loss, resistance increase [1-3]. **Prognosis** of the remaining useful life requires a diagnosis of aging modes to understand these changes [4].

3. IN-PROCESS EXPERIMENT



4. AGING MODE IDENTIFICATION METHOD



c) SoH estimation of industrial cells

- **Cell SoH:** based on capacity cycling measurement
- **SoH_{neg.} (SoH negative electrode estimation):** ICA and DVA: detection of voltage plateaus and drops → negative electrode phase information. So $SoH_{neg.}$ negative electrode :

$$SoH_{neg.} = \frac{|Q(LiC_{x_b}) - Q(LiC_{x_a})|}{y_{x_b} - y_{x_a}}$$

Where :

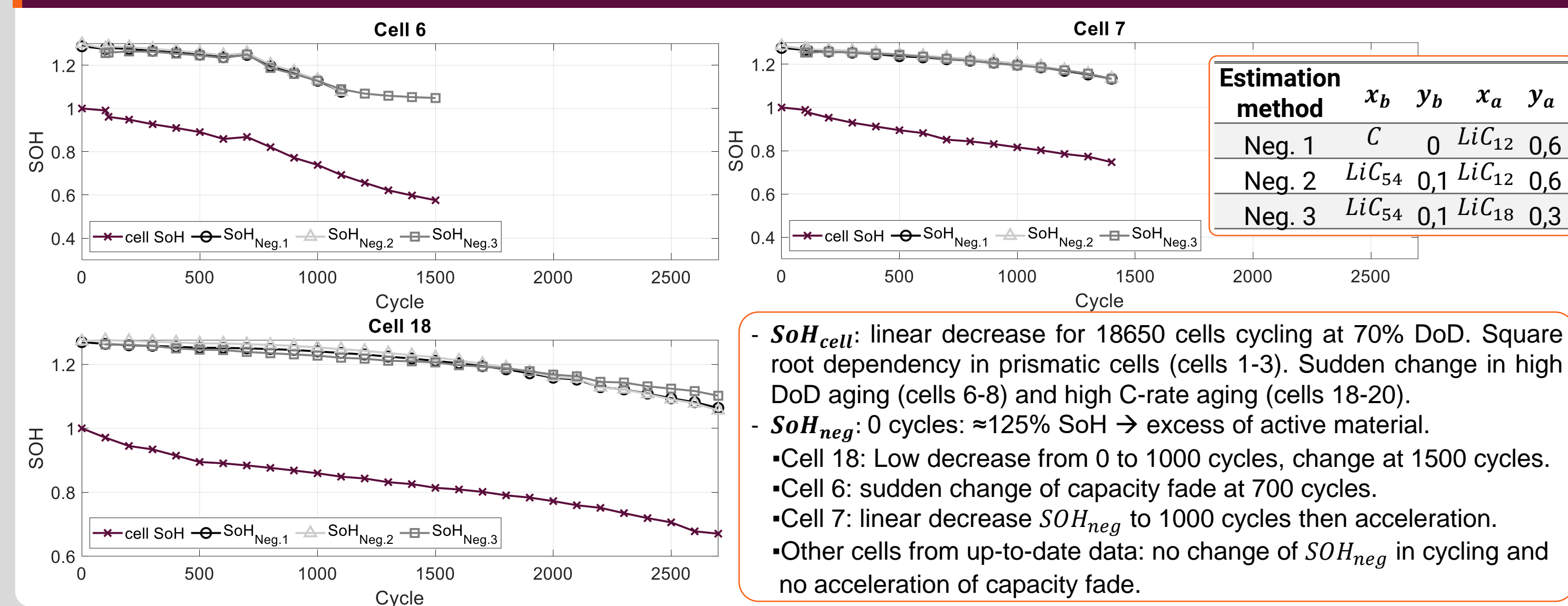
- Q the capacity measured at LiC_{x_a} and LiC_{x_b}
- y_a and y_b the negative electrode accessibility at a given phase LiC_x , respecting $x_b > x_a$.

2. EXPERIMENTAL CHOICE

- Accelerated aging study at 50°C on 23 LFP cells, prismatic and cylindrical 18650.
- Charge: CC only or CC-CV to cut off voltage : 3,65V or 3,55V. End of charge at C/10 for CV phase.
- Discharge: WLTP at C/3 average or fast discharge at 2C.
- Full or partial discharge : DoD of 100% or 70%.

Cell reference	DoD (%)	Charge type	Cut-off voltage	Charge C-rate	Discharge condition
prismatic 1	70	CC	3.65V	C/3	WLTP
prismatic 2	70	CC-CV	3.65V	C/3	WLTP
prismatic 3	70	CC-CV	3.55V	C/3	WLTP
18650 4, 5	70	CC	3.65V	C/3	WLTP
18650 6, 7, 8	100	CC	3.65V	C/3	WLTP
18650 9, 10, 11	70	CC-CV	3.55V	C/3	WLTP
18650 12, 13, 14	70	CC-CV	3.65V	2C	WLTP
18650 15, 16, 17	70	CC-CV	3.55V	2C	WLTP
18650 18, 19, 20	70	CC-CV	3.65V	2C	CC (2C)
18650 21, 22, 23	70	CC-CV	3.65V	C/3	WLTP

5. AGING MODE FOLLOW-UP



6. FUTURE WORK

- **Aging mode identification SoH_{cell} and SoH_{neg}** is possible. Evolution differs through time and may imply a change in aging dynamics. In-process experiments continue until the end of second life: $SoH \approx 30\%$.
- **Aging mode factors:** in process experiments → identification of causes for each aging mode: beneficial or detrimental impact.
- **Eligibility** for reuse in second life applications depends on **battery SoH** and future **application scenario**:
 - **Battery diagnosis** based on conducted experiments and degradation modes. Aging mode diagnosis: on-board during first life use or at the disposal plant.
 - **Battery prognosis** based on first life use and specified second life scenarios: charge and discharge C-rate, DoD, cut off voltage.
- **Remaining Useful Life (RUL):** based on the prognosis model.

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