Experimental analysis of the aging behavior of battery packs with forced air cooling and immersed cooling system

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Abstract

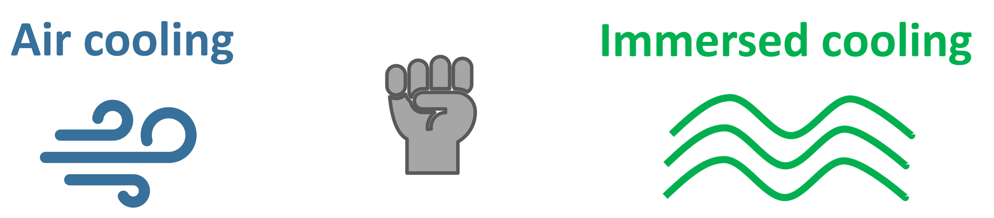
Thermal management is a fundamental factor when designing battery packs to guarantee performance, safety, and lifetime in the application. This work presents an experimental study of degradation of two 18650- battery packs, one with air cooling and one with a novel immersed cooling system. The behavior of the two packs subjected to same degradation profiles but different cell temperature distribution is analyzed.

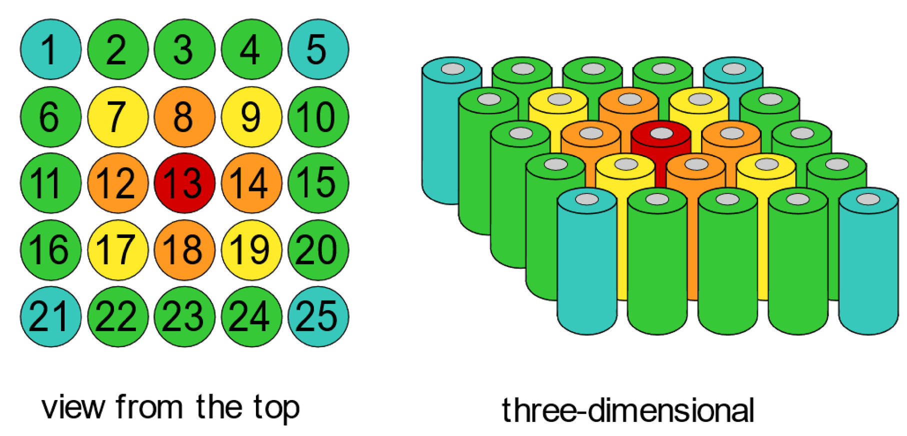
Conclusion

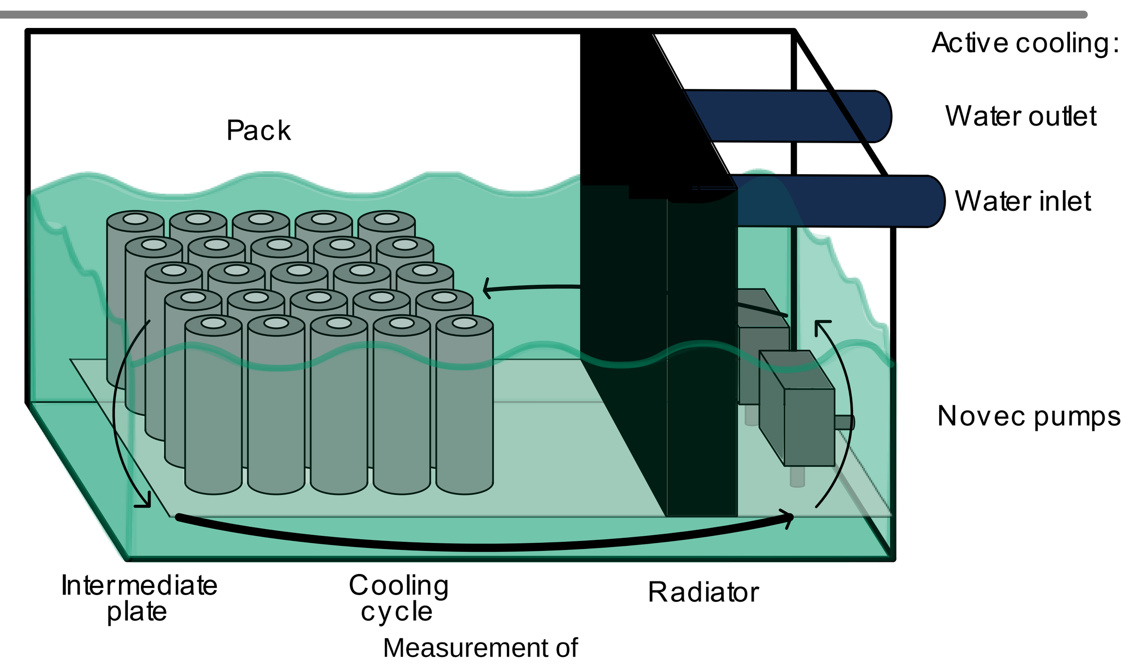
Homogeneous temperature distribution can be kept up to a maximum difference between cells of 1.5°C for immersed-cooled pack against 15°C for air-cooled pack. This generates increase of capacity retention up to 3.3% for immersed-cooled pack after 600 cycles. Even though temperature is kept uniform, immersed cooled pack experienced cell failures, which were not visible in the air-cooled pack.

Battery pack and setup construction

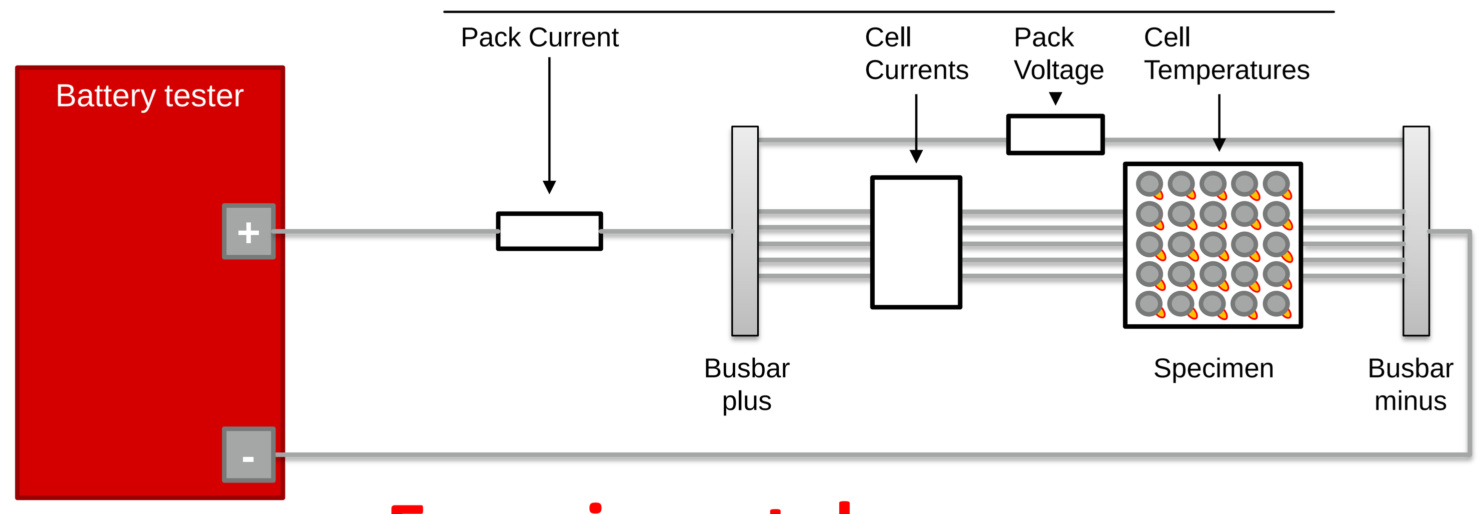
- Two battery packs with 25 cylindrical Li-ion cells of type US18650VTC6 are assembled
- Two different cooling systems:





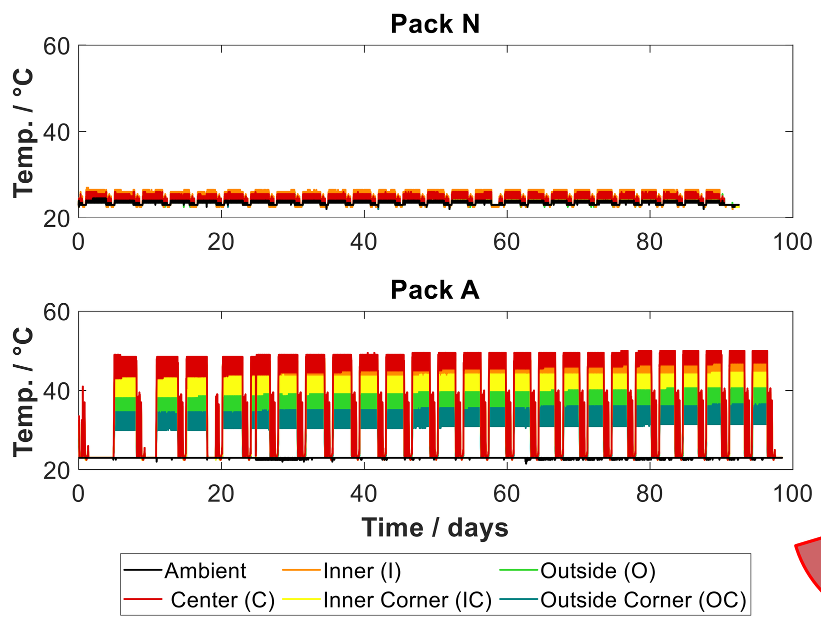


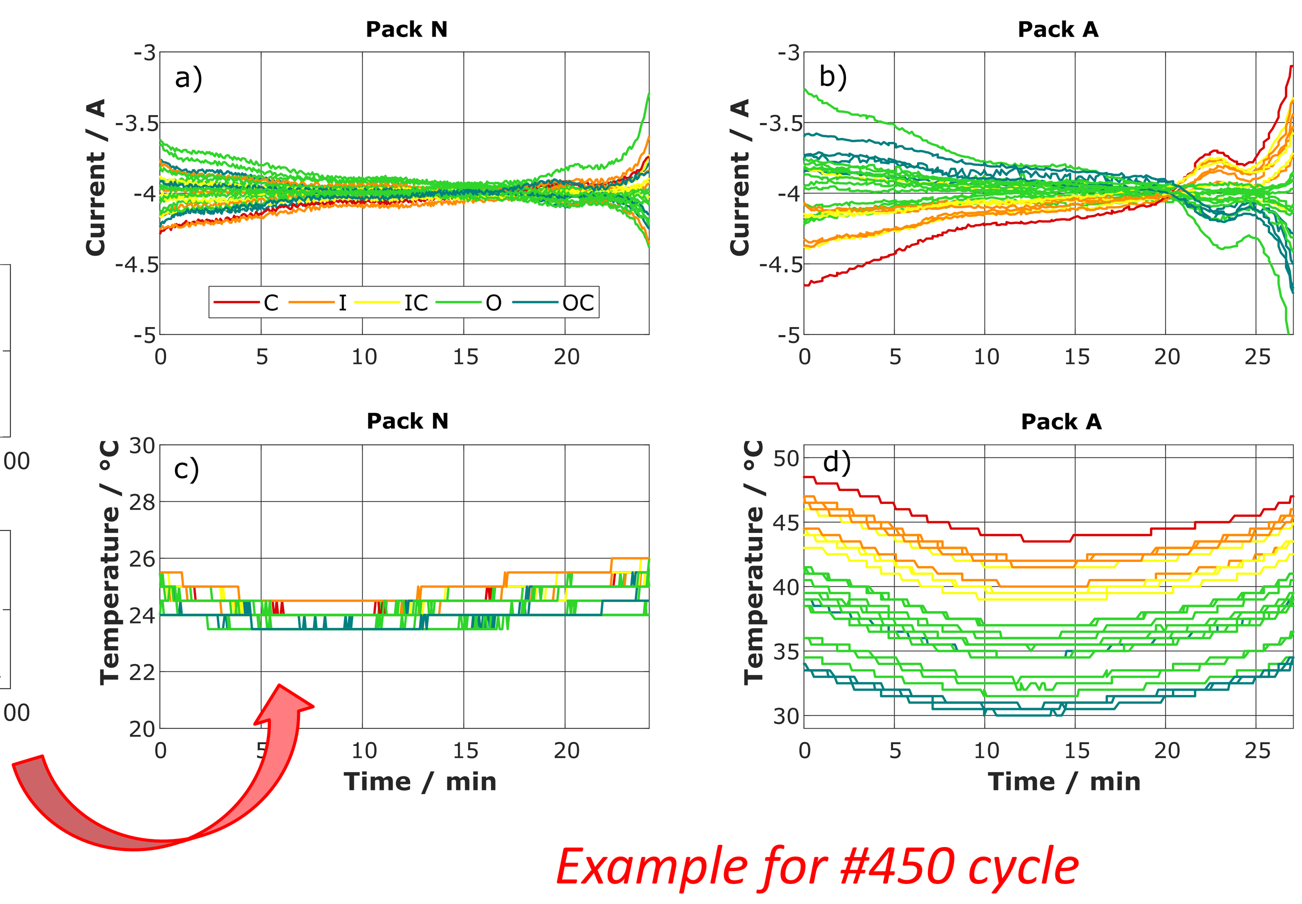
- In reference Pack A, air is circulated inside climate chamber
- Cooling liquid NOVEC[1] is employed for immersed cooling system (Pack N), where coolant is forced circulated
- Each single cell temperature and current is monitored



[1] NOVEC datasheet: https://multimedia.3m.com/mws/media/338713O/3m-novec-7300-engineered-fluid.pdf.

Temperature evolution during degradation





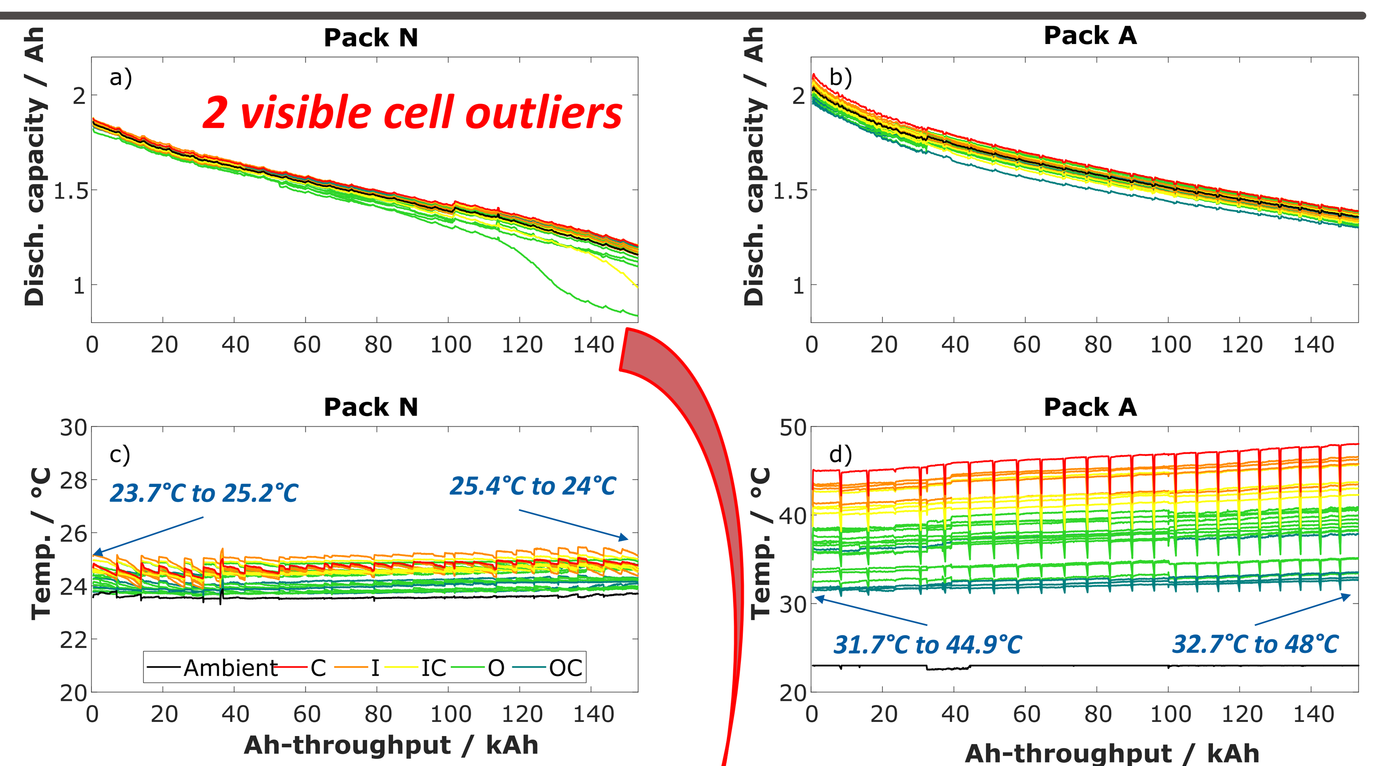
Example for #450 cycle

Experimental

- Each cell performs a checkup before assembly
- Packs are cycled with constant current of 1.33C (100 A) between 2.5 V and 4.2 V (~65% DOD at BOL)
- Pack checkup is performed every 75 cycle to measure capacity (1C) and pulse response (1C)
- Temperature of climate chamber and coolant is kept at 23°C
- EOL is defined as 80% of initial capacity

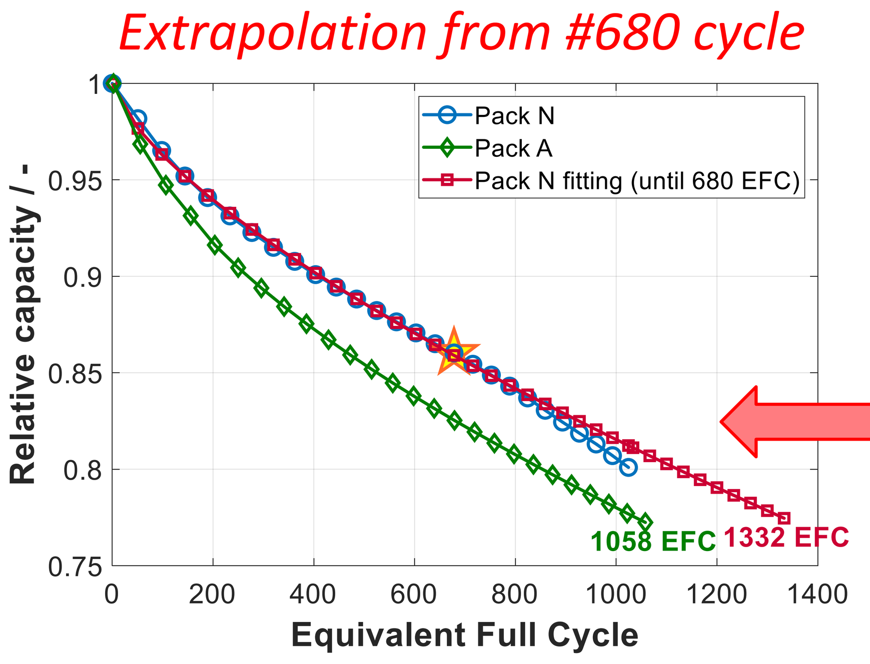
Degradation results

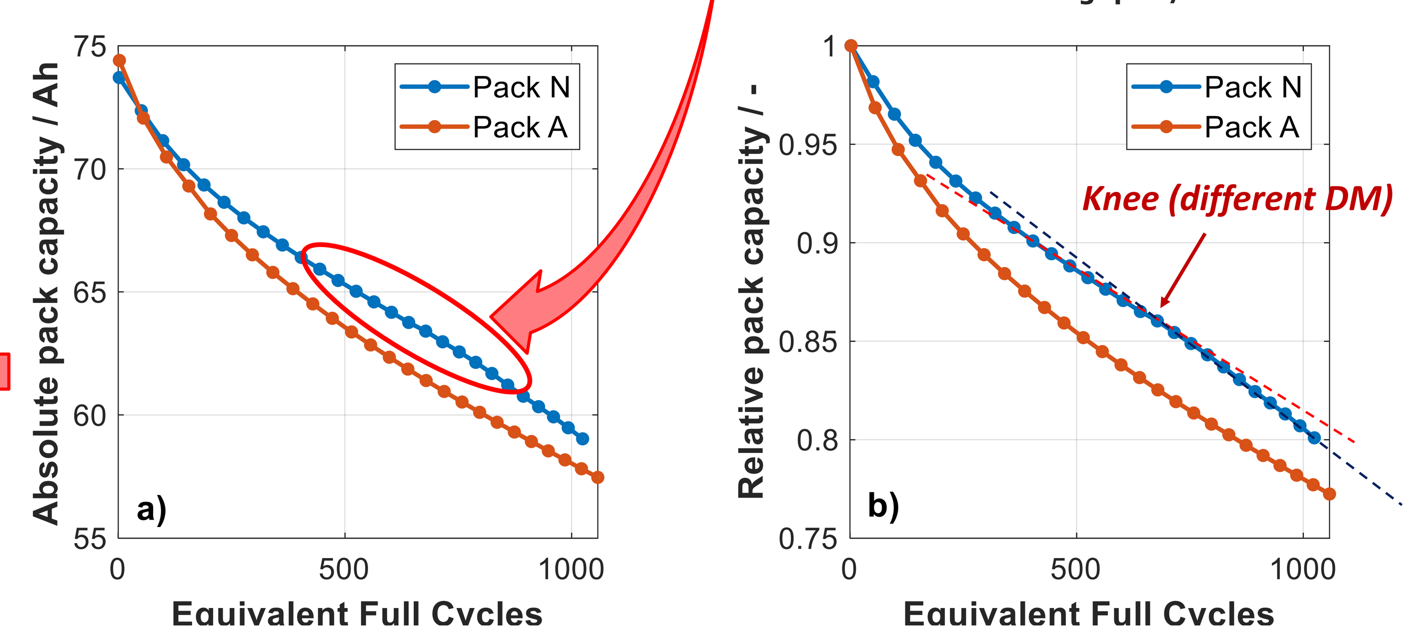
- Pack A → Rather uniform capacity fade among the cells, temperature variance among cells significant
- Pack N → Temperature rather uniform, capacity variance among cells is visible due to 2 cell outliers
  - Reasons are under investigation in disassembled pack
  - Due to this, capacity trend changes around 700 EFC



- Despite this, still Pack N reaches longer lifetime (↓ temperature)
- Extrapolation generates additional approx. 300 EFC for Pack N
- In application higher temperature of coolant shall be set to increase total available energy

Extrapolation from #680 cycle





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