Comparison of the Effect of Real and Simulated Driving Profiles on the Electric Vehicle Battery

George Baure and Matthieu Dubarry

HNEI Hawai'i Natural Energy Institute
School of Ocean and Earth Science and Technology
University of Hawai'i at Mānoa

Matthieu.Dubarry@gmail.com

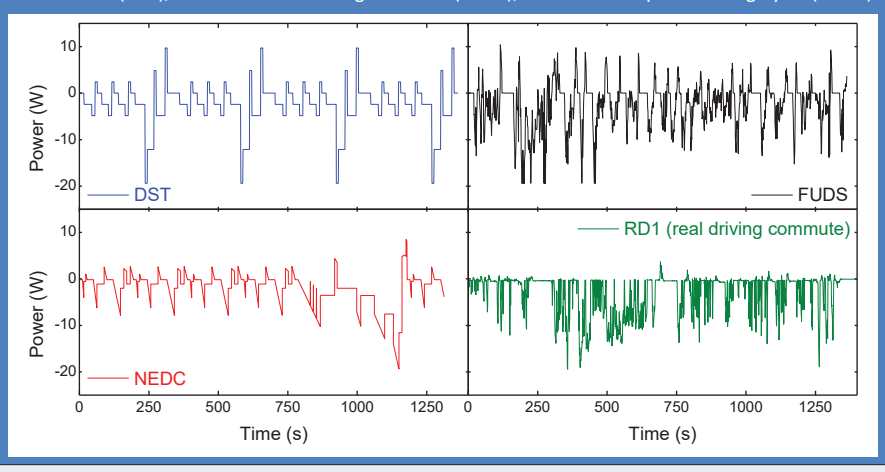
Introduction

Synthetic driving cycles and accelerated aging protocols are essential to accumulate data on electric vehicle (EV) battery lifetimes.
Battery deterioration is path-dependent and this work focused on the representability of synthetic driving cycle in terms of mimicking actual EV battery degradation.

This study aims to elucidate any significant discrepancies between simulated and real driving, suggest possible improvements, and provide a viable description of cell degradation throughout the life of the battery.

Design of experiment

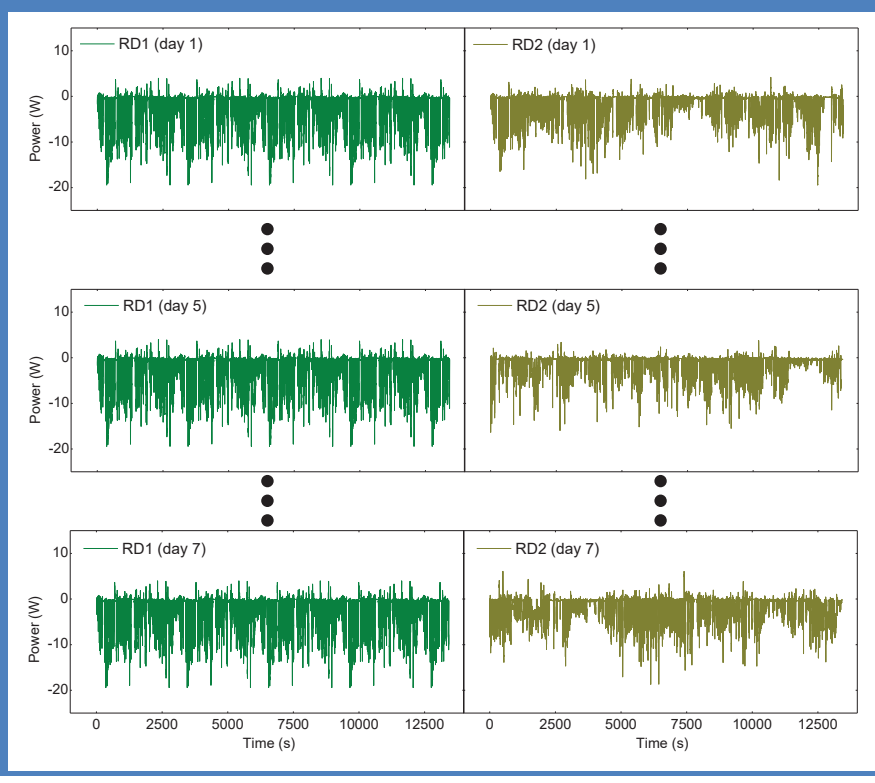
- 3 synthetic driving profiles were applied on Panasonic cylindrical 3350 mAh NCR 18650B cells:
  Dynamic Stress Test (DST), Federal Urban Driving Schedule (FUDS), and New European Driving Cycle (NEDC)



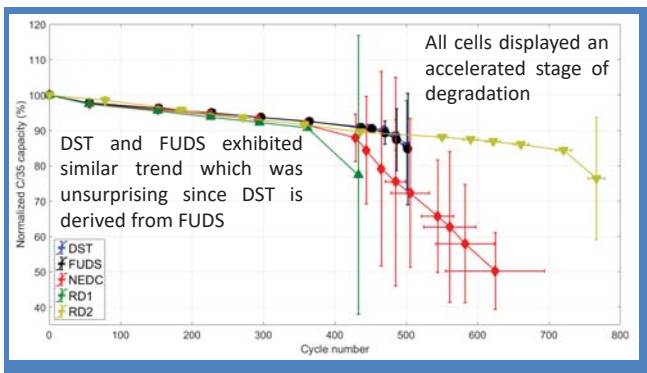
During first discharge (3 cells tested per profile, 15 cells total)					
Driving profiles	**Avg. Current (A)**	**C rate based on avg. current**	**Discharge time (hour)**	**Charge Capacity (Ah)**	**Discharge Capacity (Ah)**
DST	-0.68	C/4.8	4.03	0.51	3.29
FUDS	-0.70	C/4.6	3.74	0.56	3.20
NEDC	-0.66	C/4.9	4.25	0.30	3.13
RD1: real driving (commute comparable to simulations)	-0.73	C/4.5	4.12	0.03	3.03
RD2: real driving (complete dataset)	-0.45	C/7.3	6.73	0.04	3.01

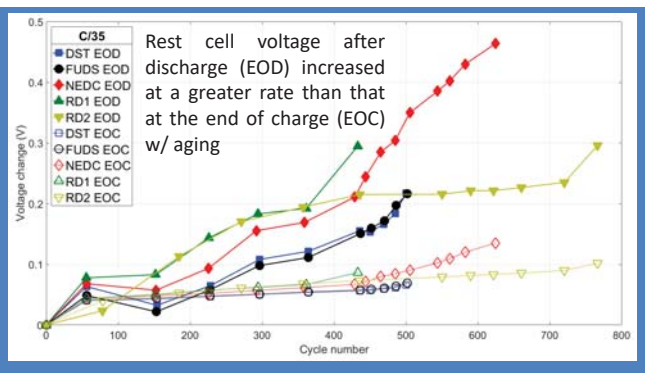
- Actual discharge time lower than expected from the average current due to the dynamic applied current
- Driving data had no regenerative braking: simulated profiles have more charged capacity during driving

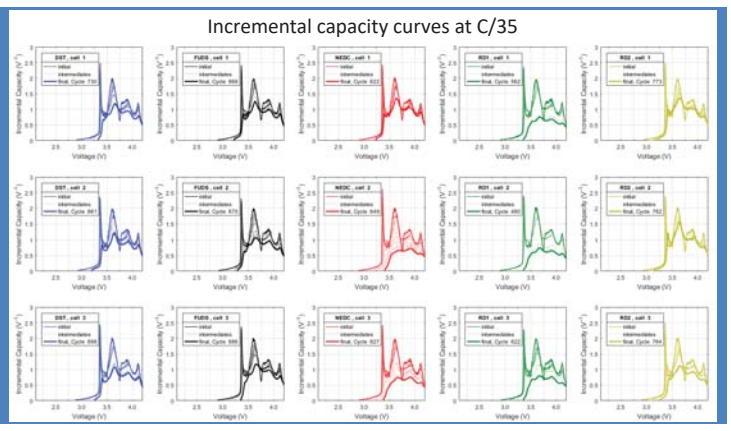
- Real driving data obtained from 2-year EV data collection program
- RD1 is 1 commute with an average discharge current comparable to the simulations
- RD2 is a set of 30 unique commutes
- Driving profiles were repeated until the cell were fully discharged



Data

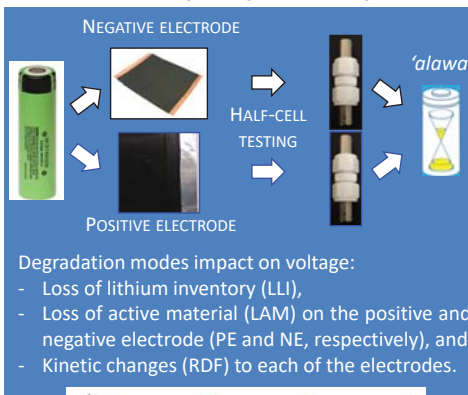




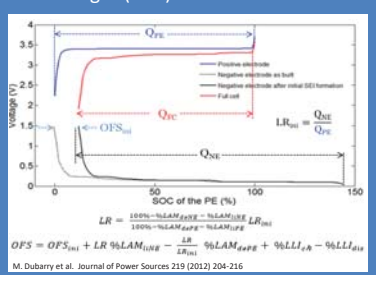


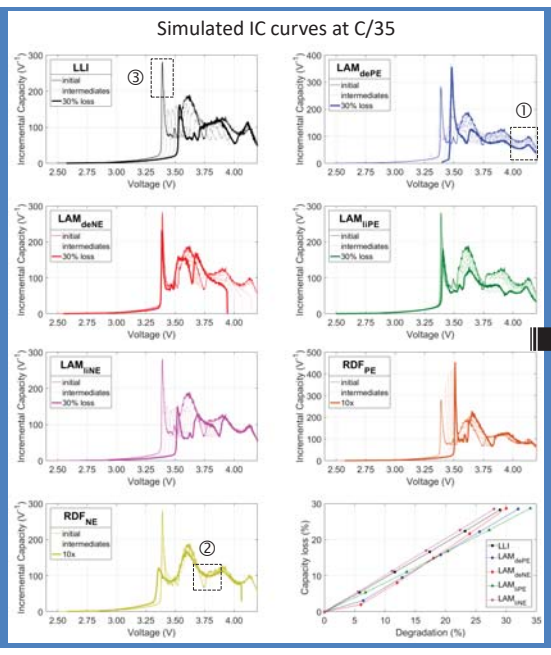
- Cells subjected to the complete real driving dataset exhibited greater capacity retention & dissimilar aging due to the lower average current applied
- Evolution of the incremental capacity curves for all the cells tested were similar indicating a specific degradation process.

Incremental capacity (IC) analysis

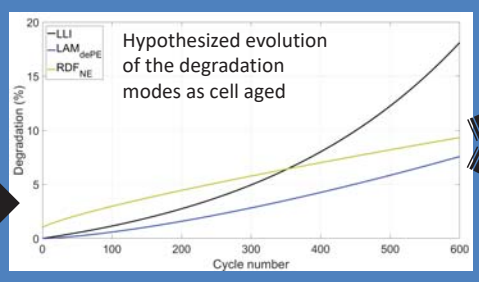


Degradation modes impact on voltage:
- Loss of lithium inventory (LLI),
- Loss of active material (LAM) on the positive and negative electrode (PE and NE, respectively), and
- Kinetic changes (RDF) to each of the electrodes.

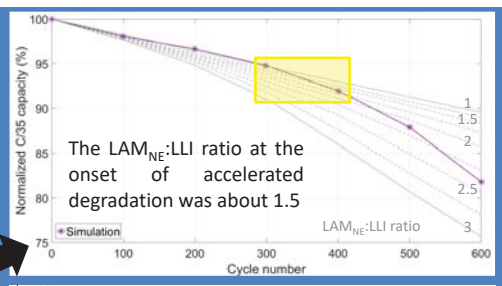


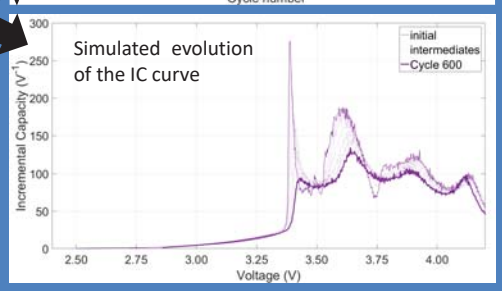


From the evolution of the features of interest ①, ②, & ③ and the change in capacity, the proposed degradation modes as a function of aging is as follows:



- The change in capacity was due to LLI
- ② changed most noticeably in the first couple hundred cycles and was due to RDF_{NE}
- LAM_{deNE} was difficult to quantify using IC curve analysis
- However, LAM_{NE} can be estimated from the change in slope signaling the onset of the accelerated stage of degradation





❖ Only broad inferences was drawn from the preliminary IC analysis, deeper analysis will be undertaken to quantify more accurately the degradation values.

Outlook

- All cells experienced a stage of accelerated capacity loss
- Average current & charge capacity during discharge are important parameters
- NEDC was closest to imitating the simulation-comparable commute
  - May be due to its relatively low charge capacity during discharge (0.3 vs. 0.5)
- Preliminary results from the IC analysis suggest some LLI associated with some LAM_{NE} at a faster rate.

Acknowledgments

This work was funded by the state of Hawaii, ONR Asia Pacific Research Initiative for Sustainable Energy Systems (APRISES) award number N00014-17-1-2206.

The authors are grateful to the Hawaiian Electric Company for their ongoing support to the operations of the Hawaii Sustainable Energy Research Facility and to Katherine McKenzie, Keith Bethune, Jack Huizingh, and Richard Rocheleau (HNEI).

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the sponsor.

University of Hawai'i Mānoa — School of Ocean and Earth Science and Technology — HNEI Hawai'i Natural Energy Institute, School of Ocean and Earth Science and Technology, University of Hawai'i at Mānoa — HiSERF