READ ME:
UofM Pouch Cell Voltage and Expansion Dataset and Modeling Code

Updated August 2020

Research Overview

The focus of this proposed research effort is to develop and analyze a multi-physics based mechanical and electrochemical model to understand how to best leverage measurement of the expansion of battery electrodes to improve state and parameter estimation for lithium-ion batteries; a) during relevant usage cycles, and b) to characterize assessment of battery SOH for different degradation mechanisms. The reduced order model is parametrized using measurements of strain, current, voltage, and temperature acquired during battery cycling on commercially relevant automotive form factors. The low rate cycling ensures that temperature and concentration gradients within the particle do not impact the measurement and enables extraction of the concentration dependent particle swelling.

Citations related to this material:

- ▪ P. Mohtat, et al., *"Differential Expansion and Voltage Model for Li-ion Batteries at Practical Charging Rates."* Journal of The Electrochemical Society 167, no. 11 (2020): 110561. [DOI: 10.1149/1945-7111/aba5d1]

Methods

The research conducted was using a pouch cell built at the University of Michigan Battery Lab (UMBL) and a newly developed fixture. The fixture was designed such that the top and bottom plates are fixed in place while the middle plate is free moving. For pouch cells, added pressure is needed to ensure the optimal performance of the battery. Hence, the fixture was designed to apply a uniform pressure on the pouch cell. This was achieved by using compression springs and polymer poron sheets (Rogers, USA). The target applied pressure of 5 psi was achieved by adjusting the spring compression to a fixed displacement using the threaded rods. The expansion

was measured using a displacement sensor (Keyence, Japan) mounted on the top plate. The dynamic testing was carried using a battery cycler (Biologic, France). The temperature was measured using a K-type thermocouple (Omega, USA) placed on the surface of the battery.
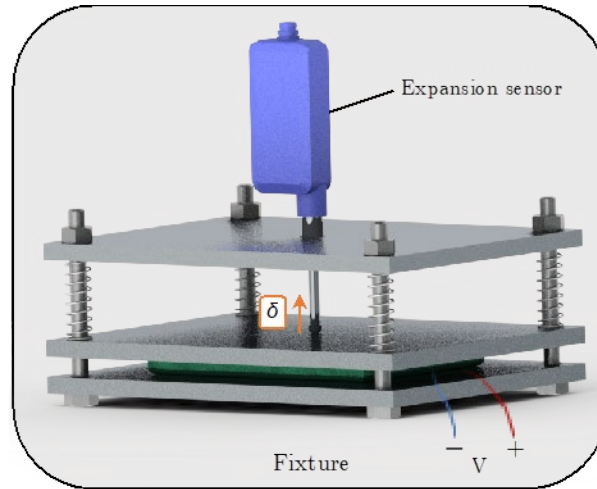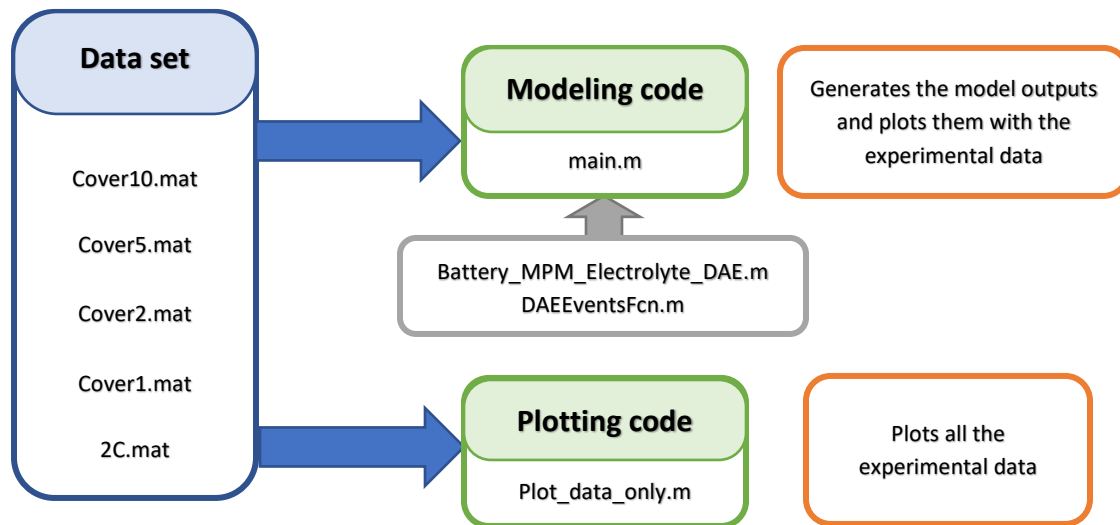

The fixture was installed inside a climate chamber with the temperature set to $25^\circ C$, then the cell was cycled 10 times at C/3 between 3.0 V and 4.2 V to ensure the repeatability of the expansion data. The cell was charged with a constant current (CC) from the fully discharged state at different rates (C/20, C/10, C/5, C/2.5, 1C, and 2C) to 4.2 V, followed by a constant voltage (CV) period until the current dropped below C/40, followed by a rest of 3 h. Then, the cell was discharged to 3 V at the same constant current. Each cycle was repeated three times and the measurements from the final cycle were reported.

The Biologic BTS-815 battery cycler was connected to a computer over the LAN network connection to transfer the voltage, current, and temperature data. BT-Lab software was used for collecting and storing this data at 10 sec intervals. The expansion data was transferred to the same computer over the serial port. A custom LabView program was used to collect and store the expansion data at 10 sec intervals. All the data was imported into MATLAB software for further processing and analysis

File Inventory

File Name	Type	Description
Cover10.mat	Data file	Charging data at C/10 rate
Cover5.mat	Data file	Charging data at C/5 rate
Cover2.mat	Data file	Charging data at C/2 rate
Cover1.mat	Data file	Charging data at C/1 rate
2C.mat	Data file	Charging data at 2C rate
main.m	Script	Main script for running the model
Battery_MPM_Electrolyte_DAE.m	Function	Function defining the DAE for the MPM
DAEEventsFcn.m	Function	Function defining the events for stopping the simulation
Plot_data_only	Script	Plots and process all the data

File Associations

Data set

Cover10.mat

Cover5.mat

Cover2.mat

Cover1.mat

2C.mat

Modeling code

main.m

Generates the model outputs and plots them with the experimental data

Battery_MPM_Electrolyte_DAE.m
DAEEventsFcn.m

Plotting code

Plot_data_only.m

Plots all the experimental data

Software requirements

MATLAB® software is required for running and accessing the model and dataset in this repository.
The code has been tested on the following Operating Systems (OS) and software versions:
- Windows 10 (version 2004) | macOS (10.15.6)
- MATLAB® 2019b

NOTES:
- The MATLAB's *Signal Processing Toolbox* plug-in is also required in order to plot certain figures. Detailed instructions are included in the scripts to disable these figures if needed.
- Windows ONLY: in some situations .mat extension becomes associated with Microsoft Access and cannot be open independently by MATLAB, on Windows 10 you can restore the file associations with the following steps:
    1. Left click the Start button and left click the gear to bring up Control Panel.
    2. Left click on the Apps icon.
    3. On the left-hand panel, left click "Default apps"
    4. Scroll down and click on the blue text "Choose default apps by file type"
    5. Scroll down to find the .mat file, then, click on the Access icon and then select MATLAB from the list of apps that appears.
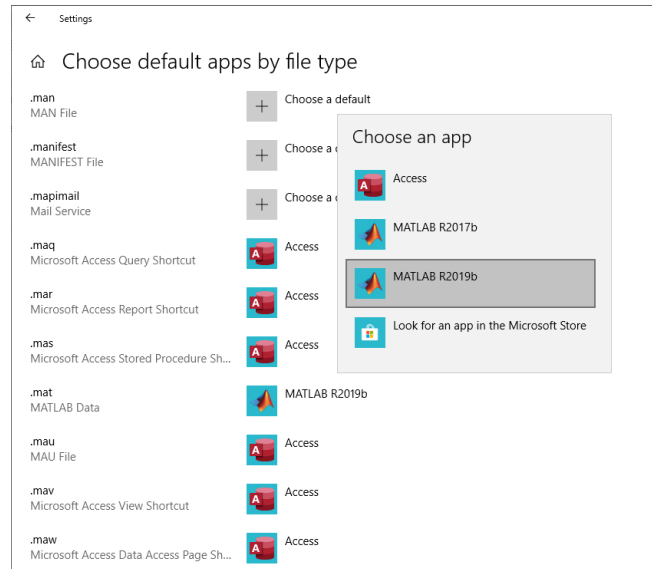
Definition of Terms and Variables

A glossary of the variables and their definition in the data set:

Vt_data: terminal voltage of the battery

Temp_data: temperature of the battery

Dis_data: expansion of the battery

dVdQ_data: first derivative of voltage with respect to Q (charge)

derv_dis: second derivative of expansion with respect to Q (charge)

Q_data: the amount of charge stored time synced for voltage

Qf_data: the amount of charge stored time synced for expansion

Qd_data: the amount of charge stored time synced for voltage differential

Qdf_data: the amount of charge stored time synced for expansion differential