Effect of Cooling the Cathode Tab Bus Bar on the Thermal Characteristics of LFP Prismatic Cells under Various Discharge Rates of Constant Current

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Maintaining uniformity of temperature between cells is an important factor in the thermal management of lithium-ion batteries. It is desirable for this variation to be in a tight range [1]. Rugh et.al. mentioned that uneven temperature distribution should be kept to less than 3^0C to 4^0C throughout the battery pack [2].

The temperatures near the positive terminal of a prismatic battery are consistently higher than those at the negative terminal. This is due to differences in the thermal conductivities of the different terminal connectors. This is true regardless of the particular lithium-based electrochemistry being used. The inherently higher electrical resistivity of the aluminum cathode creates a source of Joule heating that is located at the junction of all the tabs within the cell. This source of heat becomes more dominant during high rates of charge or discharge.

As shown in Fig. 1, thermal imagery reveals that the bus bar on the cathode tabs is the always the first “hot spot” to appear on the lithium cell pouch during either a charge or discharge cycle. The copper anode bus bar on the right tab, however, appears to increase its temperature at approximately the same rate as the rest of the cell acting as neither a significant heat source nor heat sink.

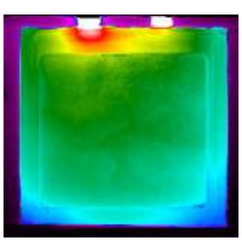

Fig. 1. Thermal image of lithium-ion pouch cell. The aluminum cathode tab is on the left.

The purpose of this research is to quantify the effects on the average cell temperature and surface temperature gradients caused by the Joule heating of the bus bar on the cathode tabs at different rates of discharge. A commercially-available 14Ah lithium-ion prismatic pouch cell utilizing iron phosphate electrochemistry will be used as the test specimen with a dimension of 220mm x 130mm x 7mm. Data will be collected with a Maccor Series 4200 battery cycler and an isothermal calorimeter.

Preliminary Findings Using Natural Convection Cooling

Some preliminary data has been collected and analyzed by the researchers to gauge the feasibility of delving deeper into this topic. This data was collected in an experimental setup that utilizes the lumped capacitance method.

The prismatic cells were initially at ambient room temperature and fully discharged from 100%SOC at a constant current. The pouch cell was held in a vertical orientation and underwent natural convection. The temperature of the cell surface was recorded with a FLIR thermal camera. Data were collected with and without the cathode tabs being cooled by a copper cold plate which used compressed air as the working fluid. Two different rates of discharge, 3C and 8C, were performed on the cells.

The Biot number is used to indicate the validity of using lumped thermal models. If the Biot number is less than 0.1, it typically indicates an introduced error that is less than 5% due to the lumped assumption [3]. From prior work by the researchers in using this type of setup, it has been determined that the Biot number is 0.002 [4]. Thus, modeling the cell as a lumped capacitance is a valid assumption and this methodology was used to quantify the heat rates.

At 3C discharge rate, cathode bus bar heating does not traverse far enough to influence the temperature at the center of the cell throughout the cycle. Therefore removing cathode bus bar heat actually results in the increase of temperature gradients on the cell surface. As a heat source, the cathode tab bus bar works with the heat of electrochemical reaction in minimizing gradients. At an 8C discharge rate from a fully charged cell, cathode bus bar heat arrives at the center spot of the cell surface after only 11% DOD. At this point, the combining of thermal loads attenuates the temperature gradients on the cell surface. At 8C discharge, cathode bus bar cooling lowers the overall cell temperature approximately 4.5^0C but has minimal benefit in reducing the statistical temperature gradient by only 9%.

References

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