Quantifying the Effects of Compressive Loads on the Heat Generation of Prismatic Lithium-ion Pouch Cells

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The proper design for a battery thermal management system (BTMS) in an electric or hybrid electric vehicle requires that all of the factors which affect heat generation within the battery cell be fully understood. Much research has been published that establishes the relationship between the rate of heat generation of a cell to its temperature, state-of-charge (SOC), and rate of charge or discharge. However, there is one factor that has mostly escaped the same level of intense scrutiny in published literature as the others: cell compression.

The influence of an external compressive load on a battery's thermal behavior is largely muted in any cell packaging format that consists of a rigid structure. Cylindrical and prismatic-can type cells are immune to the effects of an externally applied load because the contact resistance between the internal components is shielded by the housing. However, the flexible nature of the pouch format used in packaging some lithium-ion cells makes the thermal behavior much more sensitive to compressive loading. Coupled with the fact that this type of cell format is becoming the de facto standard in automotive applications, it becomes more crucial for the effects of this phenomenon to be understood and quantified.

The objective of this research will be to establish the influence that different levels of compressive load has in altering the heat generation within a lithium-ion pouch cell. Empirical equations will be developed that relate the two. A 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 system manufactured by Thermal Hazard Technology as shown in Fig. 1. This calorimeter is specifically designed for large format prismatic pouch cells. It also has a design feature which allows for different clamping loads to be exerted on the cell pouch face during operation at different temperatures.

Fig. 1. Isothermal calorimeter for large prismatic cells

Thermal Contact Resistance

When the electrode layers are assembled within a pouch cell, physical contact between the internal components is made only at a few discrete locations rather than over the entire surface area. On a microscopic level, this contact between surface irregularities of the mating electrodes provides the sole means by which heat may travel. Previous studies done in industry have shown that the effective area is only about 20% on average between electrode layers of a large pouch cell under an external pressure of approximately 5 psi. It is this minimal effective area that may allow heat to accumulate within the cell if an insufficient number of contact points exist for a given set of operating conditions. This level of physical contact between internal components gives rise to the thermal contact resistance (TCR) within a cell.

Compressive Loading and TCR –

Thermal behavior is strongly coupled to the electrochemical processes within a cell [1, 2]. In addition to having an influence on heat generation, high-rate performance in a cell theoretically tends to improve due to enhanced charge transfer reaction at electrode-electrolyte interface. However, there is a certain limit reached in the benefits gained from the compressive loading of a cell. Loss of capacity has been found to occur as a result of the elastic creep in the separator which inhibits ion transport due to pore closure [3]. The amount of set or permanent deformation of the surface asperities that occurs after repeated pressure cycling is also not clearly understood.

A secondary benefit of this data collected from this research will be the quantifying of some cell properties under varying conditions. The influence of temperature, pressure, and state of charge on thermal properties (such as specific heat capacity and thermal conductivity) will be determined. This will contribute to the accuracy of upcoming computer modeling efforts on both the cell and module level.

References

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