Thermal Model of Lithium-Ion Battery Cell

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Introduction

This work is about thermal modeling of prismatic lithium-ion battery cells commonly used in industrial applications. Battery cells must be kept within a certain temperature range in order to be efficient and healthy during operation and charging. Heating of battery cells prior to charging might be necessary if they have been stored in cold conditions. Furthermore, cooling could be needed during heavy work loads together with high surrounding temperatures. Therefore a thermal model of a battery cell is helpful when designing a heating or cooling system.

The work is focused on whether heating should be applied on the positive or negative terminal, since they have different connections to the rest of the cell. The negative terminal is connected to the jelly roll (core) via a narrow fuse. The positive terminal has a thick connection to the case.

Model

The battery cell is simplified into two main components: the aluminium case and the jelly roll. These components are divided into interconnected nodes forming a thermal network, see Figure 1. Both conduction and convection is considered.

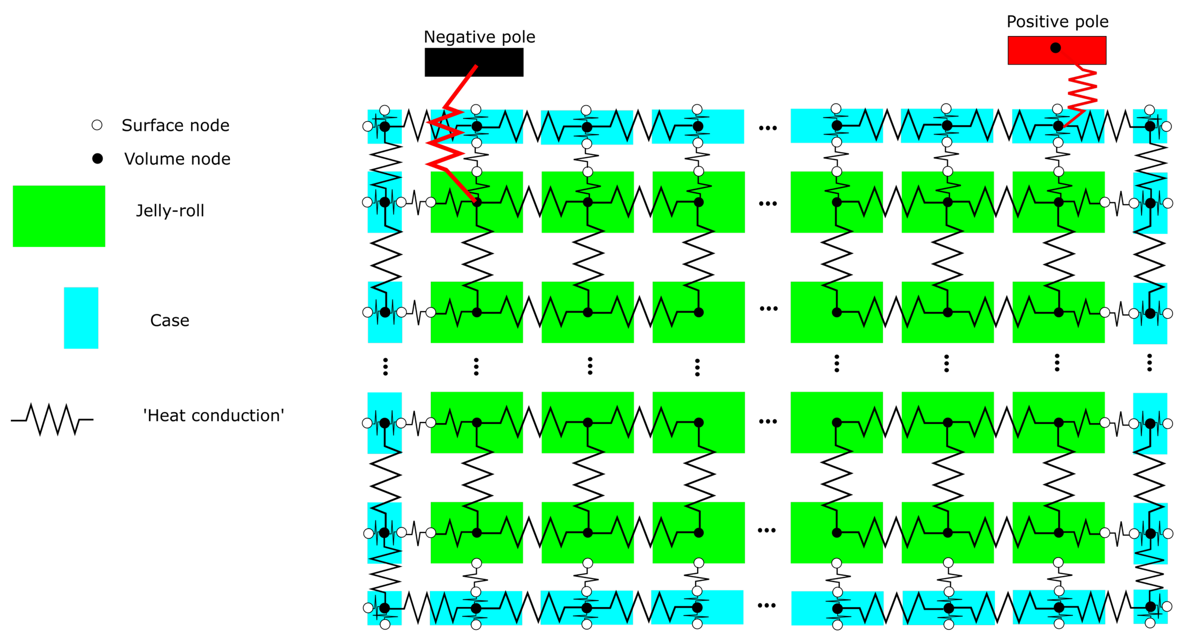

Figure 1: Thermal network of battery cell.

Heat flux due to convection and conduction in boundary layers between different materials is modelled using tuning parameters. Surface nodes are placed where convection is present as well as in boundary layers between different materials. The model is highly adjustable in the sense that dimensions, material properties, grid size and tuning parameters are modifiable.

The model was implemented in MATLAB using the open source program package TNSolver that supports relevant heating and cooling scenarios. The dynamic thermal data is presented as both graphs and a 2D heat map.

Tests and validation

Tests were ran on a battery cell using four thermoelements and a resistive heater. The results were later used to tune parameters in the model. Figure 2 shows two different tests and their corresponding model simulations after tuning.

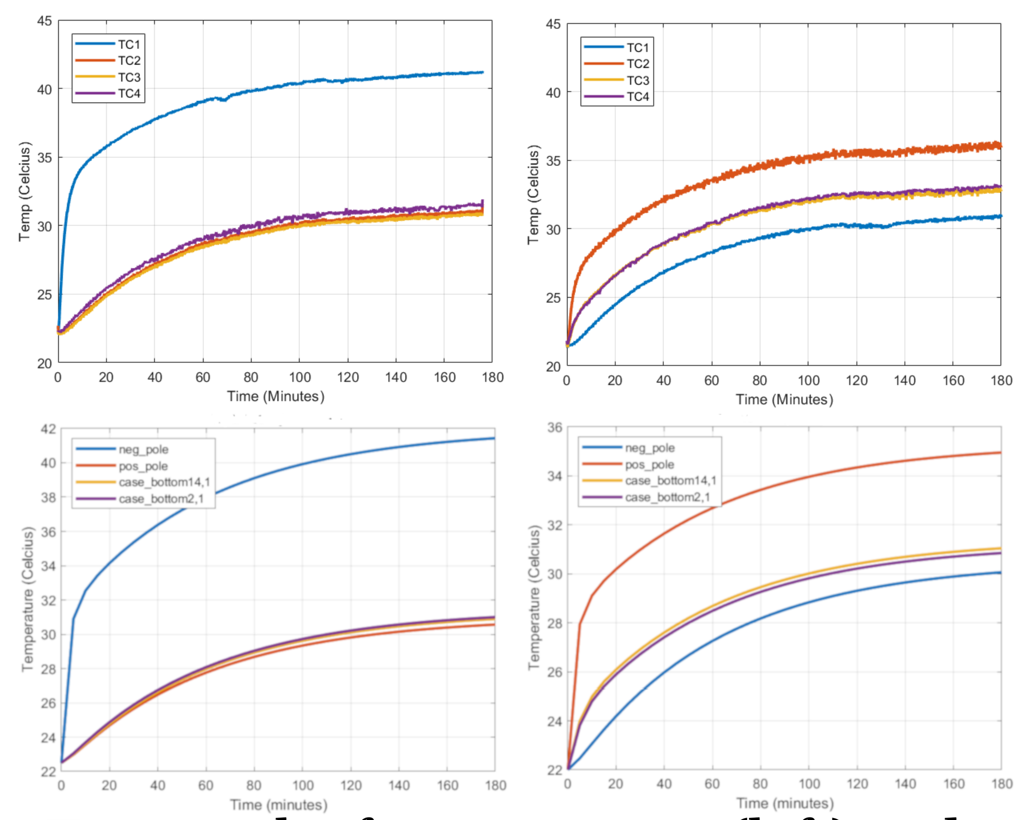

Figure 2: Test results from tests one (left) and two (right) with model simulations below.

In these tests, both battery cells were heated with 3W during 3 hours exposed to an open environment of 22°C. In the first test the heating was applied on the negative terminal, and in the second test, the positive terminal.

Figure 3: Heat map from test 1 after 1 hour 20 minutes.

Discussion and Conclusion

As can be seen in figure 2 heating of the negative terminal leads to a higher local temperature compared to heating of the positive terminal. This difference could be explained by the restrictive connection between the negative terminal and the jelly roll. High local temperature at the negative pole is not a problem in practice, provided the power is not too high, since heating is applied on cold battery cells. The positive terminal appears to easily dissipate its heat to the case which in its turn heats the jelly roll.

Since the positive terminal seems to better conduct heat from the heater to the cell, it could be preferred to apply heat on the positive terminal. The slightly higher case temperature is less of a problem in practice since battery cells typically are stacked together in a battery module. This maximizes the heating of the battery module since neighbouring cells will act as insulators.

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