

Behaviour of a Lithium-ion cell in Different Conditions using ANSYS

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Abstract- The popularity of electric vehicles in the automotive industry is ever so rising and with it is the research for performing batteries. The most opted cell chemistry in the EV market is the Lithium-ion cell since it provides optimal values of energy and power density, the two main characteristics of a cell. However, there are other external parameters as well which affect the performance of a cell. These effects are highlighted in this paper for reference using the aid of simulation software such as ANSYS.

Keywords – Battery, ANSYS, Voltage, C-Rate, Temperature

1. INTRODUCTION

With the recent up trend in the usage of Electric Vehicles amongst the public, as an engineer it is necessary to understand the technology behind it. The thermal behavior of the battery pack used to power the vehicle is to be analyzed and understood to ensure no harm during the operation of the vehicle. This paper tries to highlight the basic parameters that affect the behaviors of a battery pack by simulating a single cell. We shall touch upon the subjects such as thermal behavior and voltage drop as per different cell thicknesses and ambient thermal conditions.

2. TYPES OF BATTERIES

Batteries can be segregated according to the following classifications with some common examples: -

- 1) Based on form factors: -
 - 1.1 Prismatic cells
 - 1.2 Cylindrical cells
 - 1.3 Pouch cells
- 2) Based on cell chemistry: -
 - 2.1 Lithium Iron Phosphate (LFP)
 - 2.2 Lithium Nickel Manganese Cobalt (NMC)
 - 2.3 Lithium Nickel Cobalt Aluminum (NCA)

Note: - For this paper we shall be considering a Pouch cell with the given cell chemistry data. The following steps can be followed for any proposed form factor and cell chemistry.

3) METHODOLOGY

A. Designing a generic pouch cell.

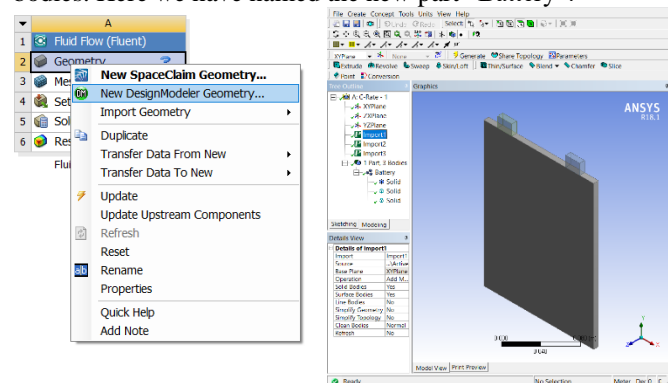
Starting with the CAD file, designing of a generic pouch cell has been done using SolidWorks. A single pouch cell of 205x157mm dimension was created with an initial thickness of 7mm. The file was then saved as a Parasolid file. Different softwares such as CATIA V5, Creo or any other 3D CAD softwares can be used, given the file is saved as a Parasolid file.

B. Use of Simulation software

There are several software programs available which can mimic the process involved in our research work and can produce possible results. One such type of software is ANSYS. They provide licenses to students and have a wide range of well explained tutorials uploaded on YouTube to refer to.

B.1.1. Setting up cell geometry

Opening up ANSYS Workbench, we select Fluid Flow (Fluent) tab and drag it onto the working space. To set up the geometry of our battery, we open up DesignModeler and import each of our battery components (ie. Active part, Positive tab, Negative tab) separately. Making sure every component lines up perfectly we then proceed to create a new part with the existing three solid bodies. Here we have named the new part “Battery”.



B.1.2. Meshing the geometry

After setting up the geometry we then proceed ahead to mesh it.

Make sure to change the three components into Solids under the geometries tab for them to be seen in conductive zones of MSMD model in Fluent. Given simple geometry we went ahead with 1mm mesh size for optimum accuracy and minimum computational time.

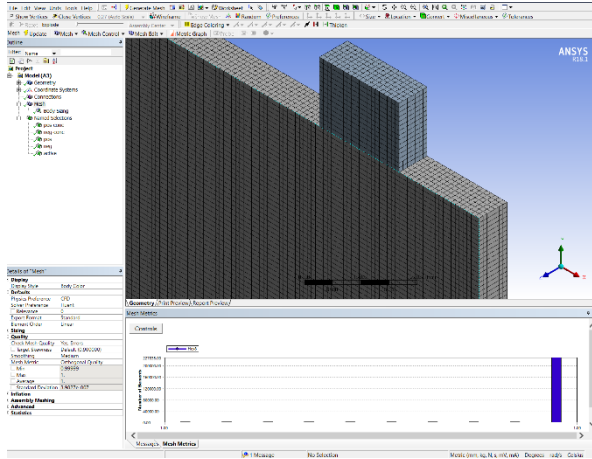


Fig:- Active Material

Quality of the mesh is to be checked, here the orthogonal quality and the skewness of the mesh were well within the desired range and hence the mesh was good to go.

B.1.3 Boundary Conditions

Once the mesh is successfully transferred to Fluent, we will now set up the actual parameters of the cell. To do so, first we need to add the MSMD model to our Fluent. The following command is to be typed into the command window “define models addon”. Once MSMD model is added in, we shall enable it in the model’s tab and fill in the data inside. In the model options. we shall be using NTGK model in this paper, and following are the cell parameters used: -

- 1) Cell capacity: - 18.6 Ah
- 2) Cell min voltage: - 2.98V
- 3) Cell max voltage: - 4.18V

The rest in the tab as well as the model parameters are left as default. In the third tab of conductive zones, we will define our active part and the tab components. In the electric zones tab, we will define the negative and positive connections of our cell and initiate. After the MSMD model is ready, we will create the material of our electrode and current collectors. The following highlights the material properties used for the simulation.

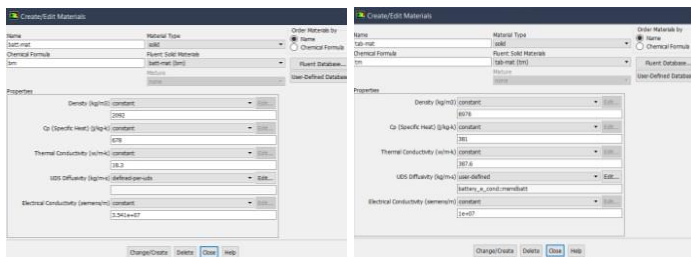


Fig:- Active Material

Fig:- Tab Material

Note: - For the tab material UDS is user defined whereas for the active part UDS input is defined-per-uds and the following is given as input: -

uds0 = 1.16e6
 uds1 = 9.83e5

The ready materials are then assigned to the respective cell zones.

To understand the battery parameters, we shall simulate various scenarios to get a grasp of how these will affect the battery.

B.1.3.1. Effects of different ambient temperatures on the cell

To understand how different ambient temperatures effect the working of the cell, we chose to simulate its operation under six different temperatures: -

- 1) -10°C ~ 263.15K
- 2) 0°C ~ 273.15K
- 3) 25°C ~ 298.15K
- 4) 45°C ~ 318.15K
- 5) 65°C ~ 338.15K
- 6) 80°C ~ 353.15K

Accordingly, the input of free stream temperature in all the walls under boundary conditions changed as per the ambient temperature we are trying to simulate.

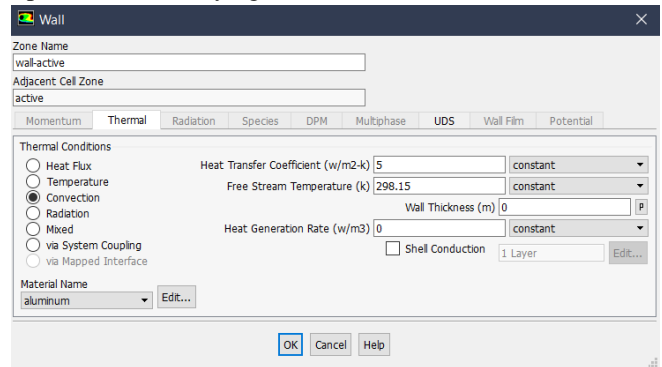


Fig:- Convection thermal setup for the walls of the battery

B.1.3.2. Effects of different C-Rates of the cell

To understand how operating the battery under different C-rates effected the working of the cell, we chose to simulate its operation under four different C-Rates: -

- 1) 1C-Rate
- 2) 2C-Rate
- 3) 4C-Rate
- 4) 5C-Rate

Accordingly, the input of C-Rate in MSMD model changed as per the condition we are trying to simulate.

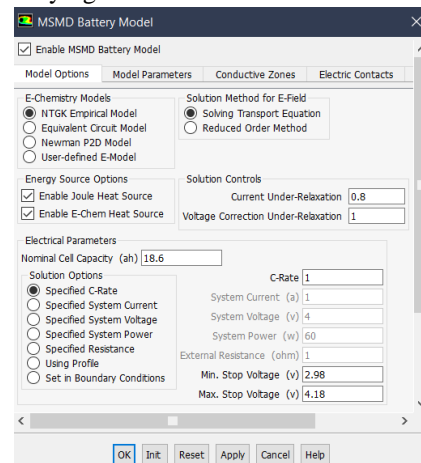


Fig:- C-Rate is changed in MSMD model

B.1.3.2. Effects of different thickness of the cell

To understand how the battery behaved with different thicknesses, we chose to simulate it under three different thickness: -

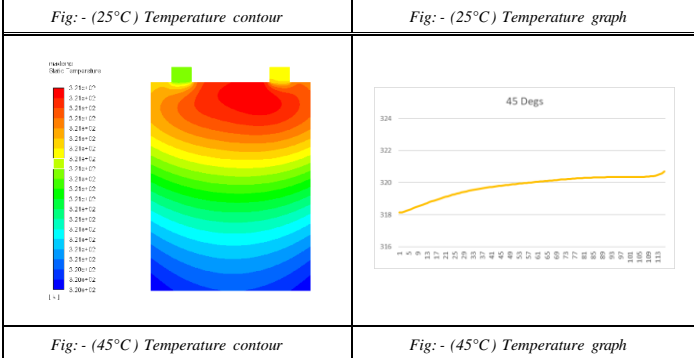
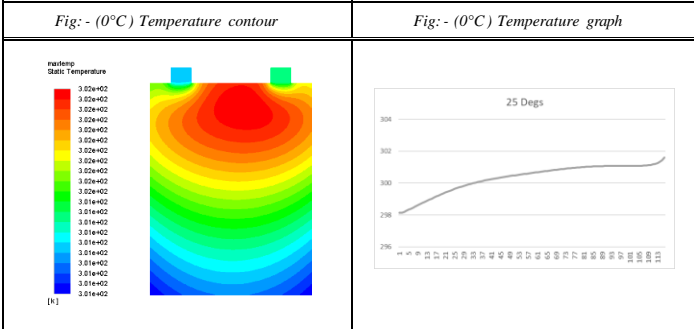
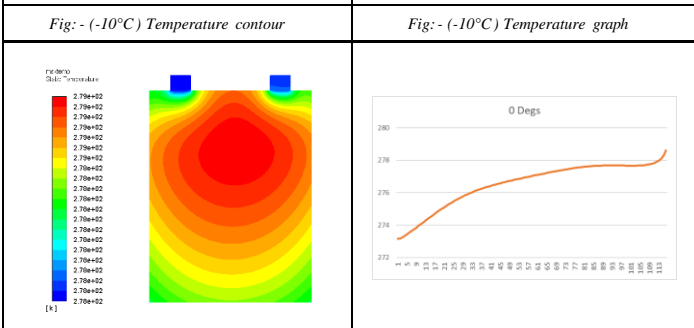
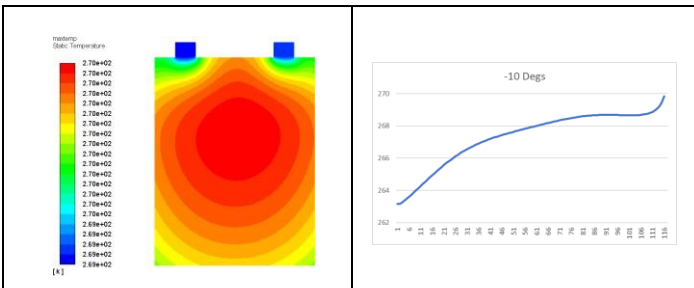
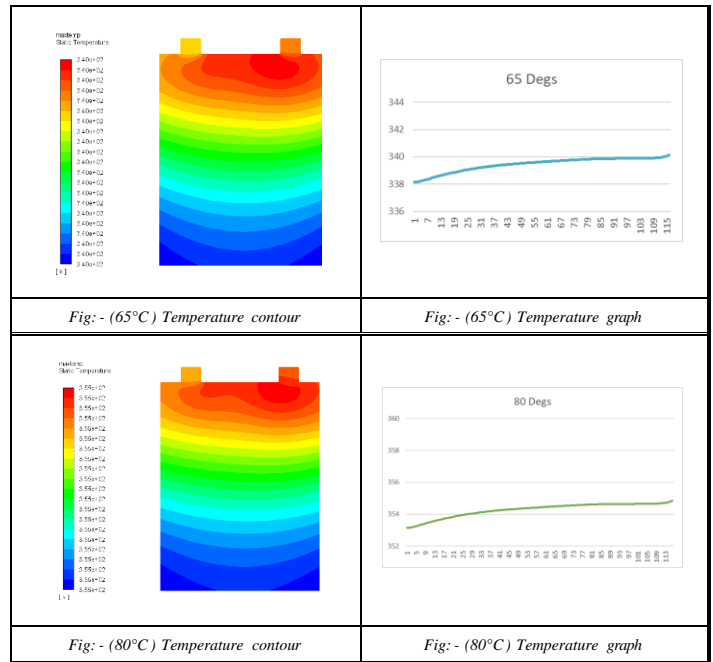
- 1) 7mm
- 2) 5mm
- 3) 3mm

Accordingly, the geometry of the cell changed, and new parts were imported in the DesignModeler.

B.1.4 Results

B.1.4.1. Effects of different ambient temperatures on the cell

Cell temperature rise with different ambient temperatures.



Cell voltage drops in different ambient temperatures.

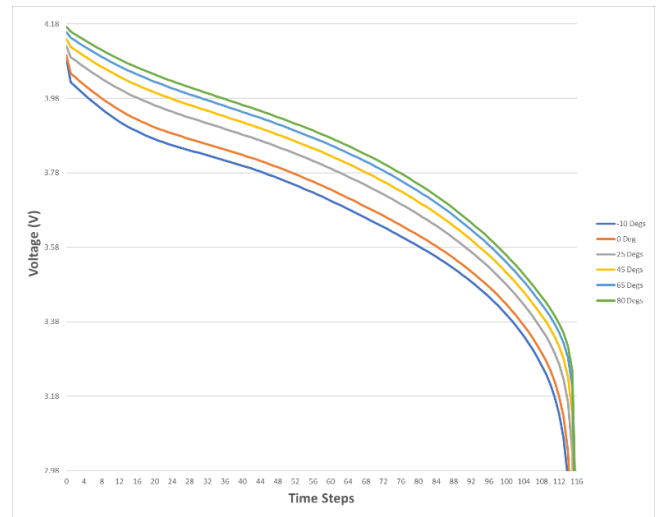


Fig: - Comparative graph of voltage drops in different ambient temperature conditions

The results above convey the battery in terms of temperature rise and voltage drop in cases of different ambient temperatures.

In the case of low ambient temperatures, the operating voltage drops significantly while the temperature rise is very large as compared to the ambient temperature on the higher spectrum.

B.1.4.2. Effects of different C-Rates of the cell

Cell temperature rise with different C-Rates

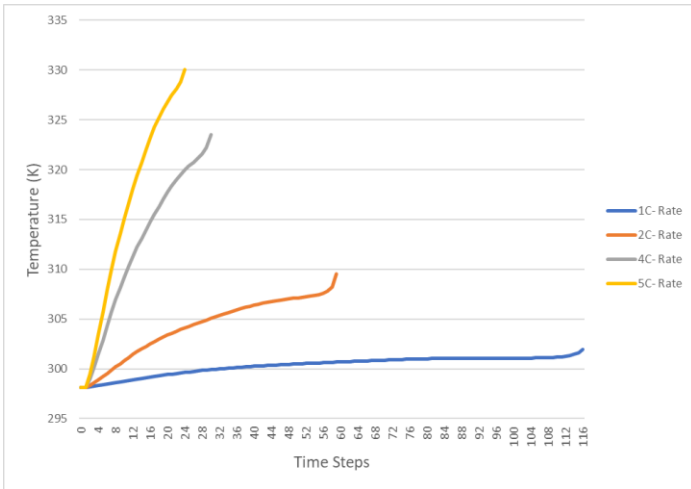


Fig: - Comparative graph of temperature rise of the cell due to different C-rates

Cell voltage drops with different C-Rates

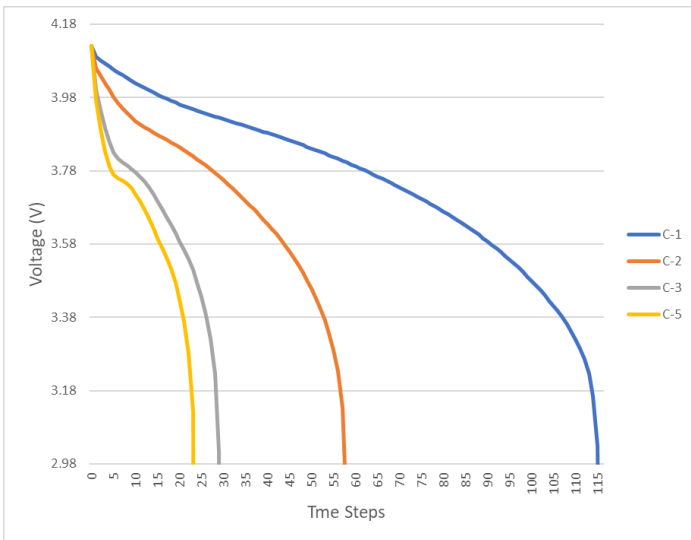


Fig: - Comparative graph of voltage drop of the cell due to different C-rates

B.1.4.3. Effects of different thickness of the cell

Considering same boundary conditions with only difference being the cell wall thickness, we can see how different cell wall thicknesses affect the heat transfer of the cell.

Heat Transfer by conduction is formulated by the following: -

$$Q = K \cdot (A \Delta T) / d$$

Where,

- Q = Heat Transfer by Conduction
- K = Thermal Conductivity
- A = Surface Area
- ΔT = Temperature difference

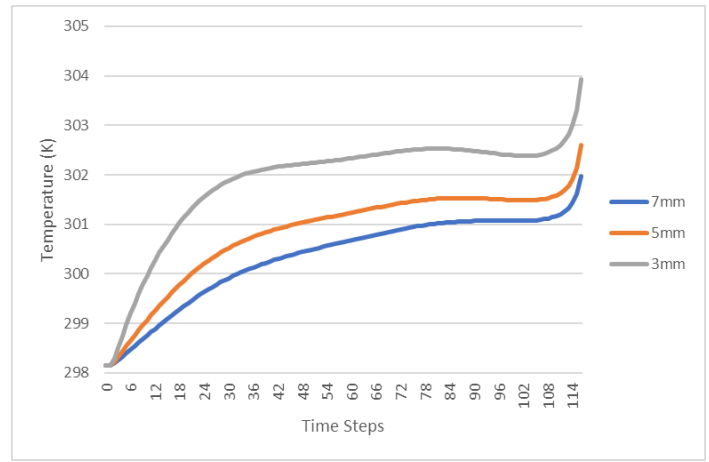


Fig: - Comparative graph of temperature rise of the cell due to different cell wall thickness

As evident from the analysis graph we see how Heat Transfer is most abundant in the cell with lowest wall thickness.

4. CONCLUSION

1. Effects of different ambient temperatures on the cell

- Voltage drops rapidly when the battery is operated at or below 0 °C.
- Higher temps such as 65 °C or 85 °C have lower hikes in temperature however at those temperatures the chances of a thermal runaways increase a lot giving a safety concern.
- Hence it is advisable to have an optimum working temperature (25 °C - 65 °C) for better battery life and user safety.

2. Effects of different C-Rates of the cell

- As observed from the results, as the operational C-Rate increases, the temperature hike also increases.
- Higher temperatures indicate greater chances of a thermal runaway situation.
- Higher C-rates deplete the voltage of the cell more quickly.
- With the above-mentioned observations, it is advisable not to operate beyond a certain C-rate for a longer period of time. An example of such would be seen in Tesla cars where a C-rate of 4C is used for quick acceleration but for a short period of time.

3. Effects of different thickness of the cell

- The battery with the least thickness has better heat transfer allowing better heat propagation when using a thermal management system.
- Having cells with low wall thickness might also prove to be beneficial in reducing overall battery pack weight.
- The thickness of the batteries doesn't affect the voltage drop significantly.

REFERENCES

- [1] [ANSYS Fluent: ECM Battery Model](#)
- [2] [Lithium Nickel Manganese Cobalt \(NMC\) cell chemistry](#)
[Lithium Iron Phosphate cell chemistry \(LFP\) cell chemistry](#)
[Other Cathode possible cell chemistries](#)
- [3] [Effect of Ambient Temperature on Voltage Drop](#)
- [4] [Effect of different C-Rates on Cell Temperature](#)
- [5] [Effect of C-Rate on Battery Discharge time](#)