The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION.
Barcelona, Spain
17th-20th November 2013

Application of the Thermal Impedance Spectroscopy method in 3 dimensions to a large prismatic Li-ion cell

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Organized by Fira Barcelona avele
Hosted by AVERE
In collaboration with Ajuntament de Barcelona
Supported by EDTA European Commission

Summary

- Overview of the project
- TIS Method
- Model and test setup
- Results and observations
- Conclusion

Project Overview

ITAQ building
St-Jérome, Québec

Tire Gantry
Crane

Project Overview

Cell Capacity	42 Ah
Mass	1.4 kg
Cathode	LFP
Anode	Graphite
Dimensions	95x28x215 mm

Cell characteristics

TIS Method

- The Thermal Impedance Spectroscopy is similar to Electrical Impedance Spectroscopy.

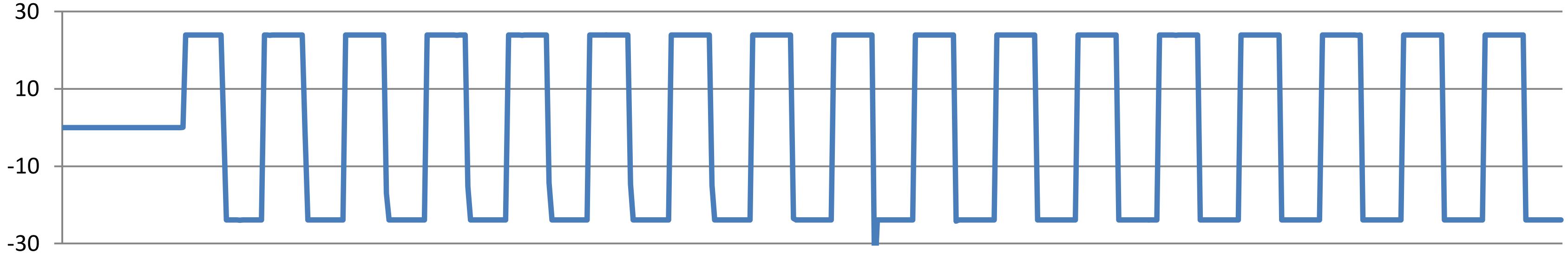
- The objective is to find the thermal impedance and fit the results to a model to obtain the thermal characteristics (C_p ,k_x, k_y, k_z)

- The heat generation (Q) within the cell is the input signal and the surface temperature is the output signal (T_{surf})

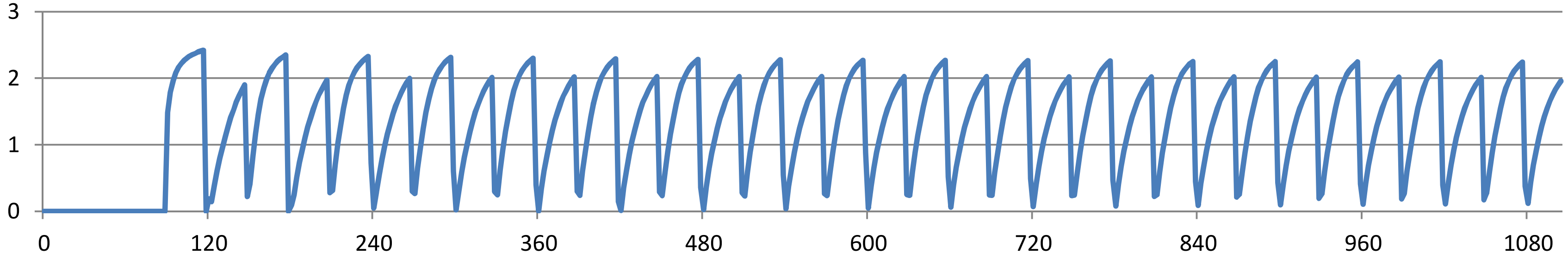
- The thermal impedance can be defined as $Z = T_{surf}/Q$

TIS Method

There are many methods to generate heat within the cell.
We chose to use the cell electric resistance.



Current as a function of time (A) f = 0.016 Hz



Heat generation as a function of time (W) Q = I|U-V|

TIS Method

To find the Thermal Impedance you either procede with a time-domain or frequency-domain approach.

- Time-domain : 1 test processed with the fft algorithm
- Frequency-domain : Several tests with the heat generation at different frequencies

π

Model

We used the Fourier law with the Finite Volume method to build the model

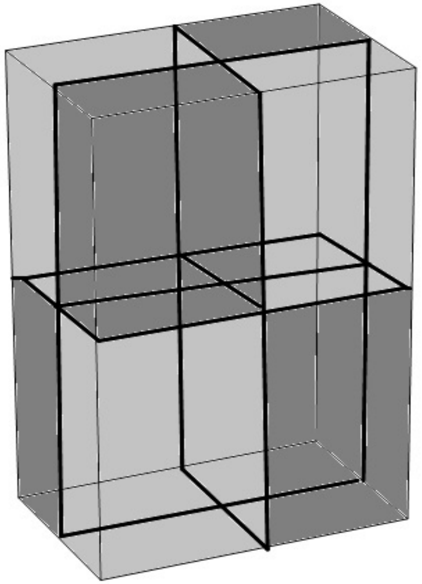
$$c_p \cdot \frac{dT(t)}{dt} = k_x \frac{dT(t)}{dx} + k_y \frac{dT(t)}{dy} + k_z \frac{dT(t)}{dz} + Q(t)$$

We applied the Laplace Transform (FFT) to transfer into the frequency domain with s = 2jπf

$$s \cdot c_p(T(s) - T(0)) = k_x \frac{dT(s)}{dx} + k_y \frac{dT(s)}{dy} + k_z \frac{dT(s)}{dz} + Q(s)$$

Model

The cell was modelled as a rectangular prism with 8 elements



The heat generation is supposed uniform.

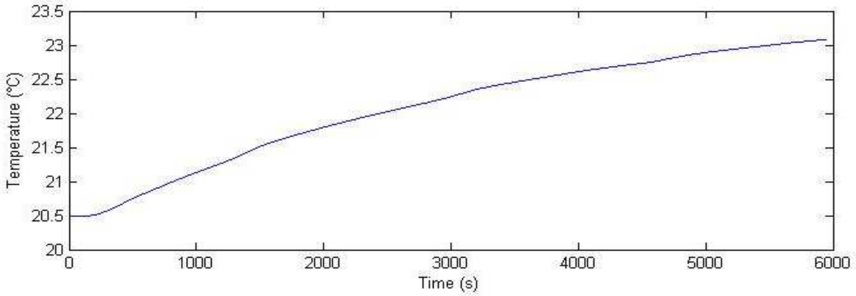
The convection heat transfer coefficients were calculated using empirical correlations for free convection (Nusselt and Rayleigh numbers)

Test Setup

We used a battery cell testing system and a small test chamber to conduct the tests. The data was recorded using an Agilent 34972A data acquisition unit

Results

We used complex least square fitting to find the heat conductivity and heat capacity



Measured temperature rise

Cp (J/(kg K))	Kx (W/(m K))	Ky (W/(m K))	Kz (W/(m K))
1142	2.4	0.3	0.1

Observations

There was no available data from the manufacturer for the cell heat conductivity and heat capacity, making it hard to compare our results

In the literature :

- The cell heat capacity can be between 830 and 1150 J/(Kg K)
- The cell heat conductivity perpendicular to the electrode stack should be around 0.35 W/(m K)
- The cell heat conductivity parallel to the electrode stack can be anywhere from 10 to 100 times the perpendicular conductivity

Observations

There is a lot of influence on the results for two parameters :

- The calculated heat generation
- The calculated free convection boundary conditions

Conclusion

- We applied the TIS method in 3D to a large prismatic Li-Ion cell.
- We need a better heat generation model or equipment with higher capabilities at high current to increase the precision of the test
- The free convection resistance is in the same order as the wanted parameters. Good control of this resistance is needed for good characterization.

Acknowledgements

We would like to thank the following partners for their contribution to the project

Enseignement supérieur,
Recherche, Science
et Technologie
Québec

CRSNG
NSERC

MJ Les Systèmes Hybrides EcoPower

Questions?