Fluent在电池包热管理中的应用

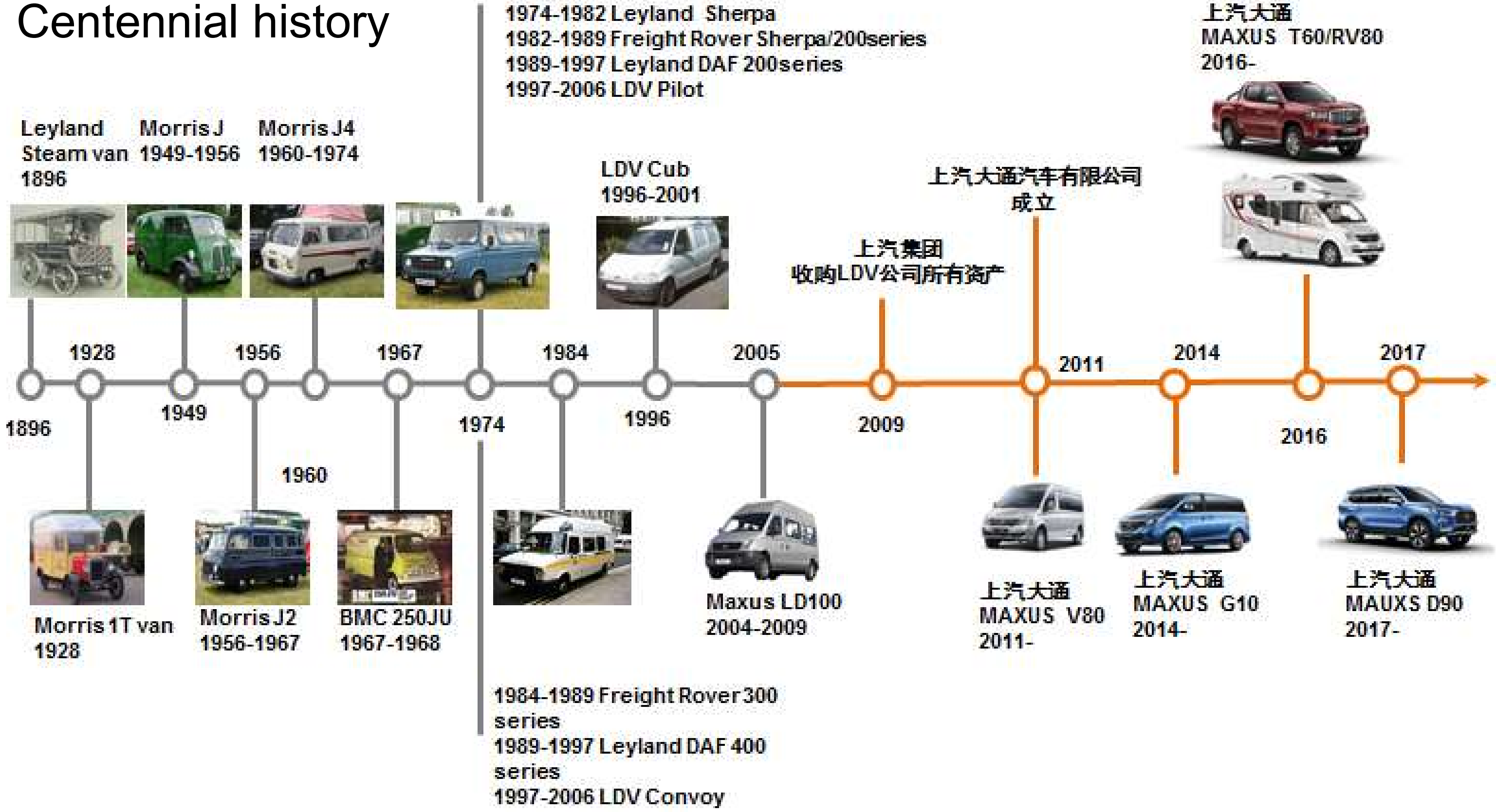
上汽商用车技术中心

电气化中心/动力电池科

韩文溪

Company overview

Centennial history



Product overview

Contents

- 3D simulation of liquid cooling pack
- Electrochemistry-thermoelectric coupling simulation

- 3D simulation of liquid cooling pack

- Electrochemistry-thermoelectric coupling simulation

Case Description

Questions

- How to do liquid cooling pack transient simulation ?
- How to do flow and temperature coupling simulation ?

Challenge

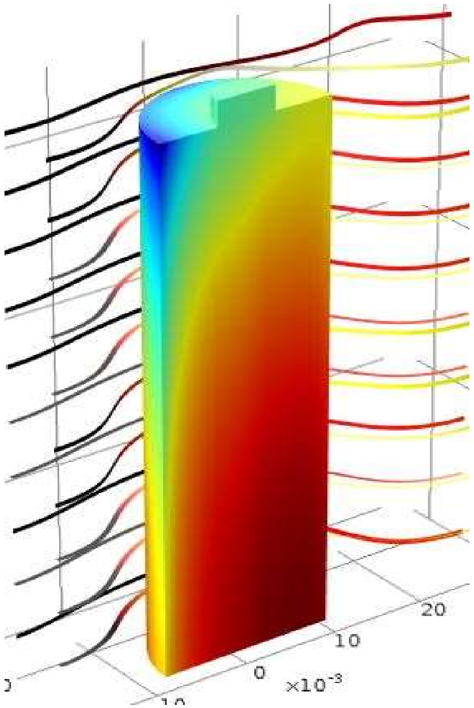
- Huge amount of grid caused by complex module structure
- Problem solving difficulty in dealing with the influence factors involving in heat transfer process

Solution

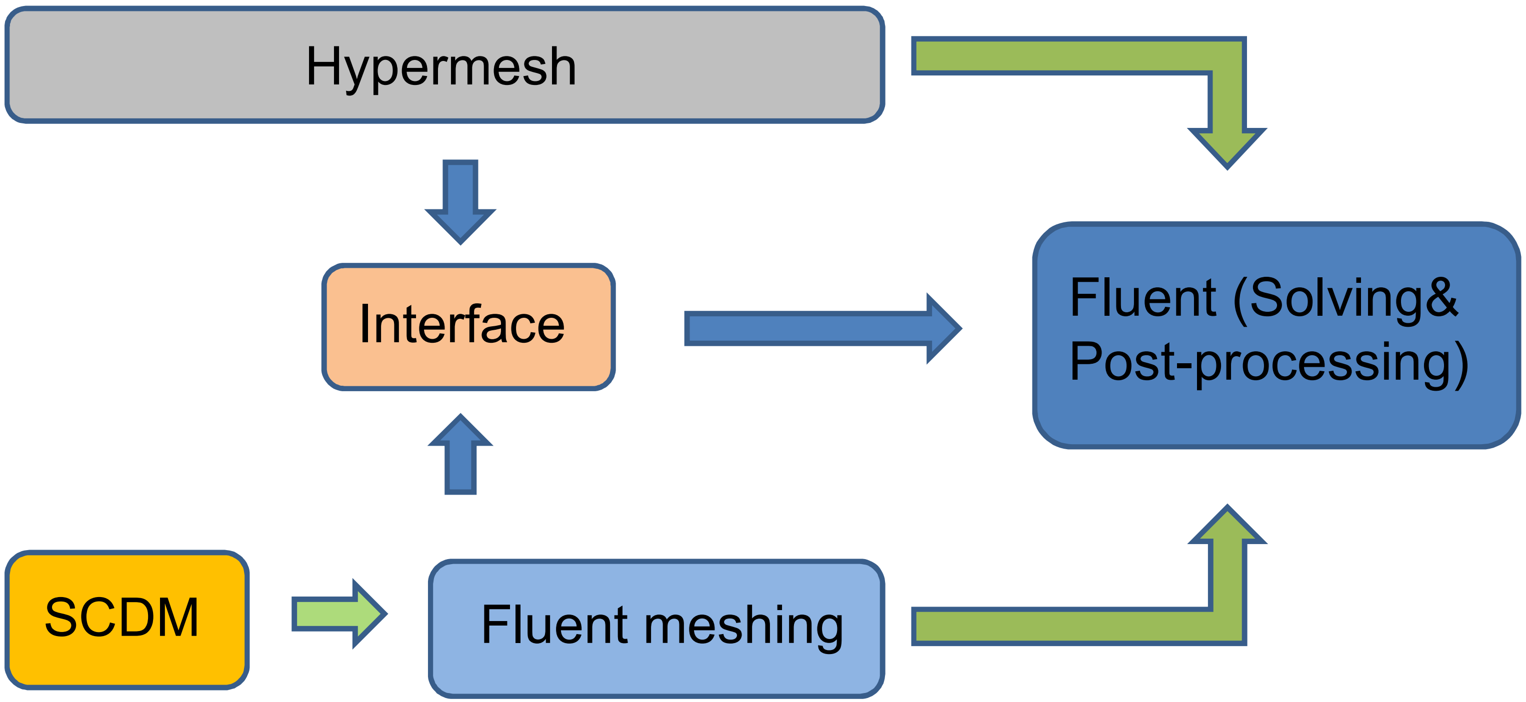
- Meshing by hypermesh and fluent meshing
- Solving with steady flow field and transient energy field

Main object : Predict Tmax and ΔT within the pack

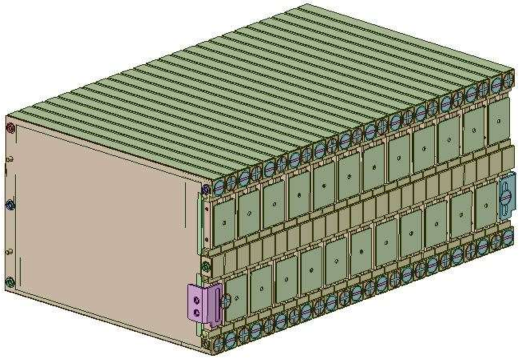
Contents



1.1 3D CFD simulation workflow

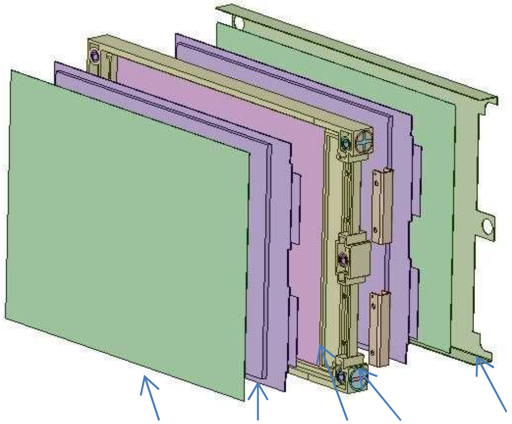


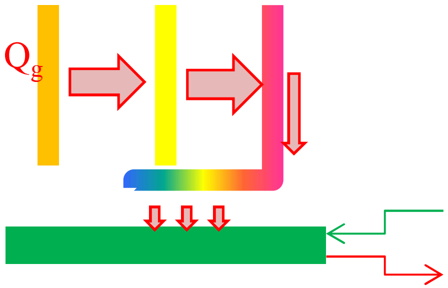
1.2 Hypermesh meshing



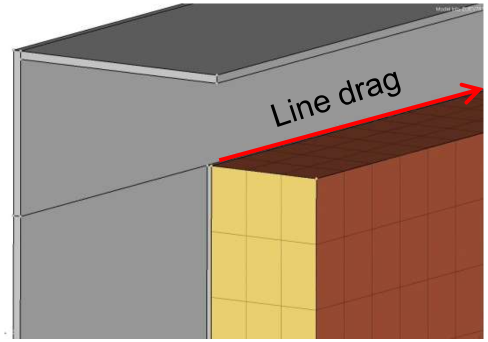
Lithium cell module

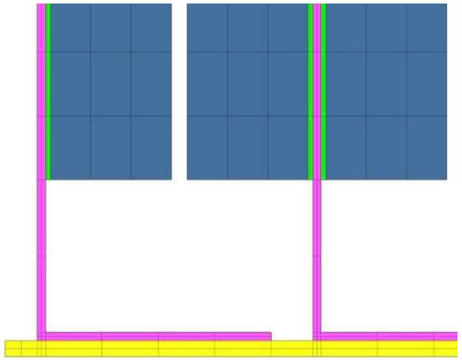
24X





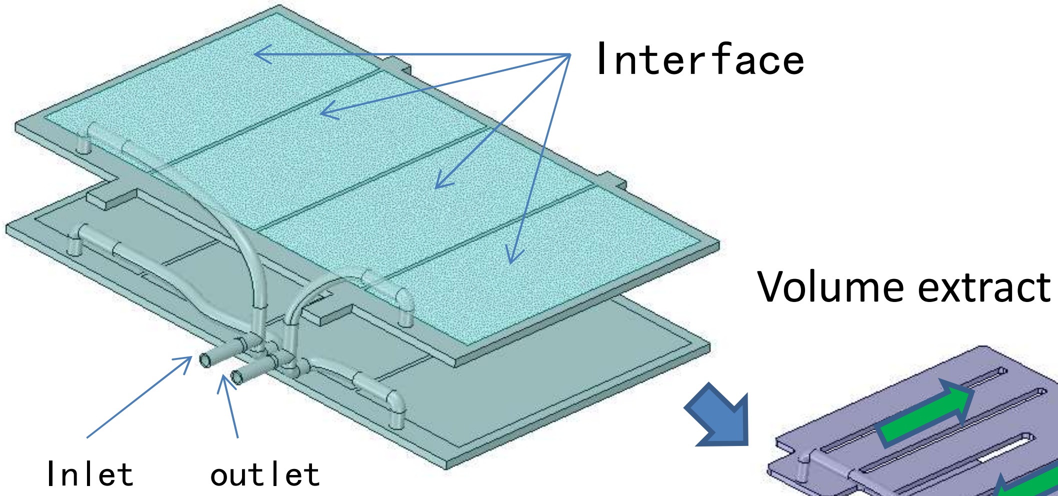
Heat transfer path

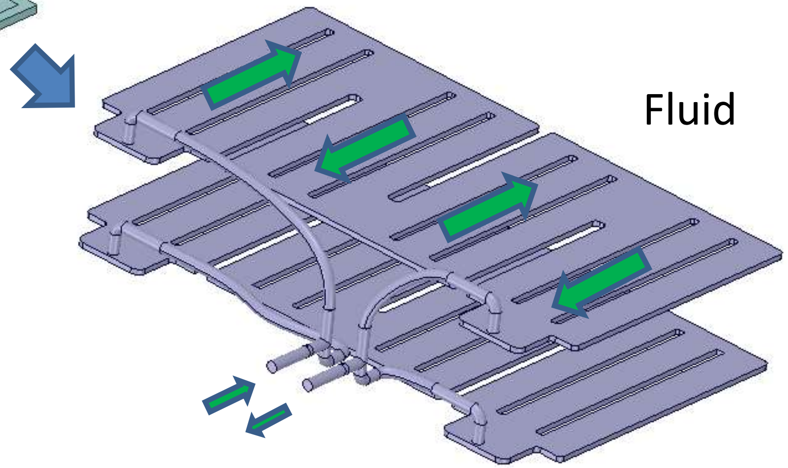




Interface

1.3 SCDM clean-up

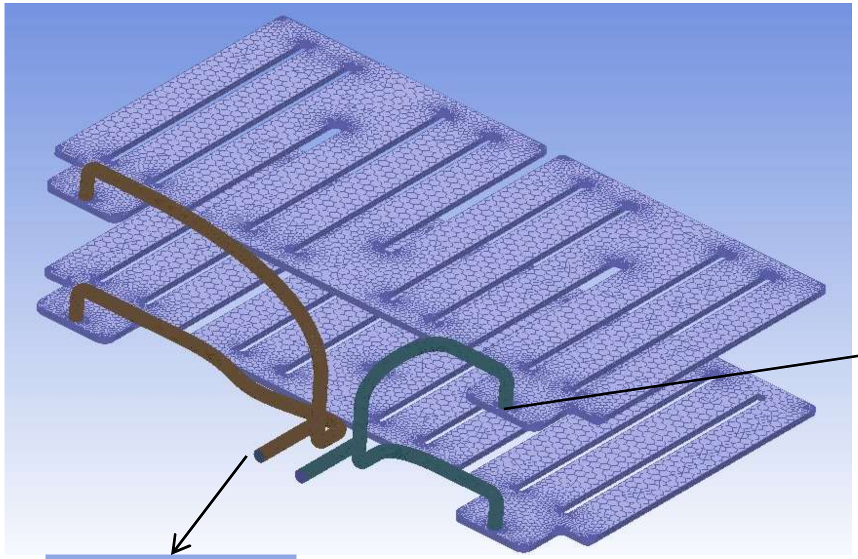


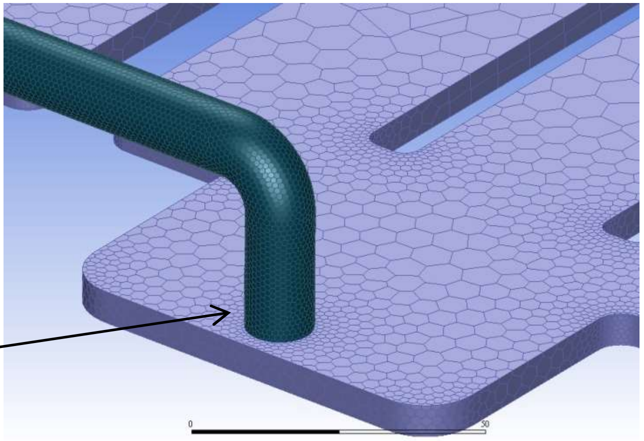


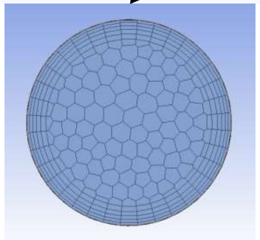
Reynolds Number			
	5L/min	10L/min	15L/min
inlet	1895.5	3791.1	5686.7
channel	410.7	821.4	1232.1

1.4 Fluent meshing/auto mesh

Auto mesh



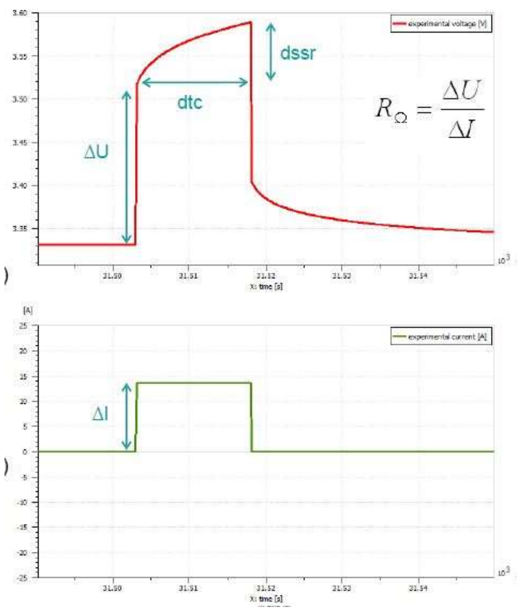


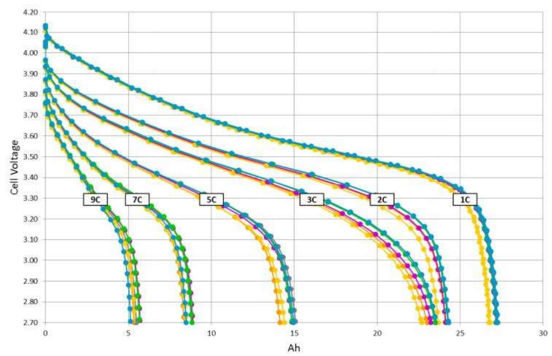


- Realizable k-Epsilon turbulence model
- Cell min size:1mm
- First boundary layer cell size: 0.12mm
- 5 boundary layers with rate 1.2

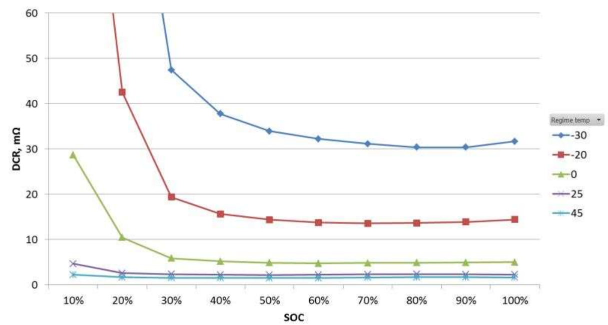
1.5 Cell heat generation rate

$$Q = I \times (U - E) + I \times T \times (dE/dT)$$





25°C voltage curve at C-rate



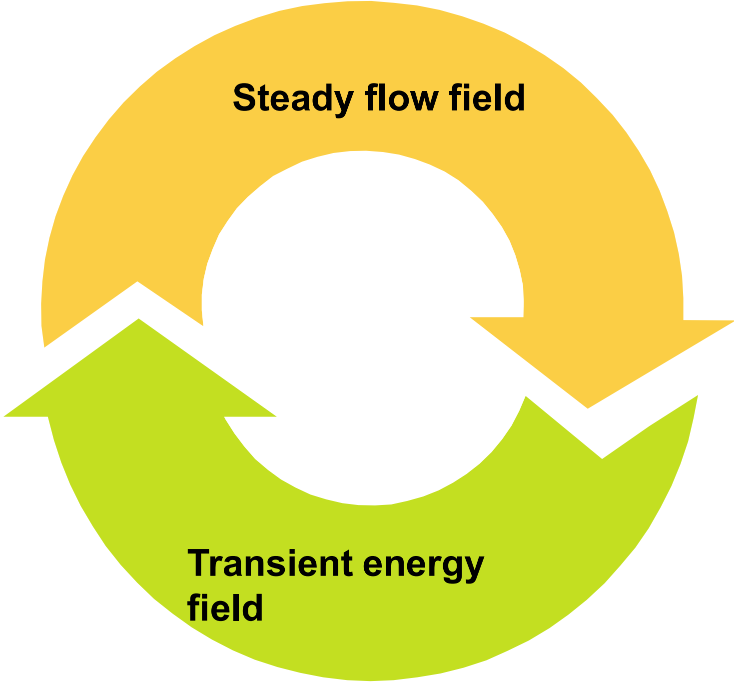
DCR vs SOC & Temperature

1.6 Solving method

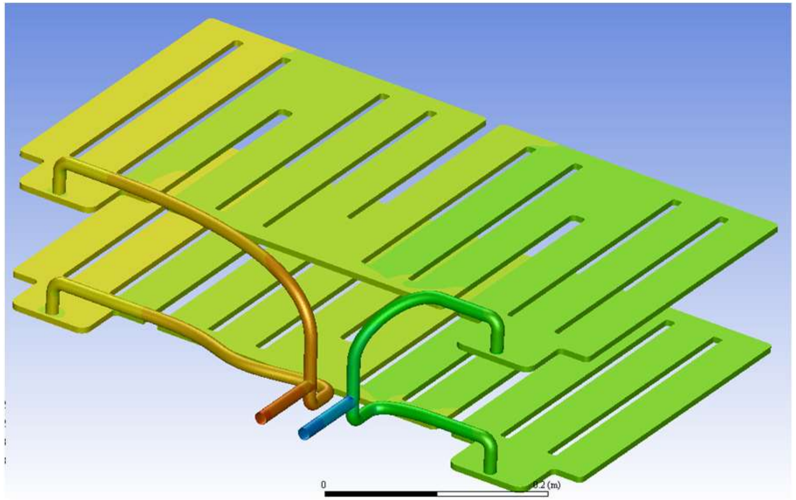
The key point of the liquid cooling pack simulation is to balance the calculation scale and the calculation accuracy.

3 tips:

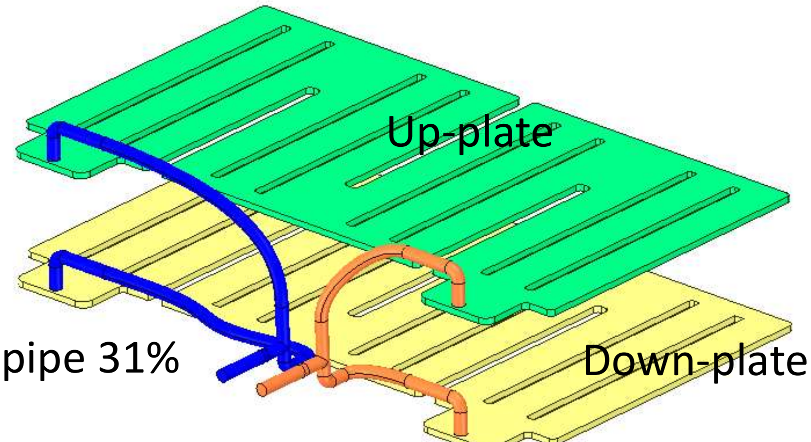
- Ignoring the temperature impact of material property ;
- Focusing on the forced convection of coolant (major thermal transfer path);
- Adding heat transfer coefficient (experiential)



Pressure drop @ 10L/min:

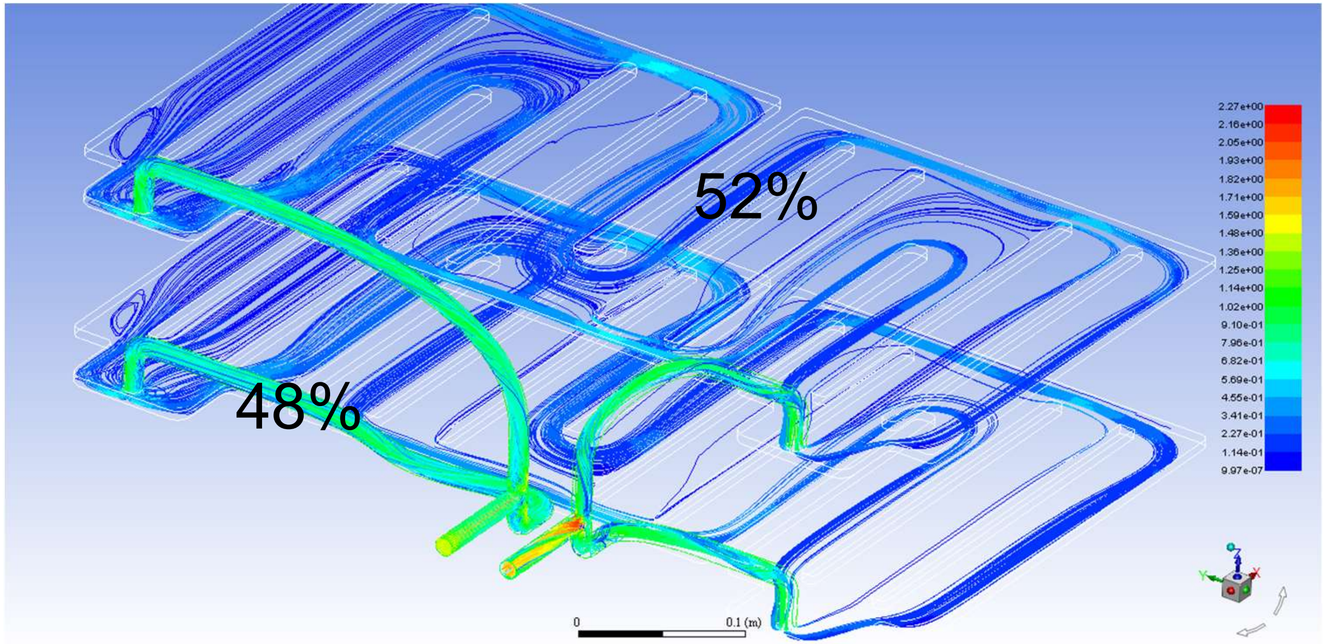


ΔP=6.9Kpa



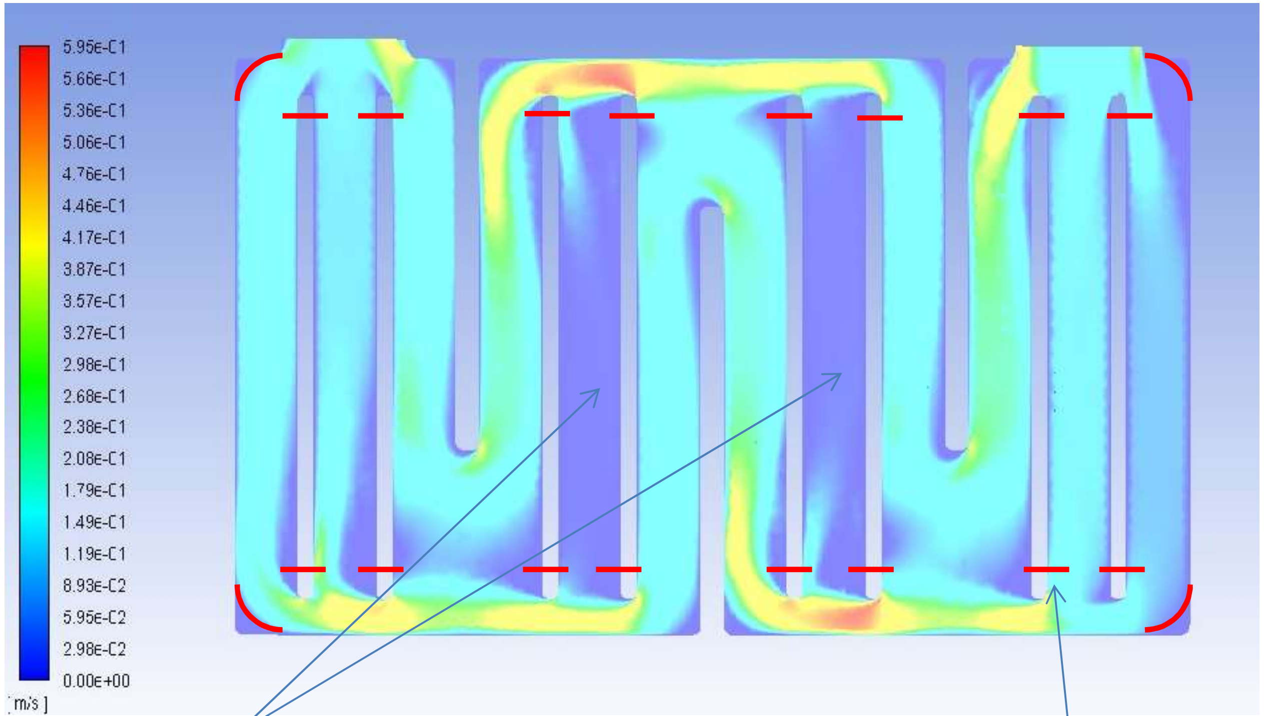
1.7 Results and analysis

Flow distribution@ 10L/min:



The mass flow difference between up and down side is in an acceptable range (±2% from a perfect 50/50 distribution)

Flow Details @10L/min:

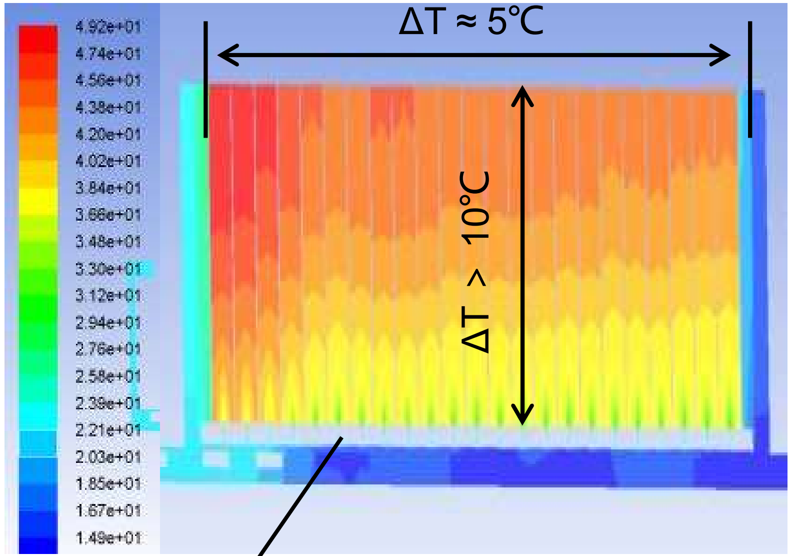


Low velocity zone

Increase the area for the flow deflection regions

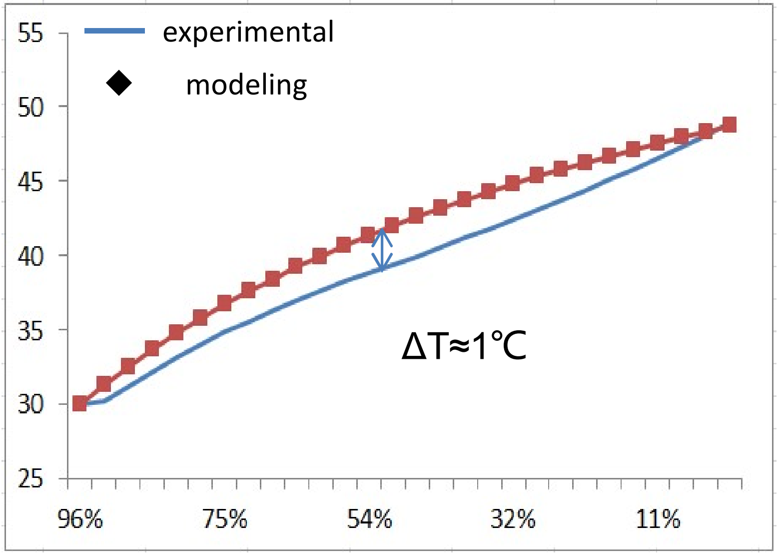
1.7 Results and analysis

T at one vehicle constant speed



insufficient thermal transfer capacity

T-curve: experimental vs modeling



Contents

- 3D simulation of liquid cooling pack
- **Electrochemistry-thermoelectric coupling simulation**

Case description:

Questions

- How to obtain the temperature distribution of the module?
- How to tell the temperature status of the busbar (sensor position)?

Challenge

- Non-uniform heat generation rate of cell
- Voltage varies with the change in SOC, I-V curve varies with the change in C rate

Solution

- Using MSMD electrochemistry module
- Applying calibration of temperature rise with different C-rate discharge

Main object: Predict Tmax of the module

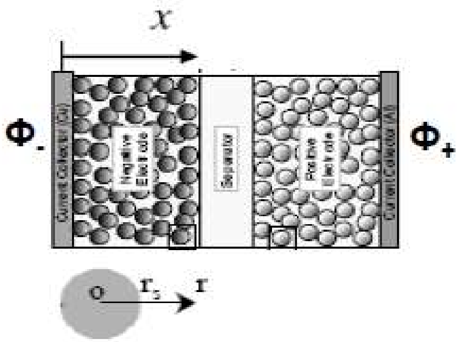
Contents

2.1 MSMD（multi-scale Multi-Domain）

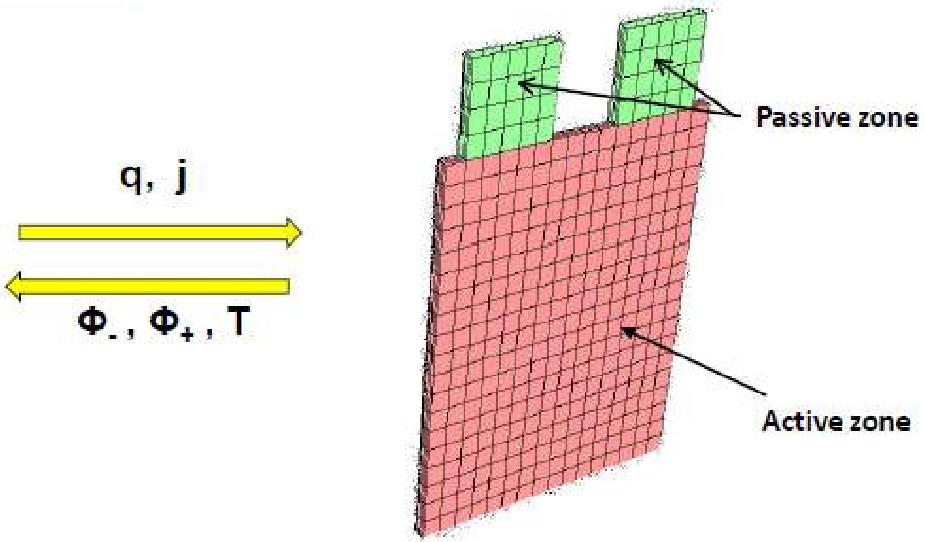
- **Separate meshes are used for different domains**
- **Each finite-volume cell is treated as a mini-battery**

sub-model called at each finite-volume cell
input: Φ_-, Φ_+, T, C_s (X, x, r, t_0), C_e (X, x, t_0)
output: j, q, C_s, C_e

CFD mesh: need not resolve electrode layers
model: anisotropic conductivities
solve: Φ_-, Φ_+, T



Electrode scale sub-model
(NTGK for example)



2.2 NTGK sub-model

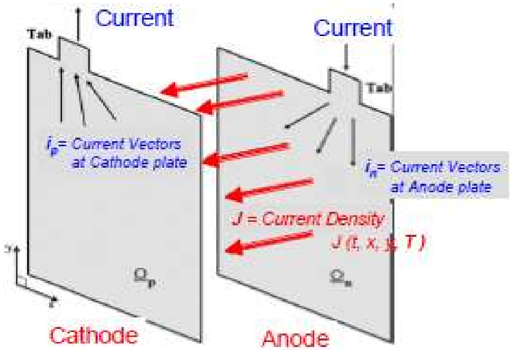
- Newman & Tidemann: 1D
- Gu: 1D
- Kim et al: 2D
- ANSYS: 3D

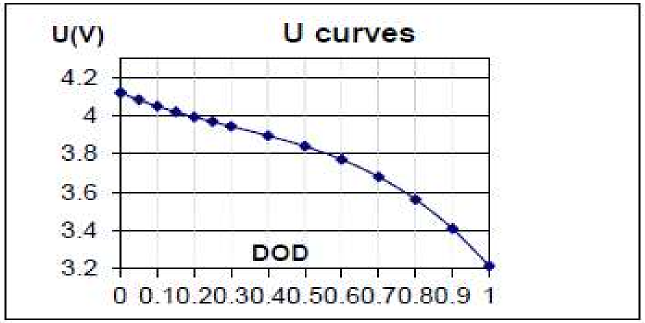
$$\nabla \cdot (\sigma_+ \nabla \phi_+) = -j$$

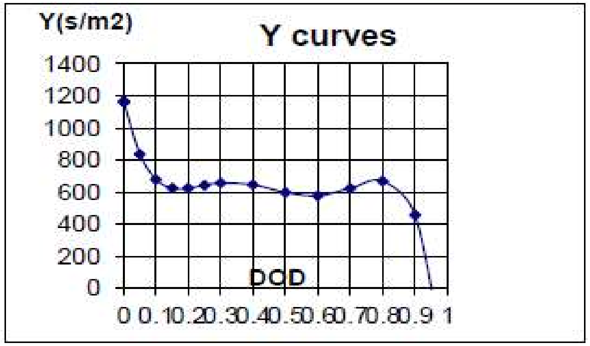
$$\nabla \cdot (\sigma_- \nabla \phi_-) = +j$$

$$j = Y(\phi_+ - \phi_- - U) \qquad DoD = \left(\int_0^t j\,dt\right) / Q_T$$

$$Y = \left(\sum_{n=0}^{5} b_n (DoD)^n\right) e^{C_1\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)} \qquad U = \left(\sum_{n=0}^{5} a_n (DoD)^n\right) - C_2 (T - T_{ref})$$







U.S. Kim et al, "Modeling the Dependence of the Discharge behavior of a Lithium-Ion Battery on the Environmental Temperatur" J. Electrochem. Soc., 158(5), A611-A618 (2001)

2.3 Experimental data and parameter identification

- **Data input： Voltage curve at different C-rate**

```
/define/models> battery-model

/define/models/battery-model> pet
Parameter Estimation for Model:
     1: NTGK Model
     2: ECM Model
     3: Thermal Abuse Model
Model option:  [1] 1
Number of discharging curves: [4] 4

-- Make sure every input file has this format --
        Crate      1.0
        time_1     voltage_1
        time_2     voltage_2
        ...        ...
------------------------------------------------

 file name for curve 1 []
```

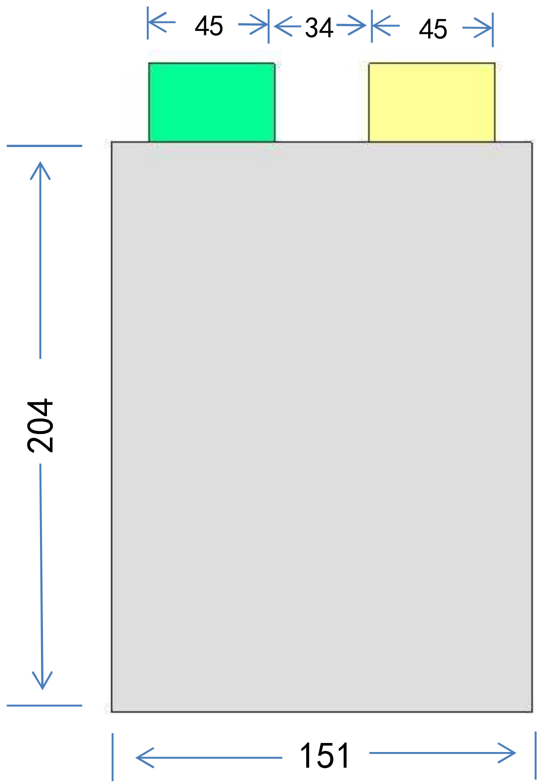
1C.txt - 记事本

文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)

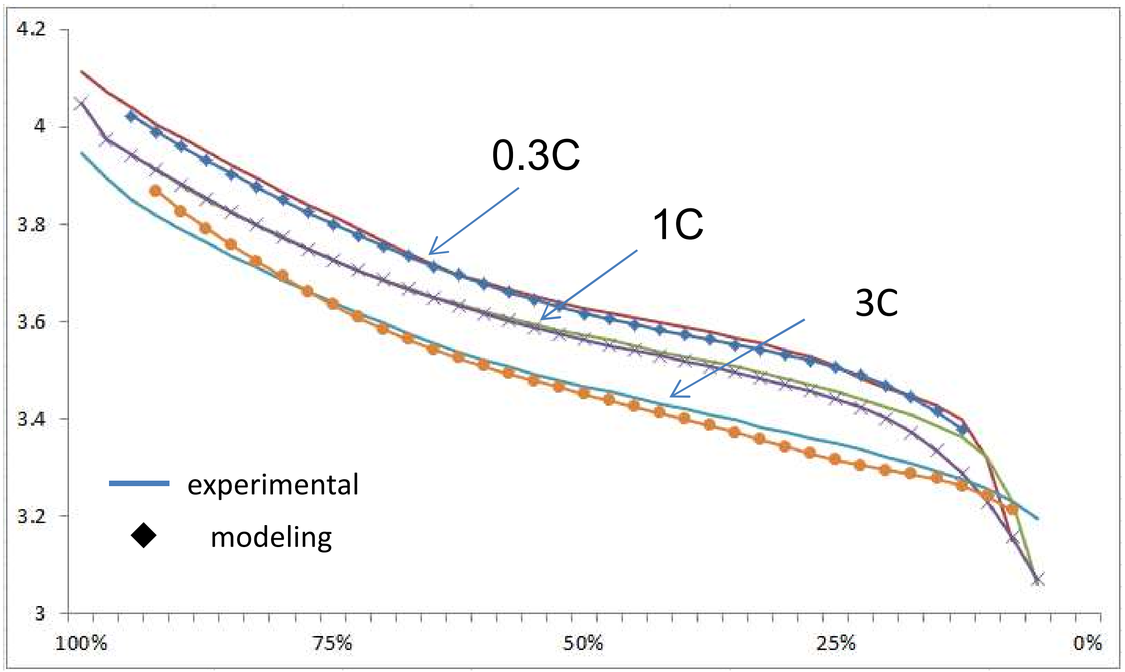
Crate	1.0
1	4.1309
30	4.064
60	4.0449
90	4.0301
120	4.0161
150	4.0055
180	3.9963
210	3.986
240	3.9757
270	3.9655
300	3.9564
330	3.9464
360	3.937
390	3.9277
420	3.9146
450	3.8993
480	3.8878

2.4 Calibration: Voltage

Cell dimension：δ=7.5mm

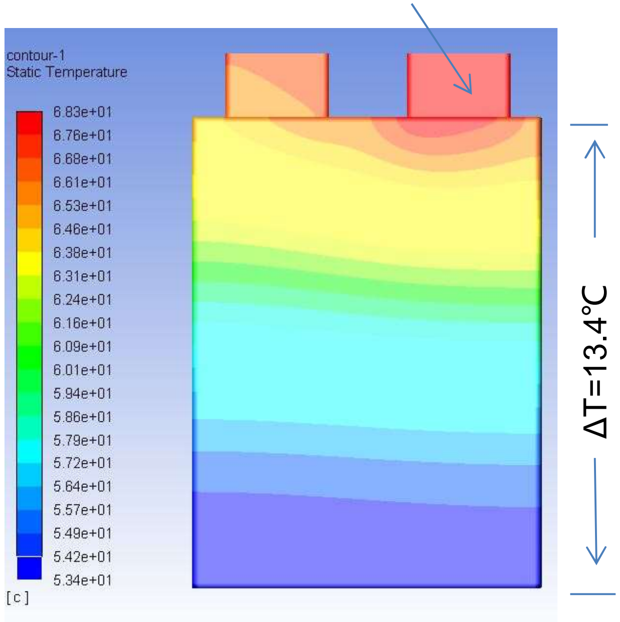


Voltage curve at different C-rate: Modeling VS experimental

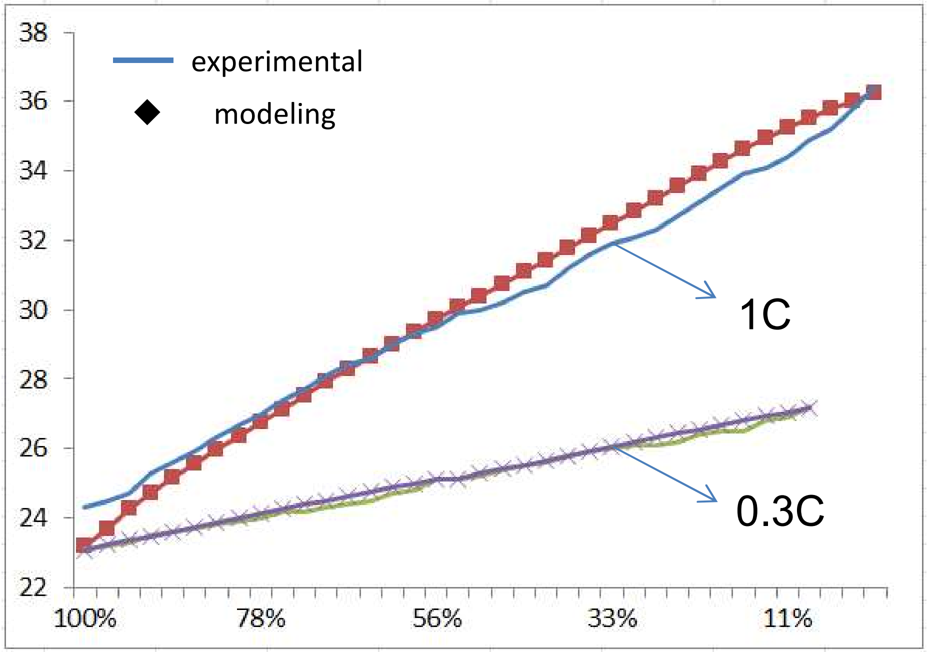


2.4 Calibration: Temperature

Temperature @ 3C discharge:

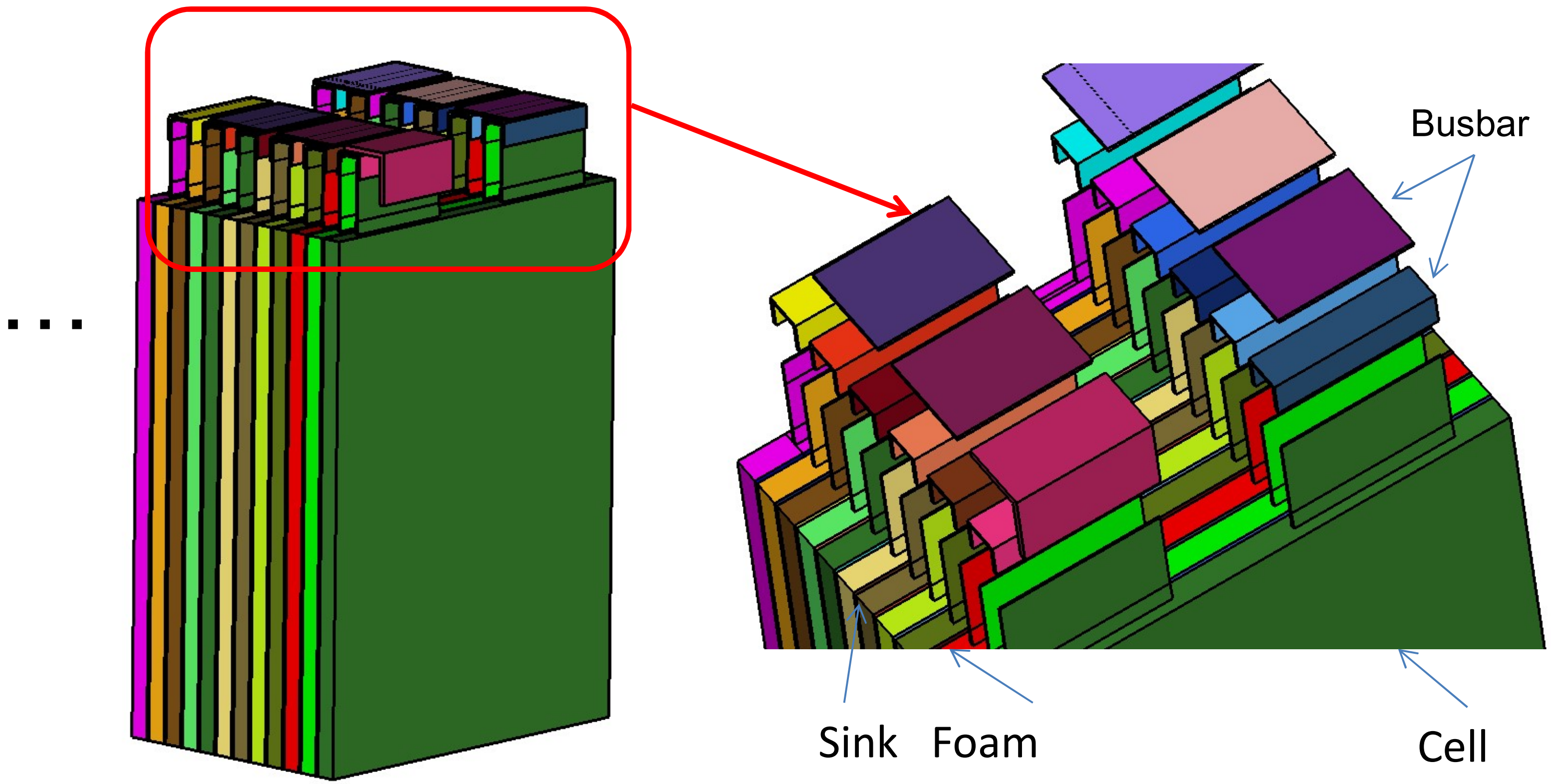


Temperature rise at 0.3C and 1C discharge

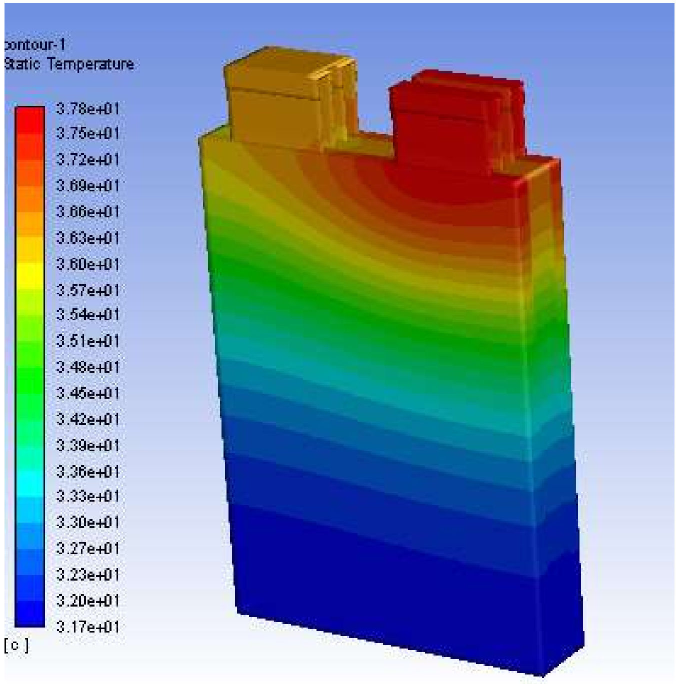


2.5 Modeling description

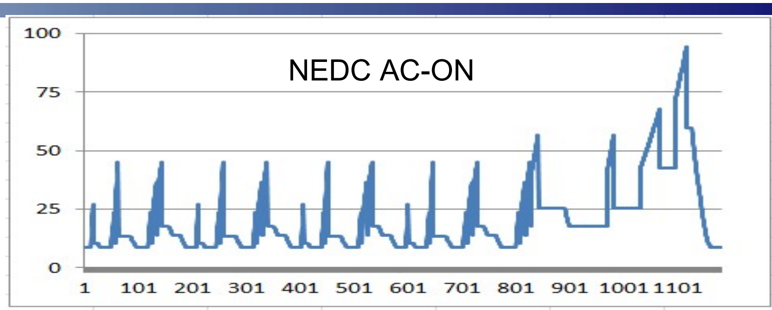
2PNS module

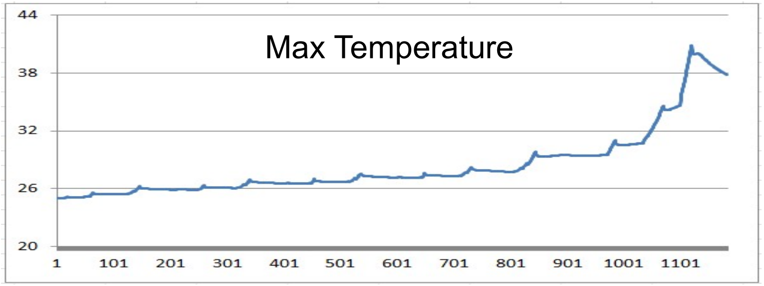


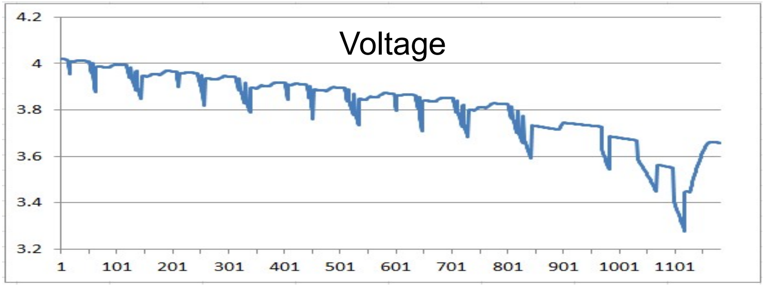
2.6 Result



Temperature distribution of 2p2s module







THANKS!

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Back-up