evs 27

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Modeling and thermal simulation of a PHEV battery module with cylindrical LFP cells

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Outline

- Research context
- Research objectives
- Methodological approach
- Experimental tests
- Thermal model for one cell
- Battery model (test case)
- Simulation
- Conclusion

Research Context

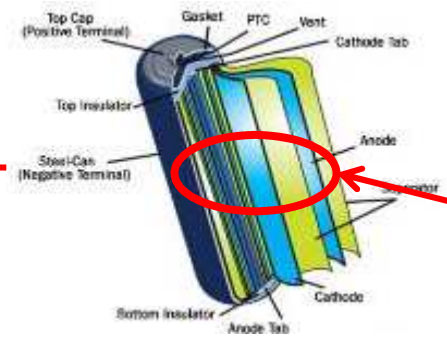
Hybrid and Electric Vehicles

- **feasible solutions for sustainable urban transportation**
- **business opportunity for industry**
- **development of customized product (SMEs)**

Li-ion Battery

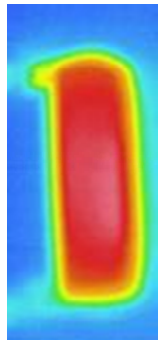
- **Many advantages:** high energy density, capacity, etc.
- **Some disadvantages:** cost, weight, aging effect due to temperature, **safety use**, electrochemical **heat generation**, **cooling system** necessity.

Thermal Dissipation



Electrochemical Heat (inside)

Temp. increasing



Research objectives

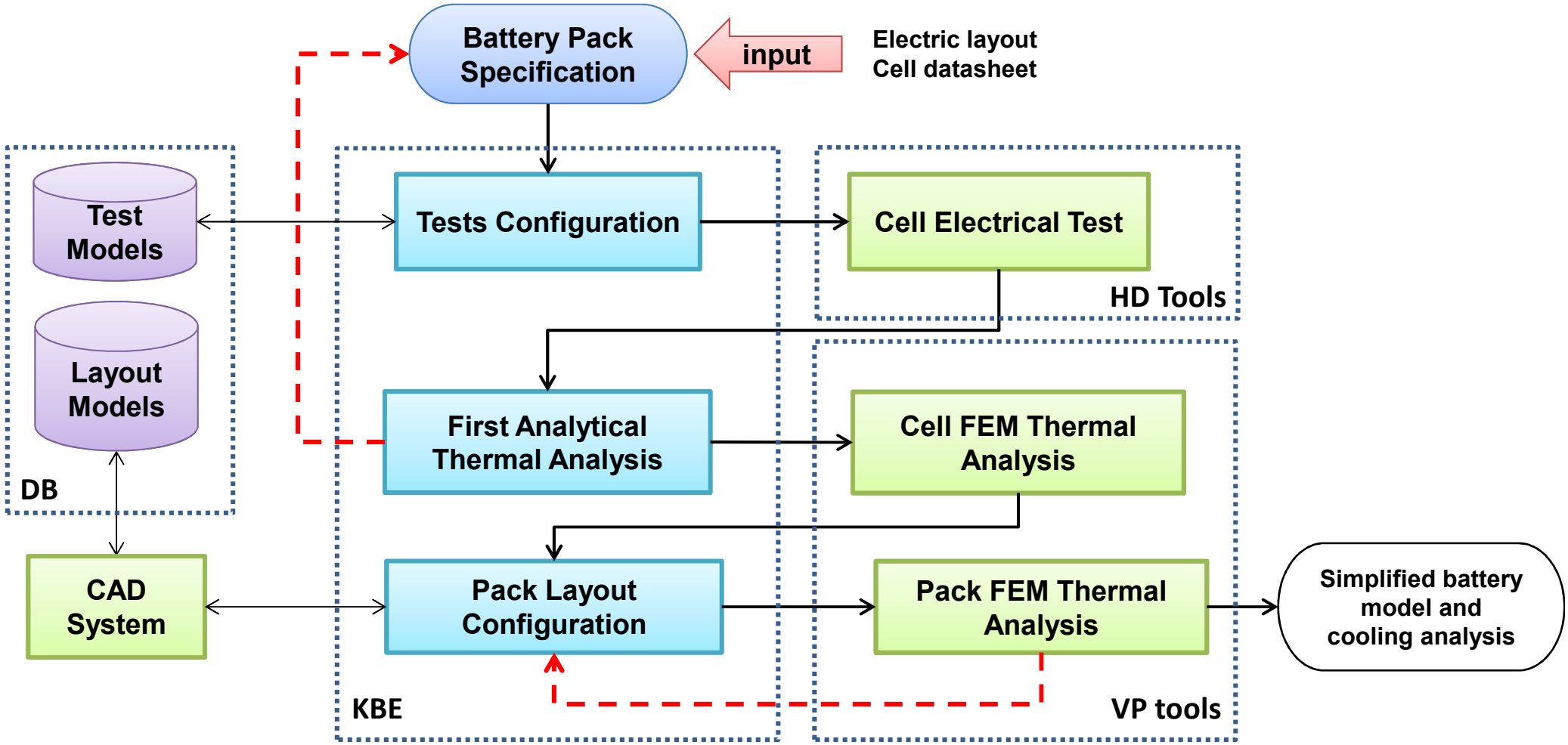
The research aims to analyze a design methodology to support the engineer on evaluating the thermal behavior and the cooling performance of a Li-ion battery pack for customized EV/PHEV

HOW

Using the Virtual Prototyping tools and methods integrating with an analytical thermal approach for modeling the reaction heats

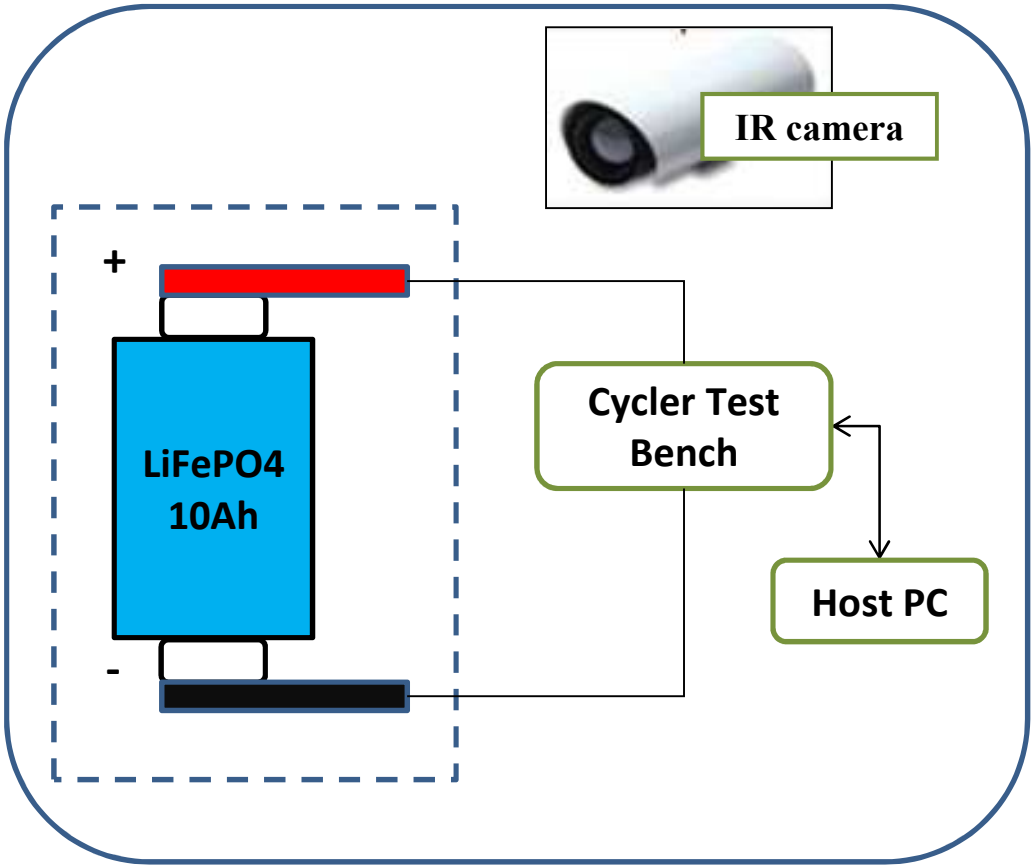
- Li-ion cell testing
- analytical thermal model
- cell thermal simulation
- battery pack CFD analysis

Methodological approach

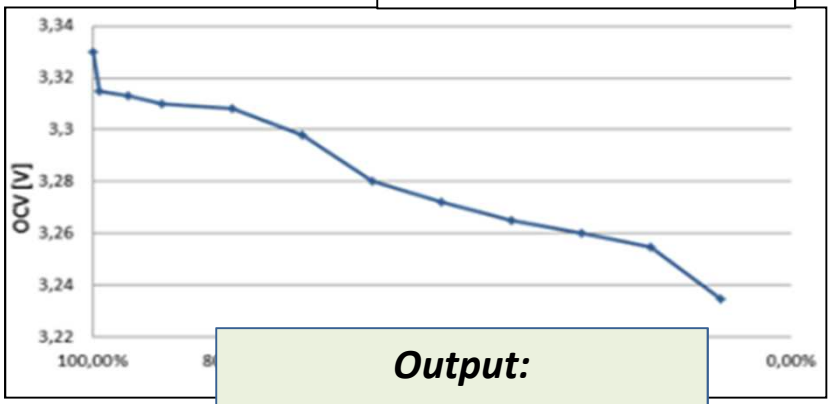


Cell characterization

Experimental Tests

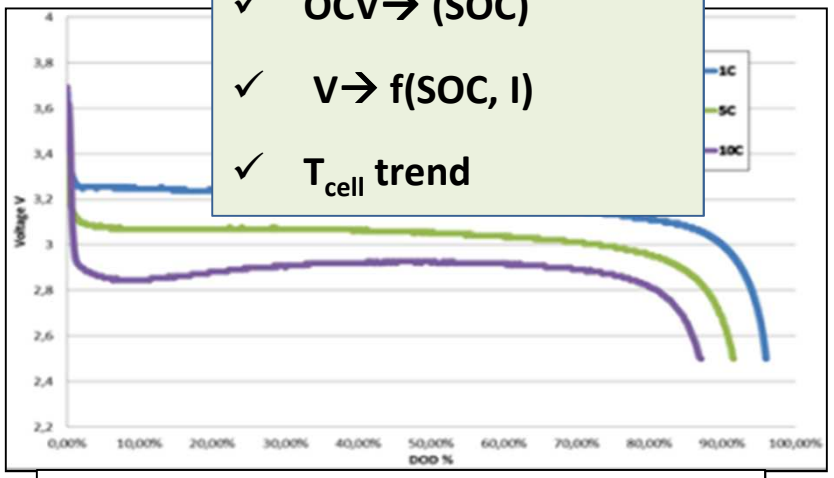


- **OCV tests (0.33 C)**



Output:

- ✓ OCV→ (SOC)
- ✓ V→ f(SOC, I)
- ✓ T_{cell} trend



- **Charge, Discharge tests (1C, 2C, 3C)**

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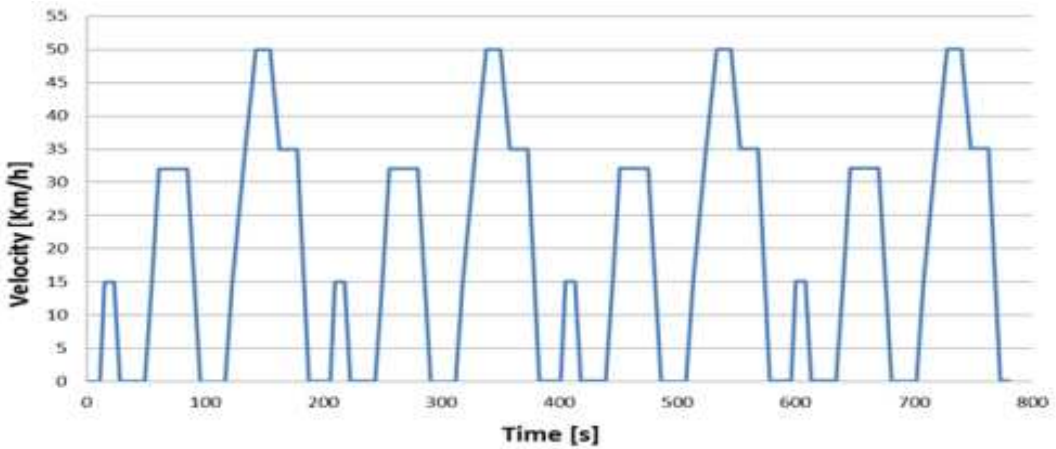
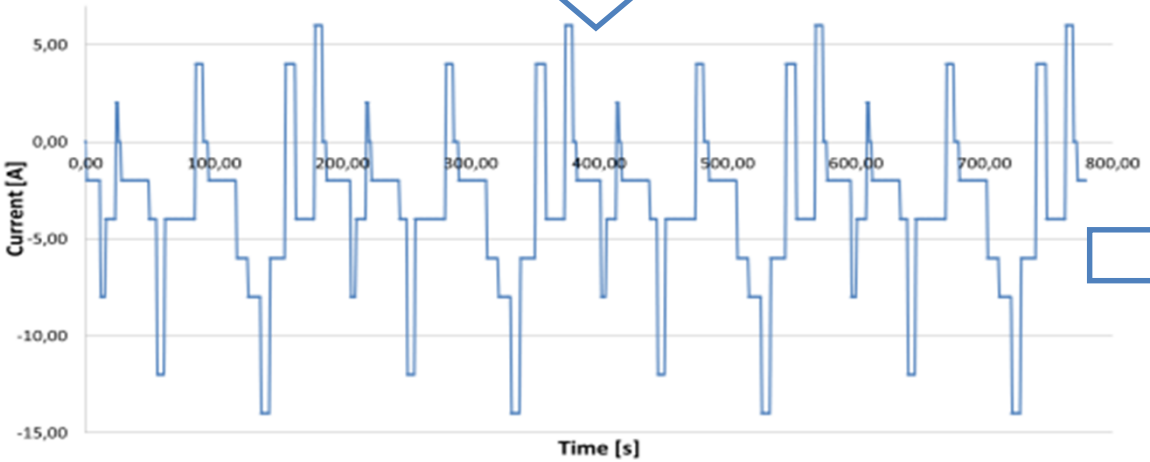
Experimental Tests

NEDC test profile



Evaluated current rate on one cell

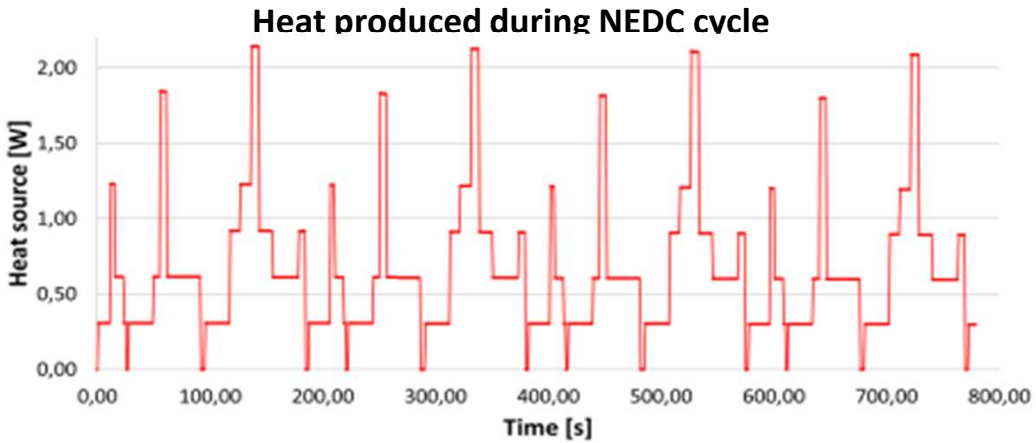


Test output:

- ✓ **V values**
- ✓ **T trend**

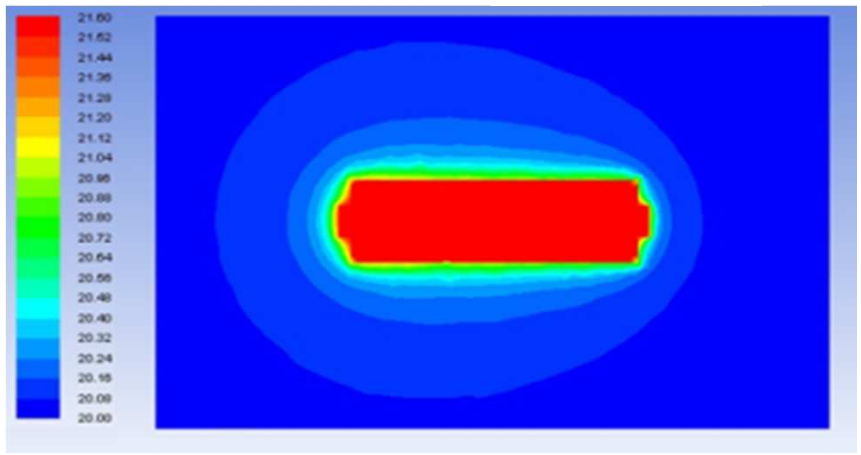
Thermal Model for one cell

Tests ⇨ $\dot{Q} = I(V - E_0) - IT\frac{\partial E_0}{\partial T}$ ⇨

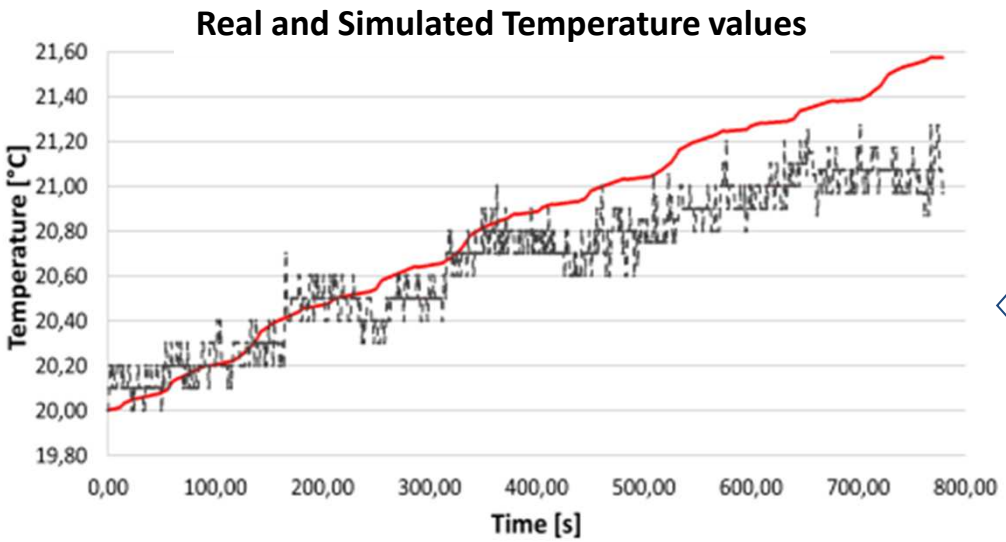


⇩

Cell simulation



⇦



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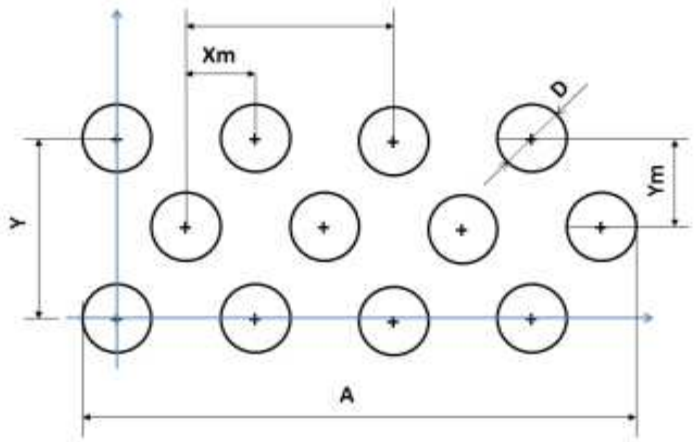
Battery Model

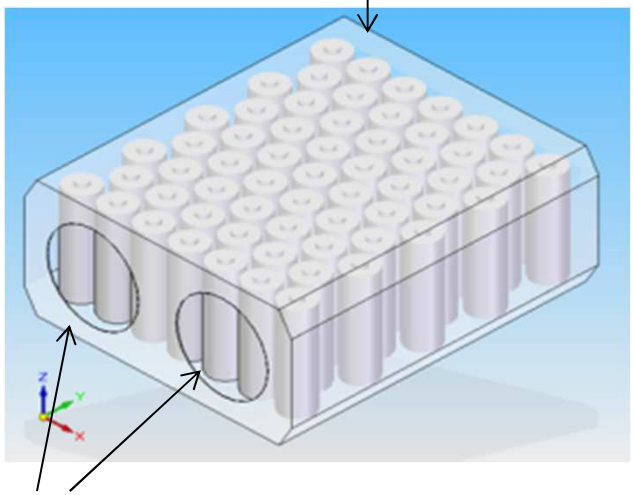
- Battery for PHEV prototype (customized vehicle): 25 kW drive electric motor, 7.55 kW Li-ion battery pack, and 1.2 L ICE (max speed 50 km/h if electric powered)
- 236 cells in 4 module of 59 elements (test case)

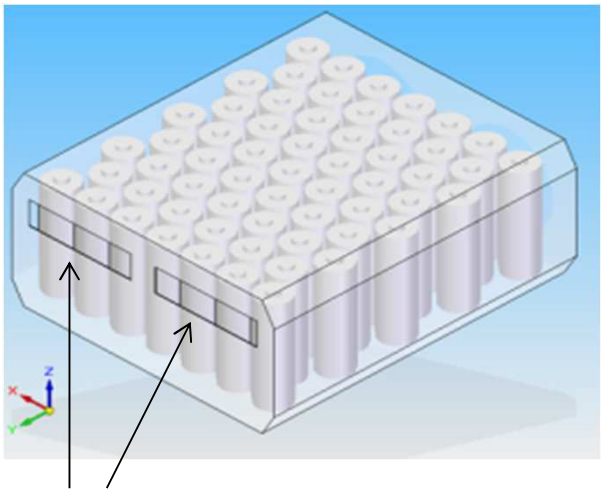


❑ Parametrical layout

❑ Battery model

Chemistry	LFP (LiFePO4)
Nominal Voltage	3.2 V
Geometry	Cylinder
Nominal Capacity	10 Ah
Max Discharge	3C (30 Ah)
Max Charge	2C (20 Ah)





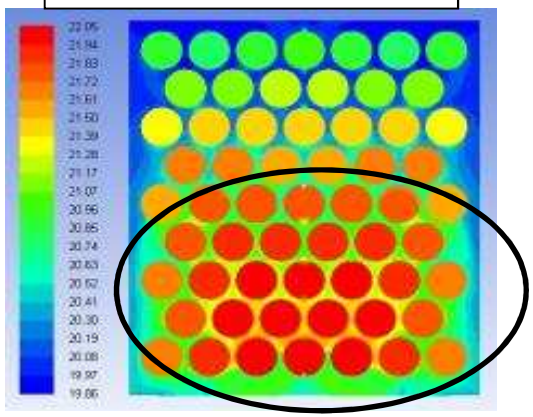
Fan wheels

Inlet

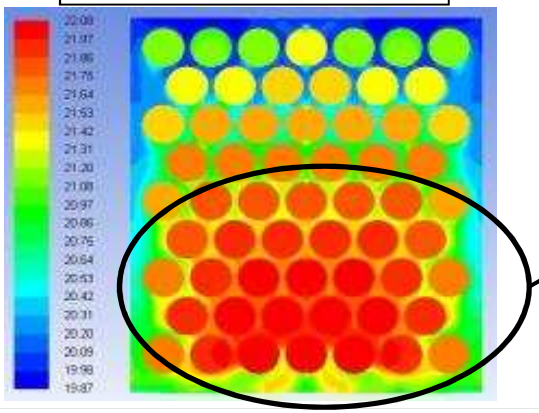
Simulation

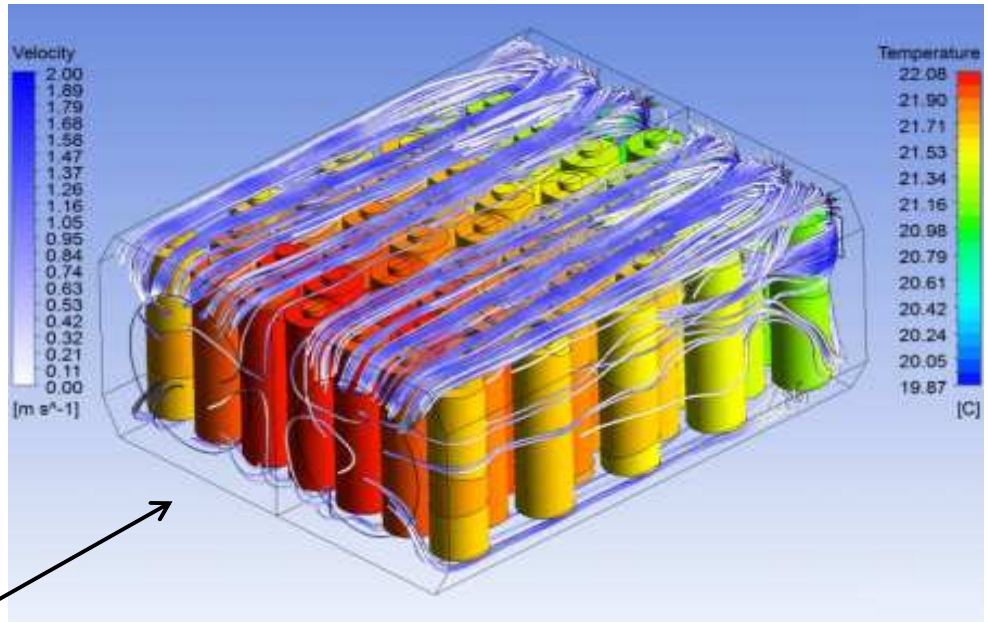
Simulation concerns CFD analysis regarding thermal behavior of battery pack during NEDC cycle (780 s)

150 m^3/h air @ 20° C



50 m^3/h air @ 20° C





Conclusion & Development

- A methodology has been proposed to integrate the experimental data of one Li-Ion cell in a virtual analysis
- Virtual simulation solves thermal model through an analytical calculation of heat source
- A CFD simulation has been proposed to evaluate cooling performance in a prototype battery pack during a NEDC cycle

Future works:

- evaluate BMS effect in thermal simulation
- extend proposed approach to different cell type and battery layout

Thank you for your attention!

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