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UNIVERSITY OF APPLIED SCIENCES

Thermal Analysis on Module Level in an Automotive Battery Package

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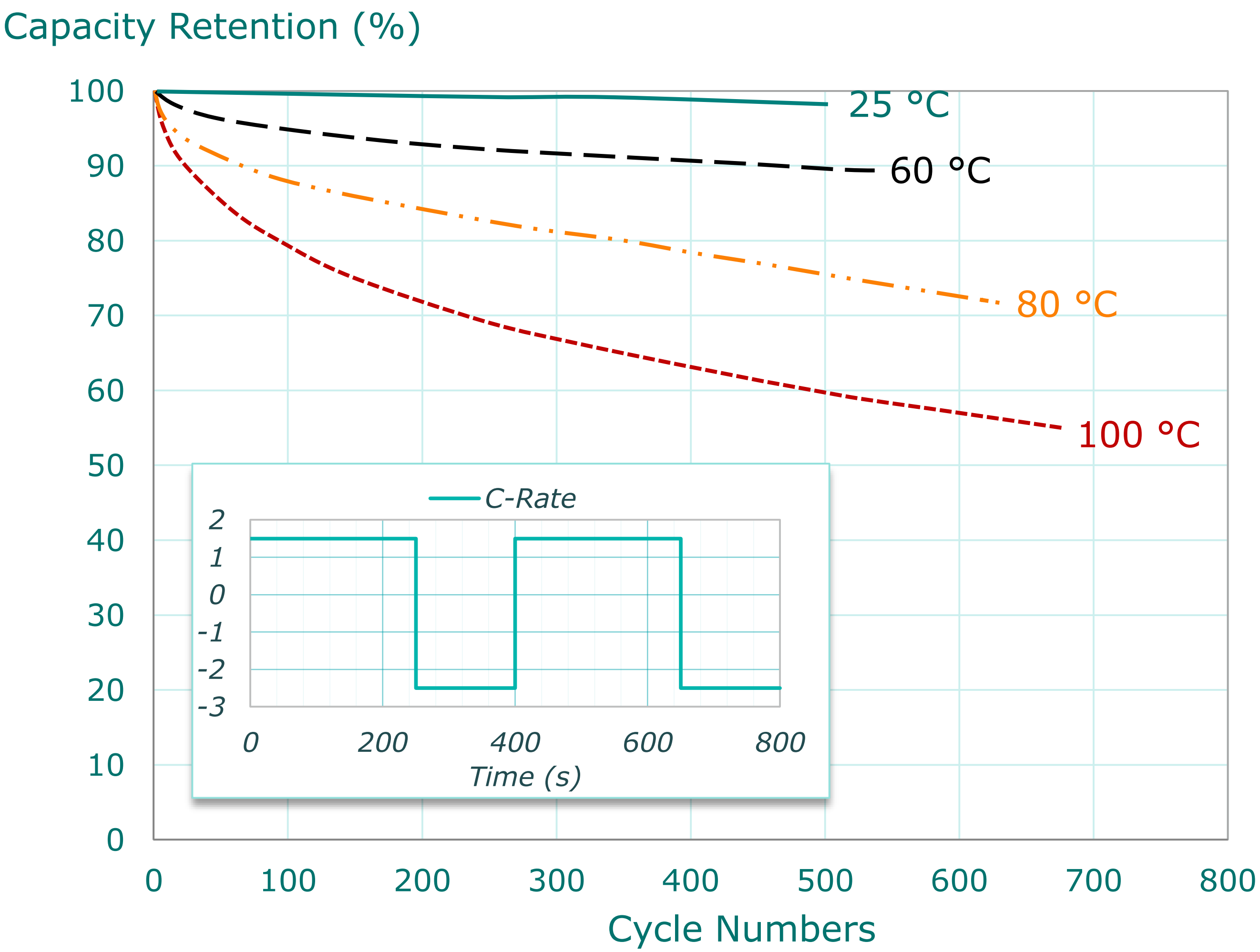
Content

Thermal Analysis on Module Level in an Automotive Battery Package

Motivation

- Individual batteries have their own operational temperature ranges
- Many Li-Ion cells do not function well above 60 °C
- A good understanding of the thermal behavior of the batteries has its significance during designing safe and robust battery packages

AHR18700M1Ultra graphite/$LiFePO_4$ cell from A123 Systems



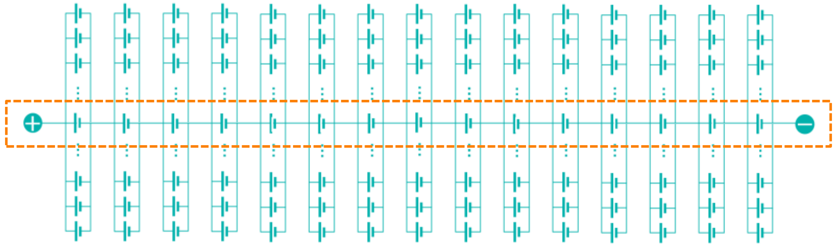
[Source: photo, ebaracus.com]

[Source: Linden's Handbook of Batteries]

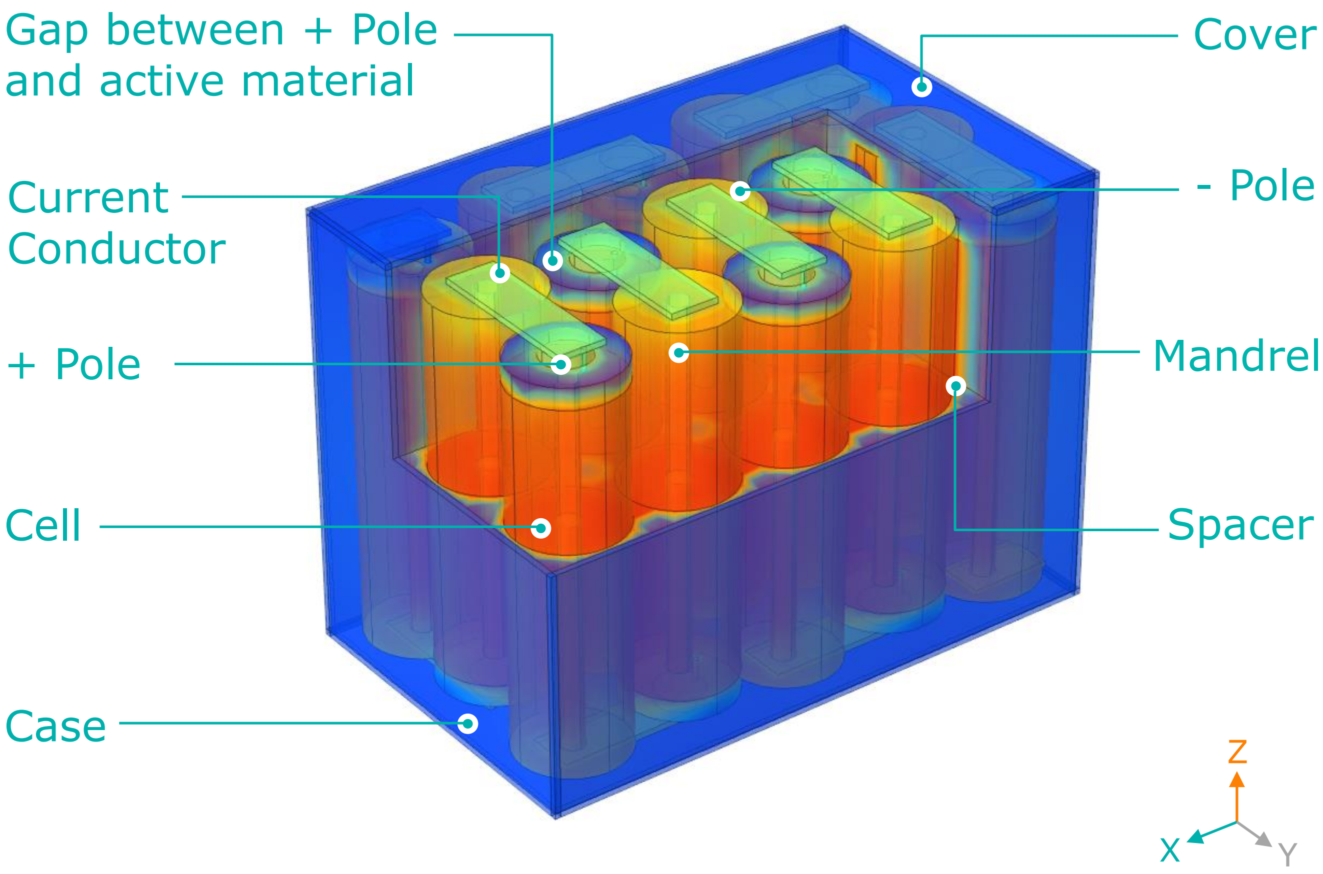
Thermal Analysis on Module Level in an Automotive Battery Package

Ground Model - Battery Module

- 48 V battery module with a least number of cells



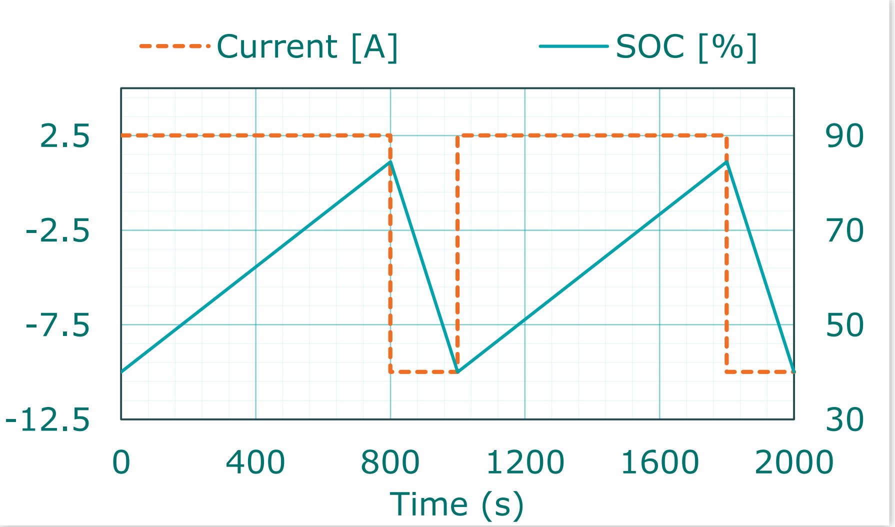
- 15 identical cells High capacity power cell from K2 Energy - K218650P01



[Source: K2 ENERGY]

Ground Model - Load Profile

- Load profile is derived from the technical data
- Charging at 2 C-rate
- Discharging at 8 C-rate
- Cell Heating: $\dot{Q}_{Cell} = I^2 \cdot R$
- Simulation duration: $20 \cdot 10^3$ *second*



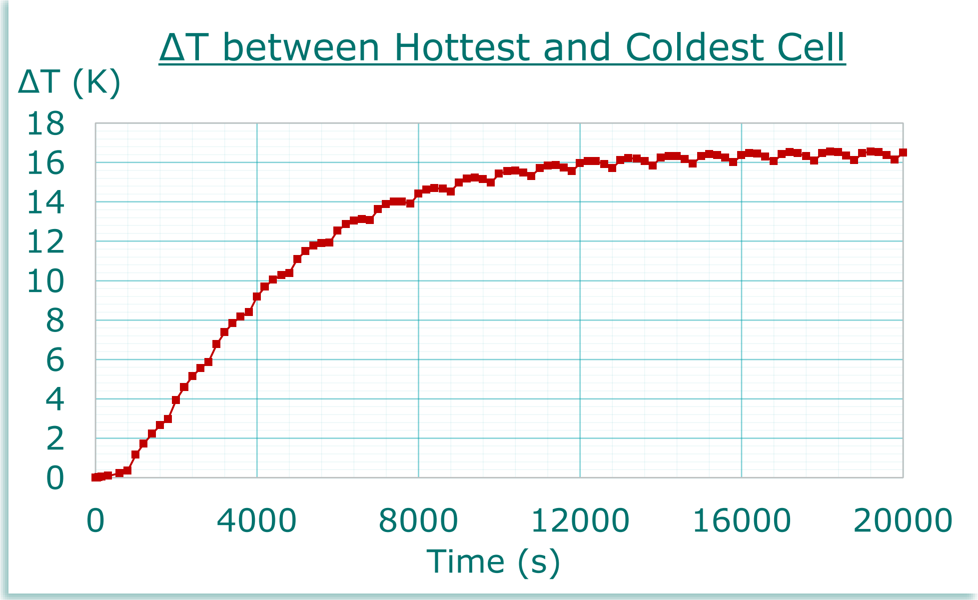
SPECIFICATION	
Nominal Capacity @ C/5 (Ah)	1.25
Average Operating Voltage @ C/5 (V)	3.2
Internal Impedance @ 1kHz, AC (mΩ)	<19
RECOMMENDED OPERATING CONDITIONS	
Continuous Discharge (A)	5.0
Charge Current (A)	≤1.25
High Operating Temp (°C)	60
Low Operating Temp (°C)	-20
MAXIMUM OPERATING CONDITIONS	
Continuous Discharge (A)	21
Charge Current (A)	2.4
High Operating Temp (°C)	85
Low Operating Temp (°C)	-40

[Source: K2 ENERGY]

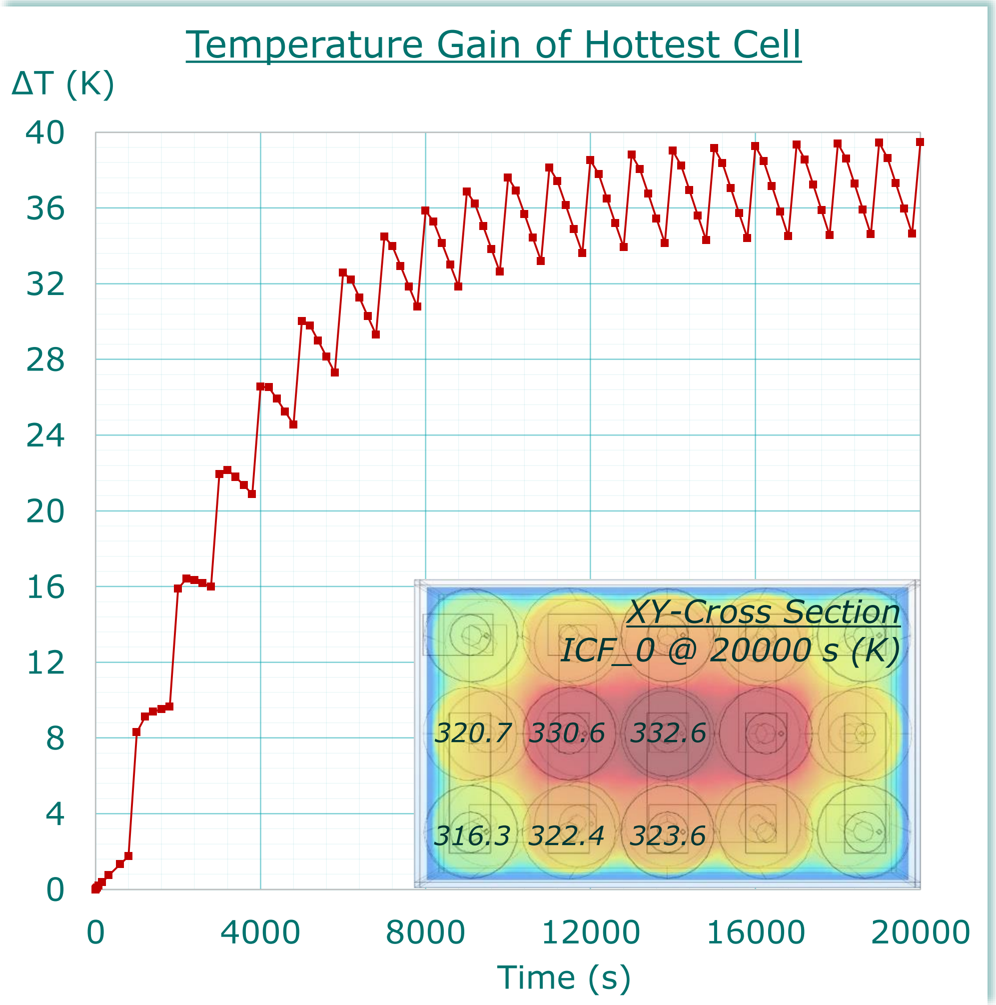
Thermal Analysis on Module Level in an Automotive Battery Package

Ground model – Results

- Temperature - $T_{ext} = T_0 = 20\,°C$
- Convective Heat Flux - $q_0 = h \cdot (T_{ext} - T)$
- Constant $\text{htc} = 20\ W/(m^2 \cdot K)$
- Objective 1: $T_{Cell} \leq T_{recommended\ operation}$
- Objective 2: $T_{Cell\_Max} - T_{Cell_{Min}} \leq 3\ K$



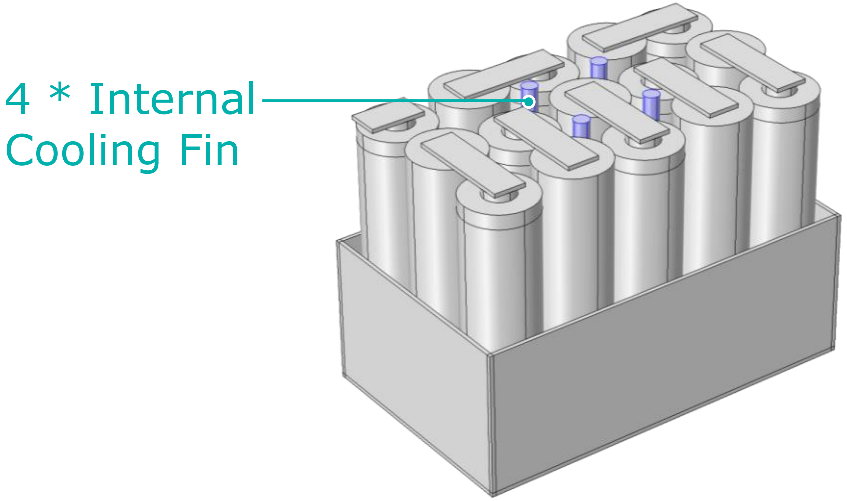
ICF_0

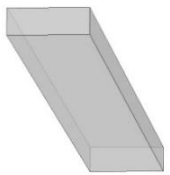
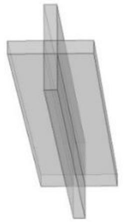
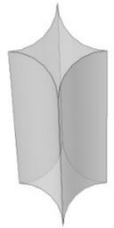


Thermal Analysis on Module Level in an Automotive Battery Package

Internal Cooling Fin - Concept

- Temperature: $T_{ext} = T_0 = 20\,°C$
- Convective Heat Flux: $q_0 = h \cdot (T_{ext} - T)$
- Constant $\mathrm{htc} = 20\ {}^{W}/_{(m^2 \cdot K)}$
- <u>Objective 1</u>: $T_{Cell} \leq T_{recommended\ operation}$
- <u>Objective 2</u>: $T_{Cell\_Max} - T_{Cell\_Min} < 3\ K$



	ICF_1	ICF_2	ICF_3	ICF_4	ICF_5	ICF_6
Internal Cooling Fin (ICF) Concepts						
XY-Cross Section (mm²)	11.95	12.00	12.00	12.00	12.00	12.01
Circumference (mm)	12.25	25.13	16.00	19.00	26.00	23.50

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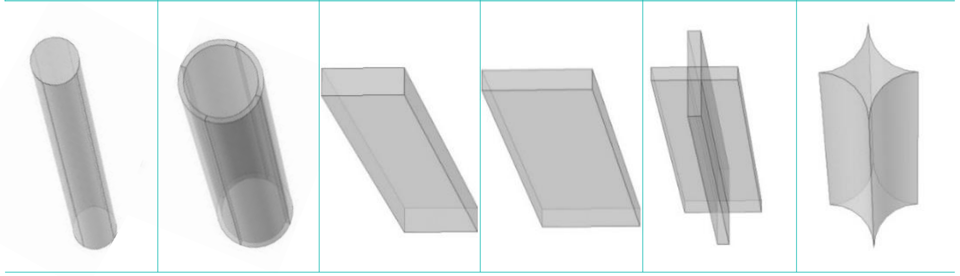
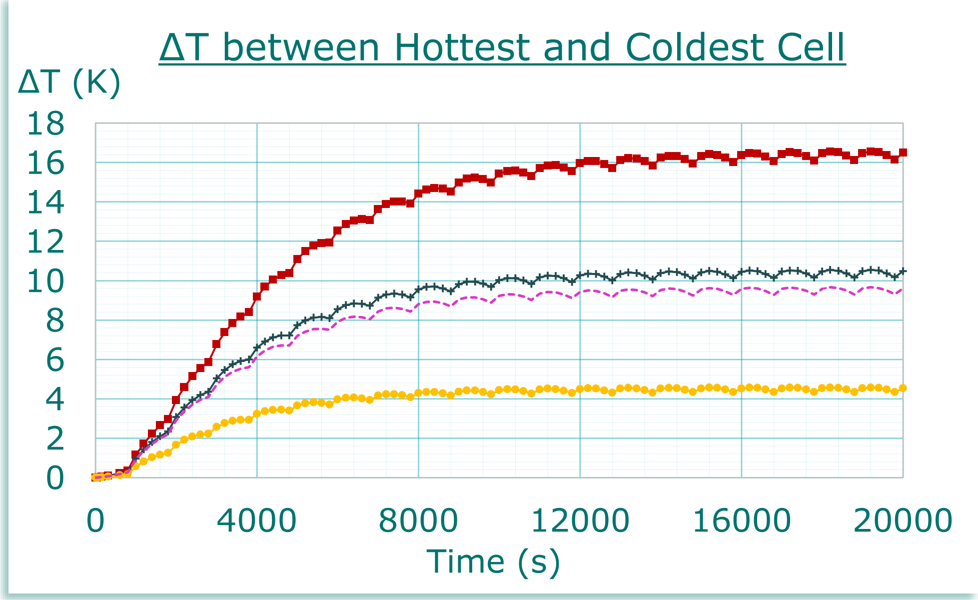
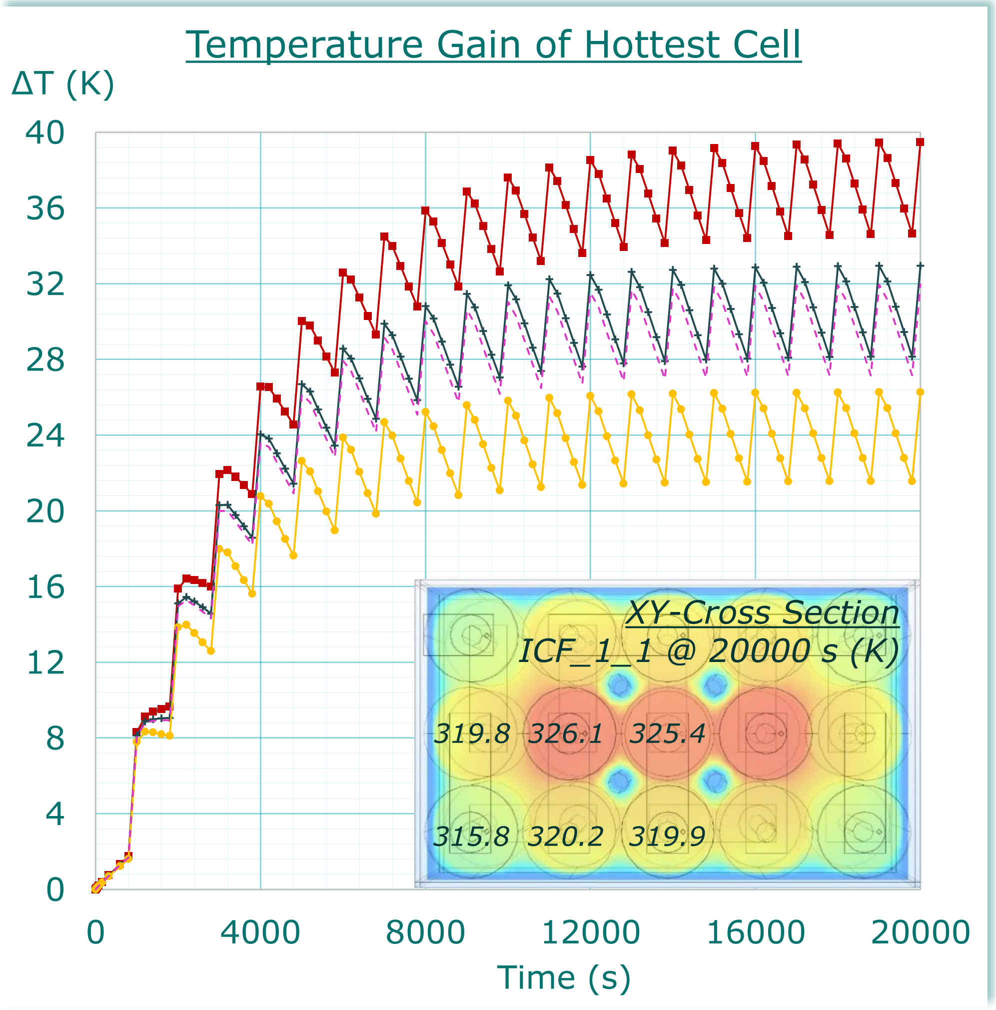
Internal Cooling Fin - Results

ICF_1	ICF_2	ICF_3	ICF_4	ICF_5	ICF_6





ICF_0
ICF_1_1
ICF_3_1
ICF_4_1
ICF_5_1
ICF_6_1
ICF_2_1



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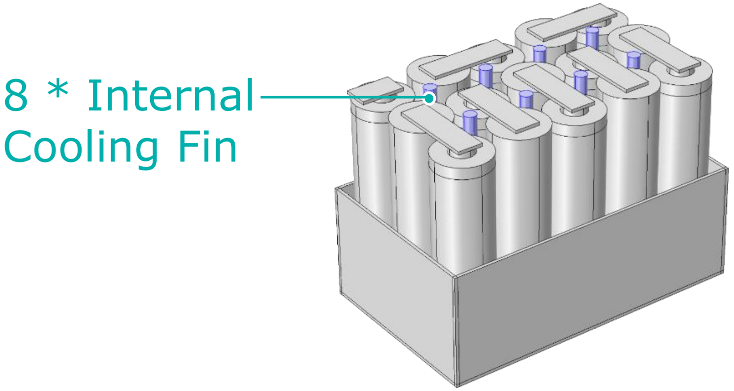
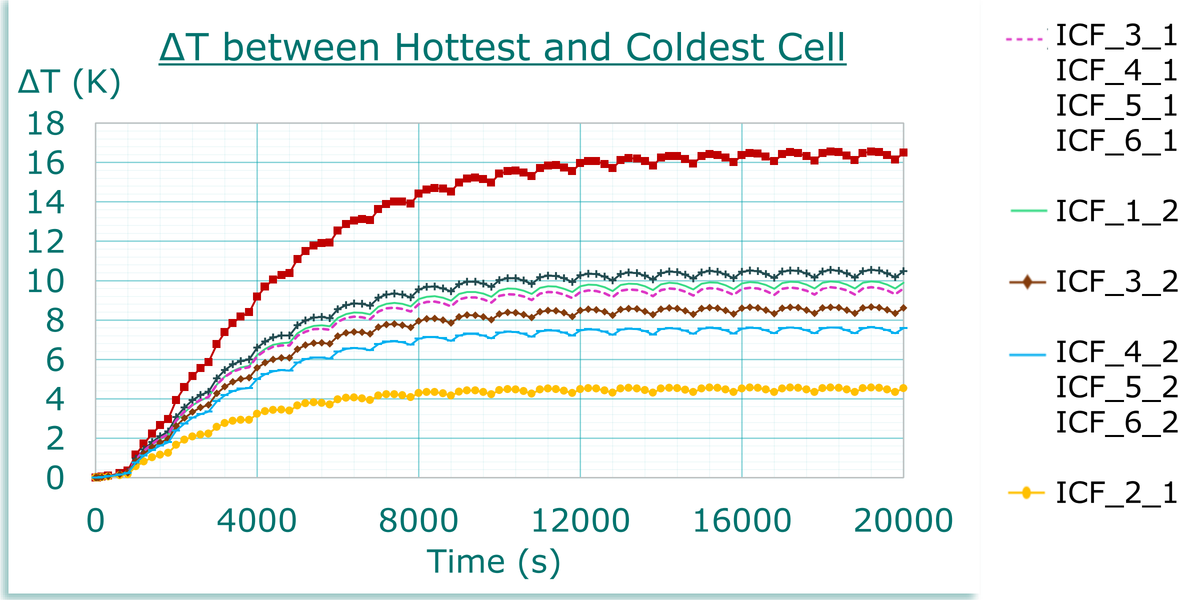
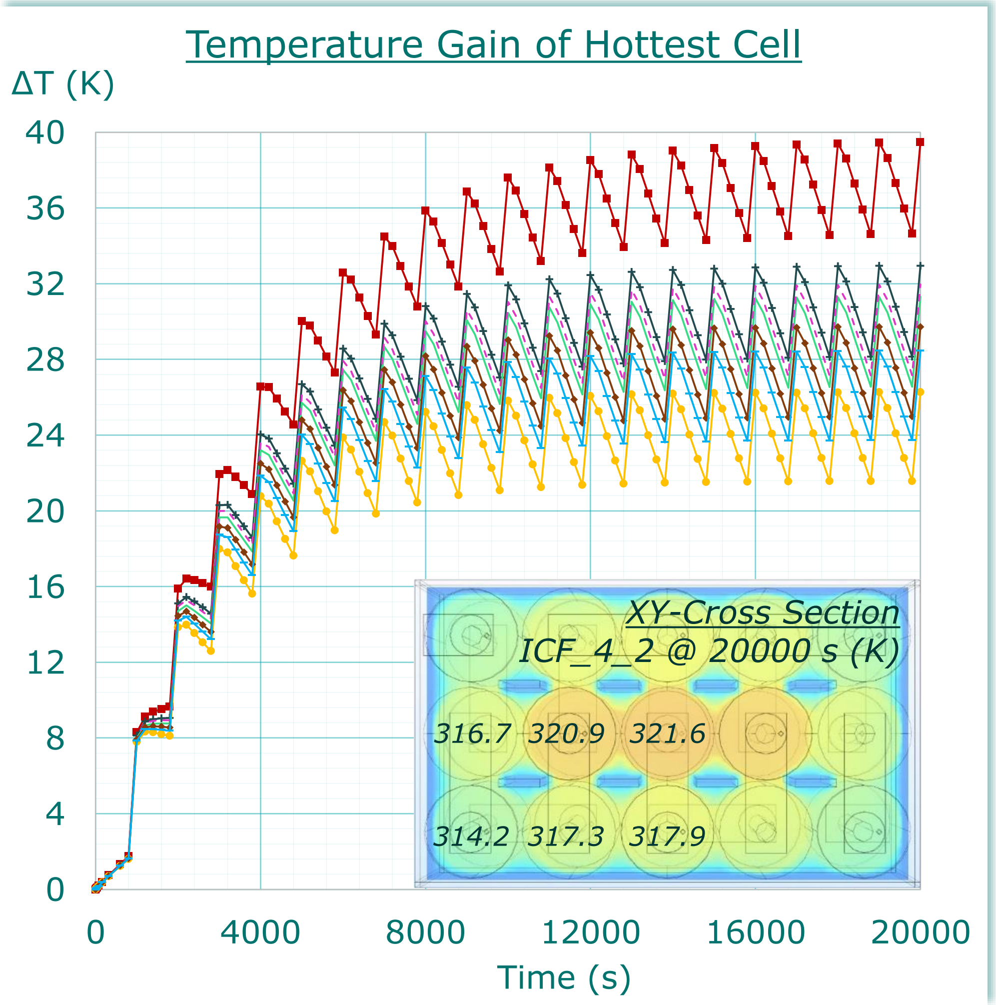
Internal Cooling Fin - Results







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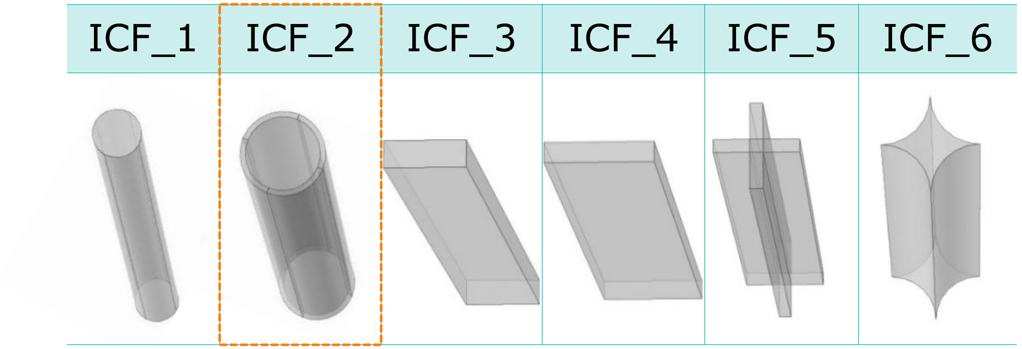
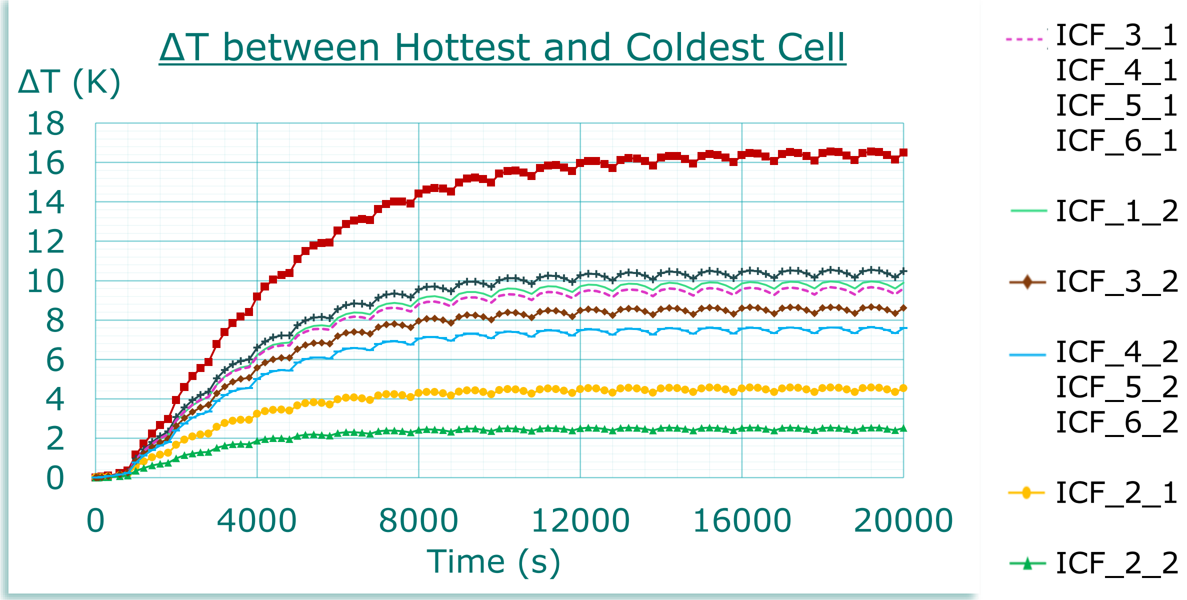
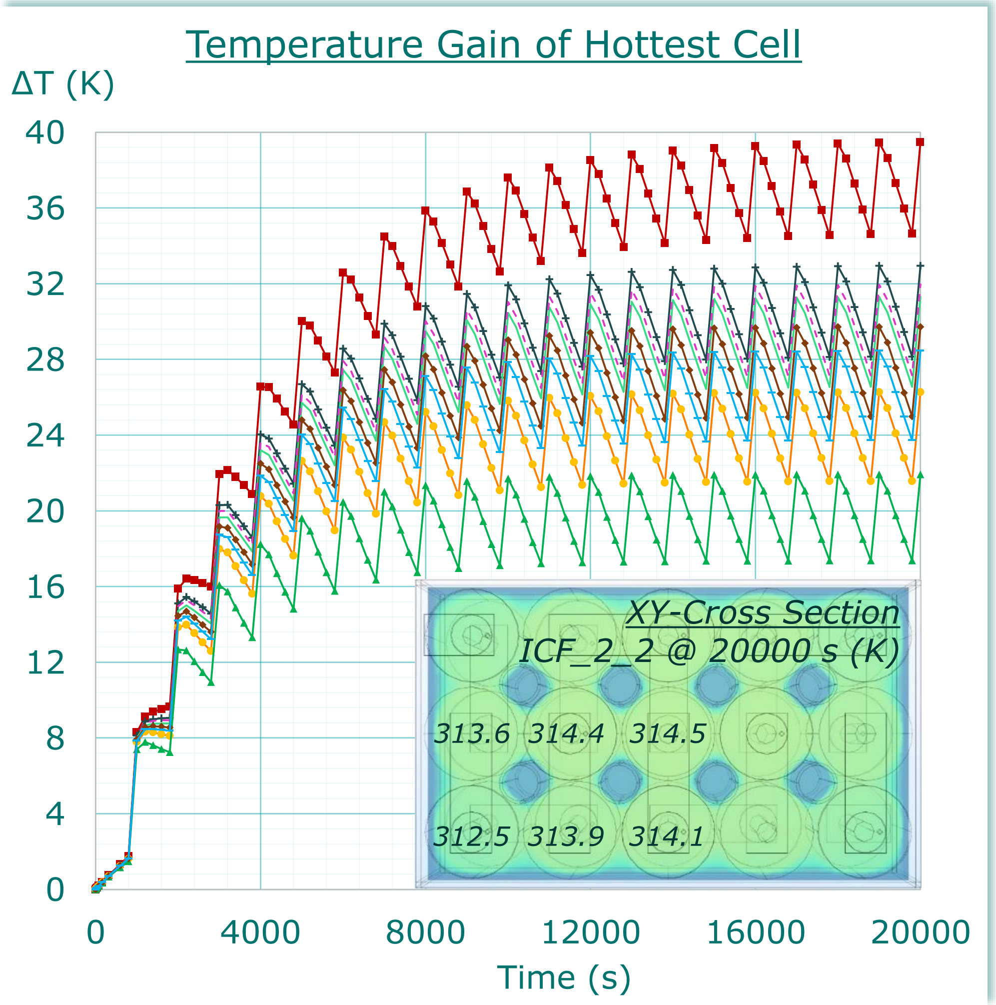
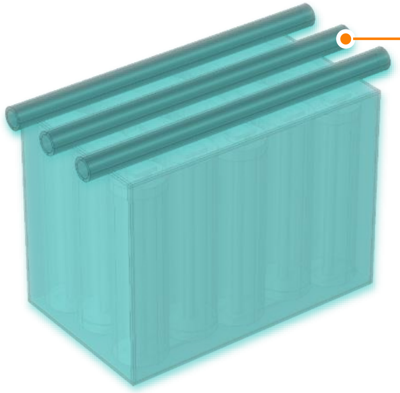






Thermal Analysis on Module Level in an Automotive Battery Package

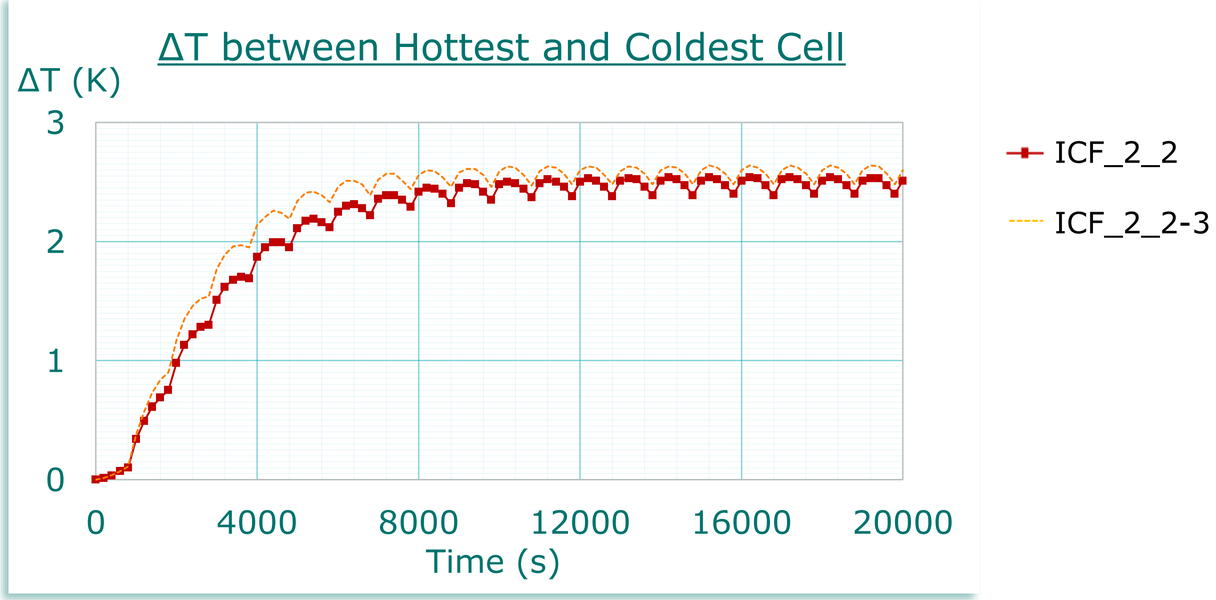
ICF & External Water Cooling

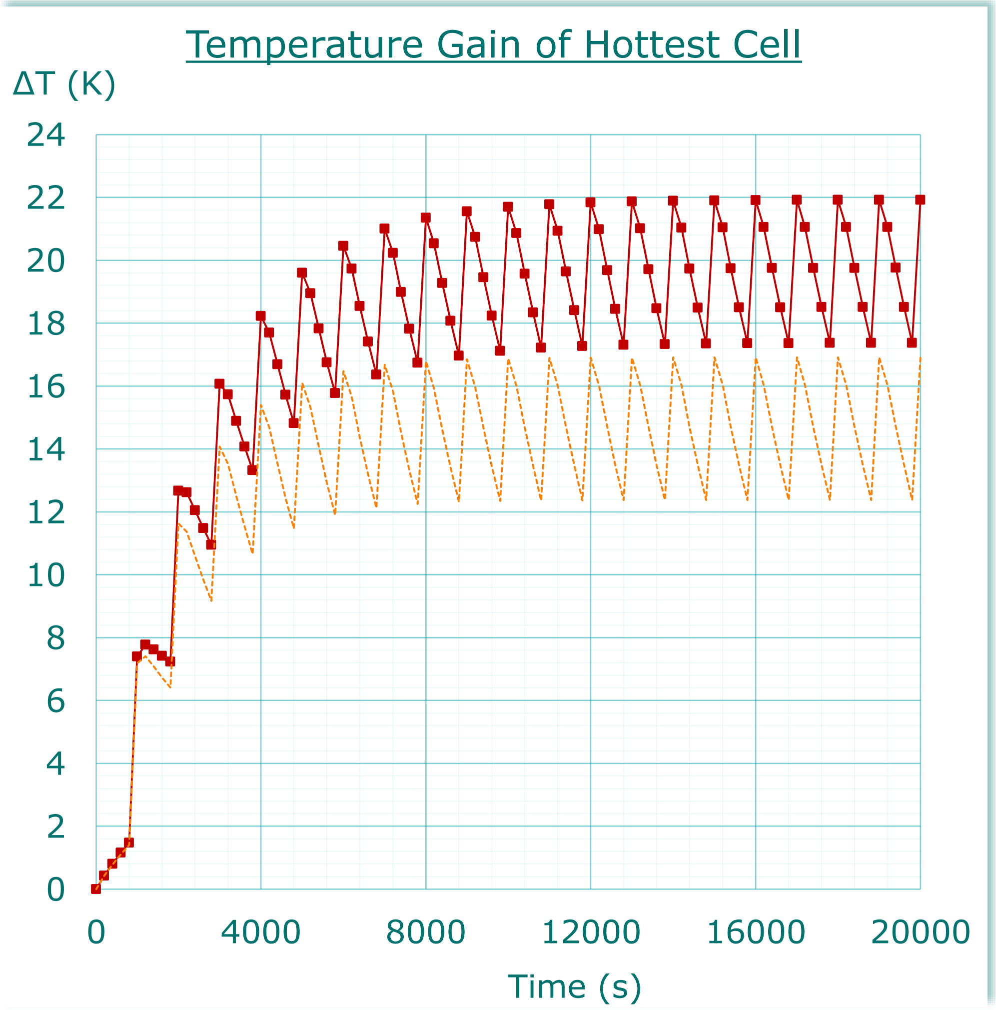


External Water Cooling

- 8 * ICF_2
- Temperature -

  $T_{ext} = T_0 = 20\,°C$
- Velocity: $U_W = 1\,{}^{m}/_{s}$





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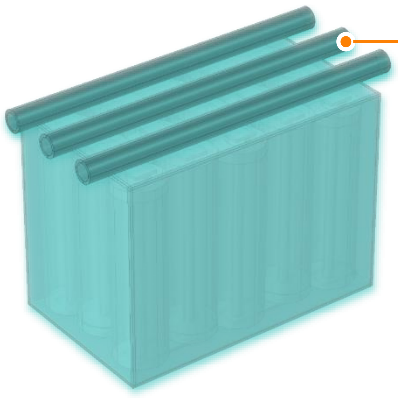
ICF & External Water Cooling



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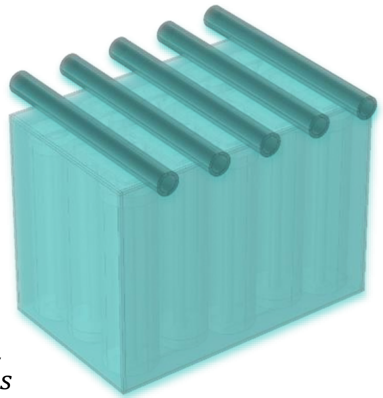

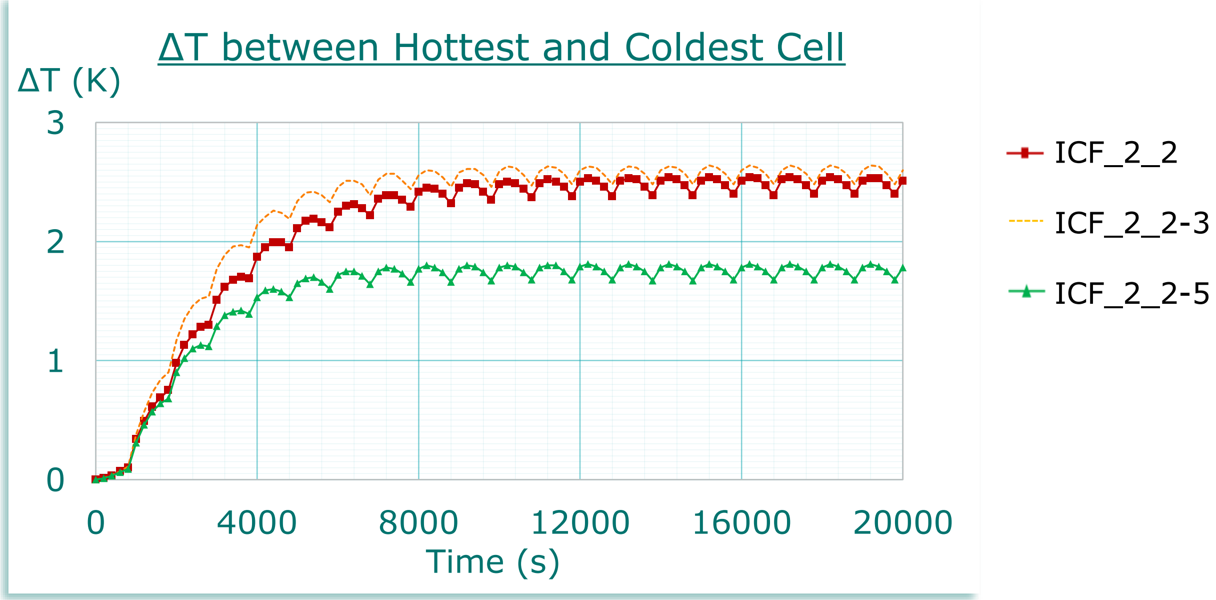

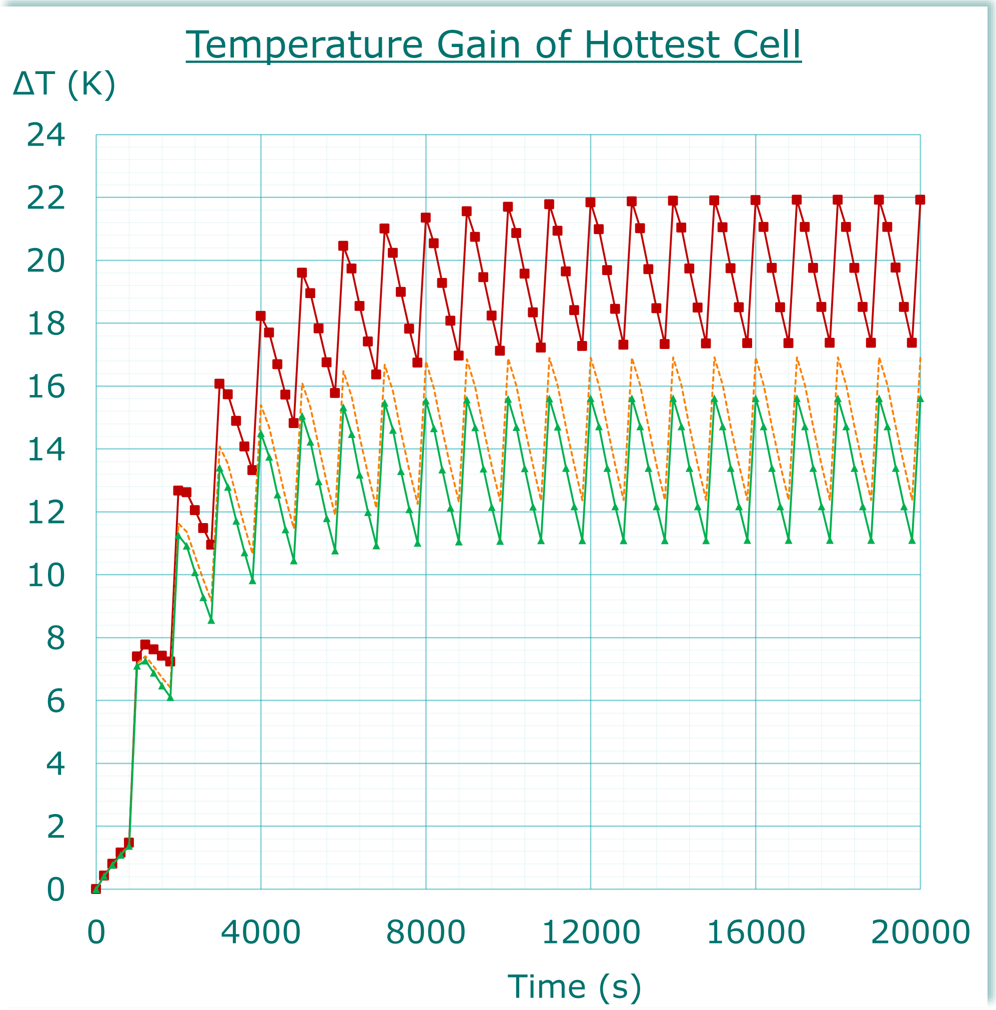

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Summary

- Simulative thermal analysis contributes in gaining knowledge of the cell heating during operational conditions
  - → a helpful step before conducting actual tests
- The simulation results show, the temperature distribution in the ground model of the battery module is greatly uneven
  - → differences in cell cycle life within the same battery module
  - → a shortened cycle life of the entire module
- Cooling systems for the battery module shall be considered as an indispensable component in battery systems for automotive applications
- Combine systems with different cooling principle shall be involved for large battery module
  - → a homogenous temperature distribution
  - → ensure the function of all cells

Thank you!

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