Thermal Analysis on Module Level in an Automotive Battery Package

Ziyi Wu, Hans Kemper
Energy Storage Systems, FH AACHEN - UNIVERSITY OF APPLIED SCIENCES, Germany. Contact E-mail: wu@fh-aachen.de

FH AACHEN UNIVERSITY OF APPLIED SCIENCES

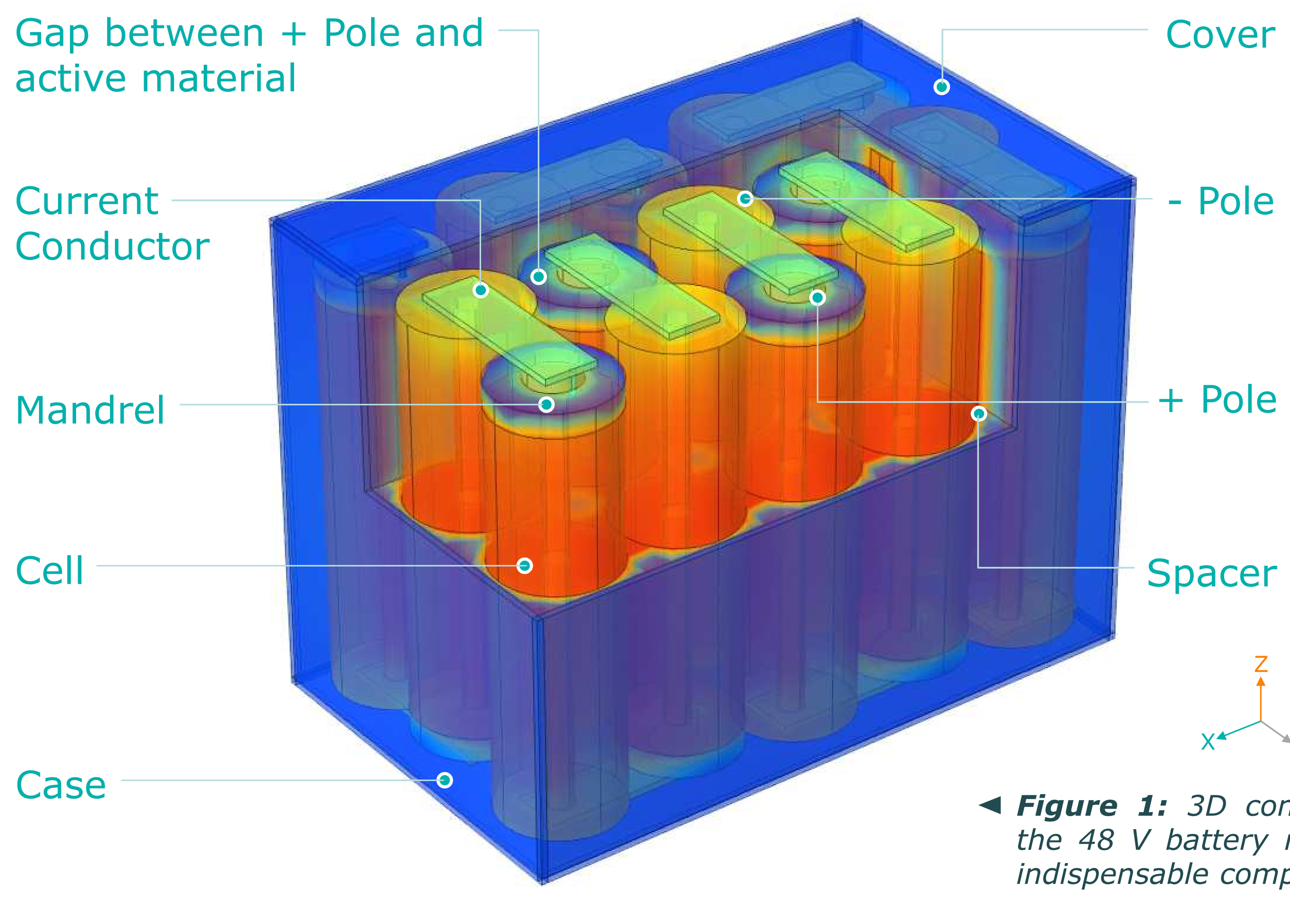
Motivation

Individual batteries have their own operational temperature ranges, which shall be respected to avoid both destroying of the cells and shortening of the cycle life. A better understanding of the thermal behavior of the batteries has therefore its significance during designing safe and robust battery packages. Simulative thermal analysis contributes in gaining knowledge of the heating of cells during operational conditions and hence a helpful step before conducting actual tests. This study dedicates to analyze the thermal behavior of a 48 V battery module for automobile applications with a least number of cells. In order to suppress self-discharge of the cells, it's one of the primary goals to maintain the temperature of all cells not only below the maximal operational temperature, but also below approximately 40 °C by implementing internal cooling fins. The other objective of this study is to minimize the differences in cell temperature aiming at minimizing the differences of the cycle life of cells within the same battery module.

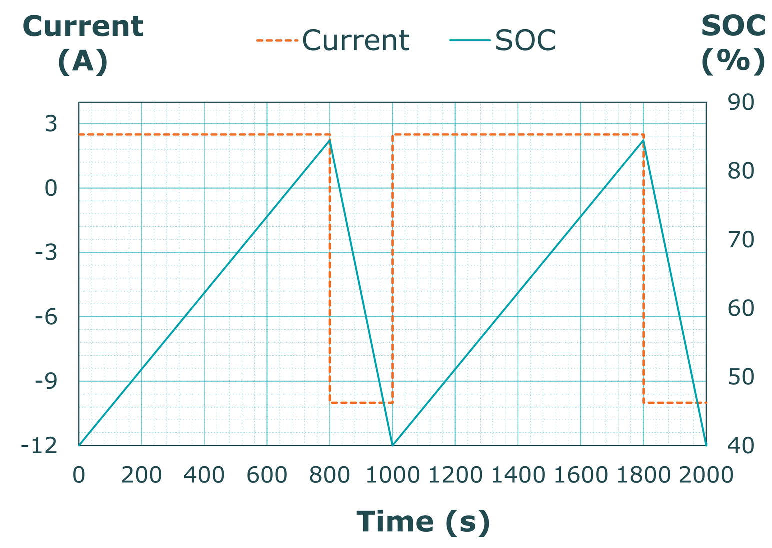
Approach

The thermal model presented contains 15 identical $LiFePO_4$ cells. The construction of 18650 cells (fig.1) and definition of the load profile (fig.2) are derived from the technical data of a suitable candidate for automotive applications. Different cooling fin concepts (tab.1) with the same cross section are involved in the simulation. The number of internal cooling fins is doubled to improve the cooling effect.

Applied Functions:
- Heat Radiation $\dot{q}'' = \epsilon\sigma\left(T^4 - {T_U}^4\right)$
- Heat Convection $\dot{q}'' = \alpha(T - T_U)$
- Heat Conduction $\dot{q}'' = -\lambda\frac{\partial T}{\partial n}$



◄ *Figure 1: 3D construction of the 48 V battery module with indispensable components.*



▲ *Figure 2: Load profile utilized in the simulation models and the SOC variations.*

- Tool – COMSOL Multiphysics
- Principle – Instationary FEM

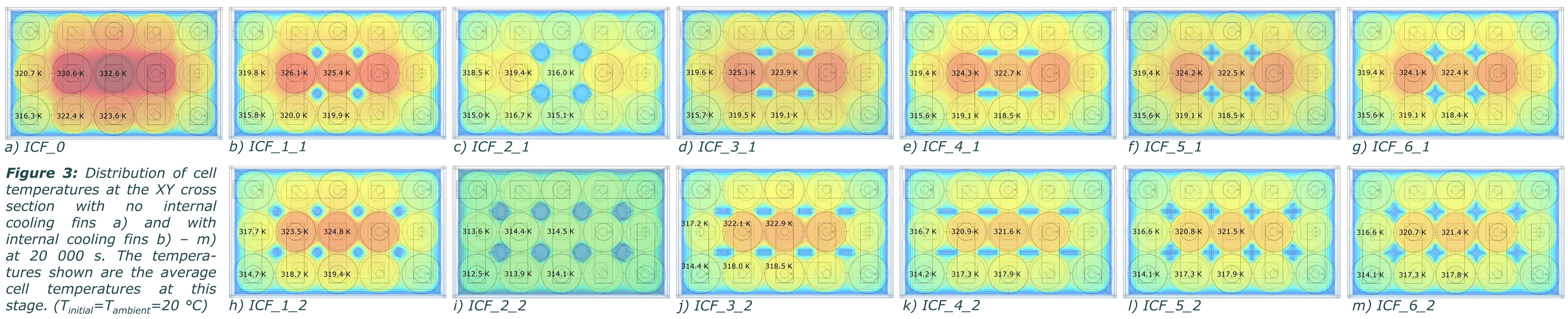
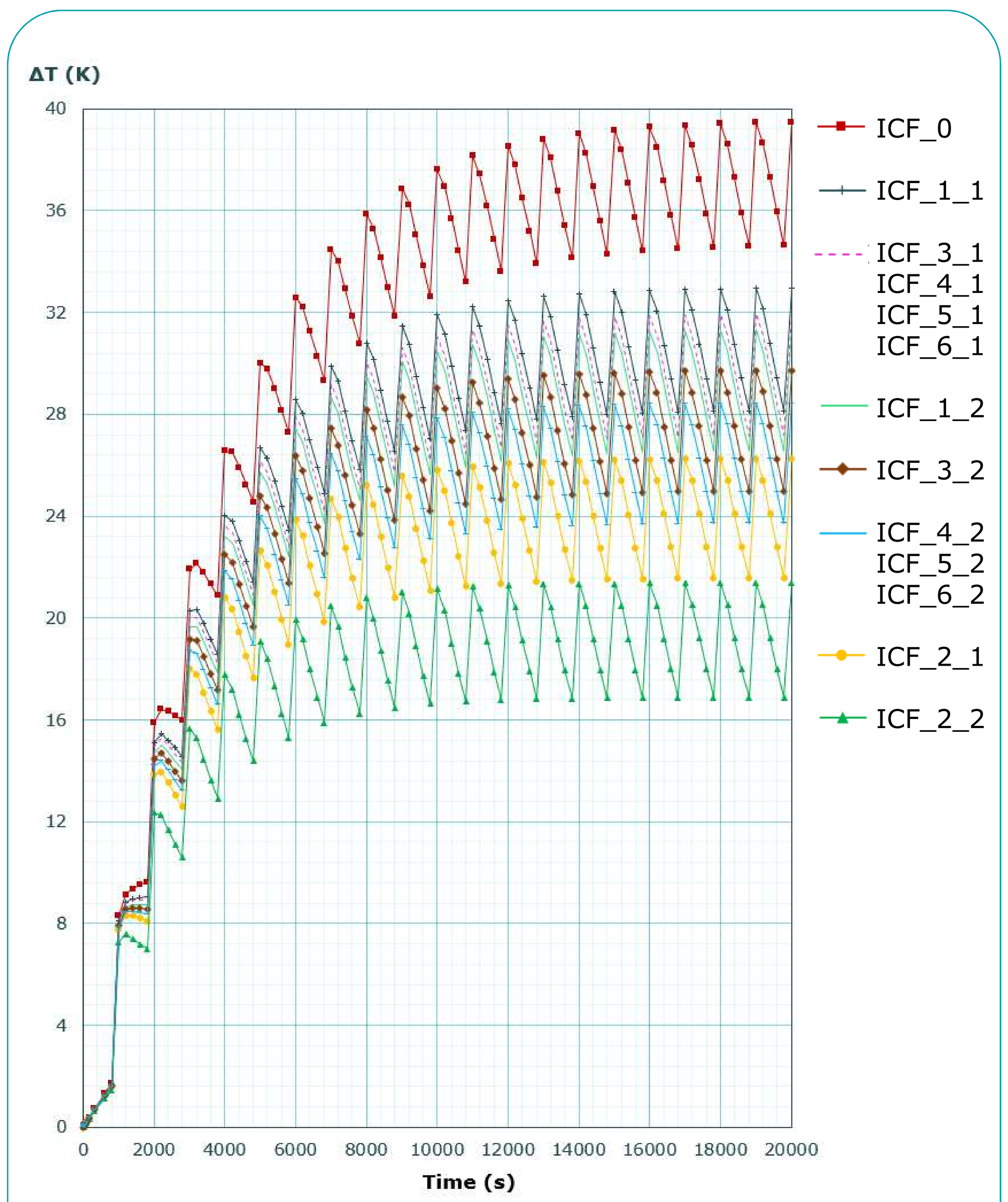


Figure 3: Distribution of cell temperatures at the XY cross section with no internal cooling fins a) and with internal cooling fins b) – m) at 20 000 s. The temperatures shown are the average cell temperatures at this stage. ($T_{initial}$=$T_{ambient}$=20 °C)

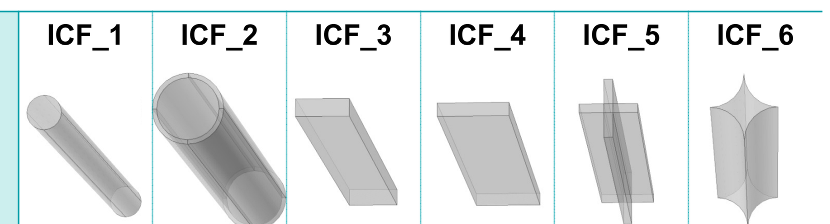
Conclusion

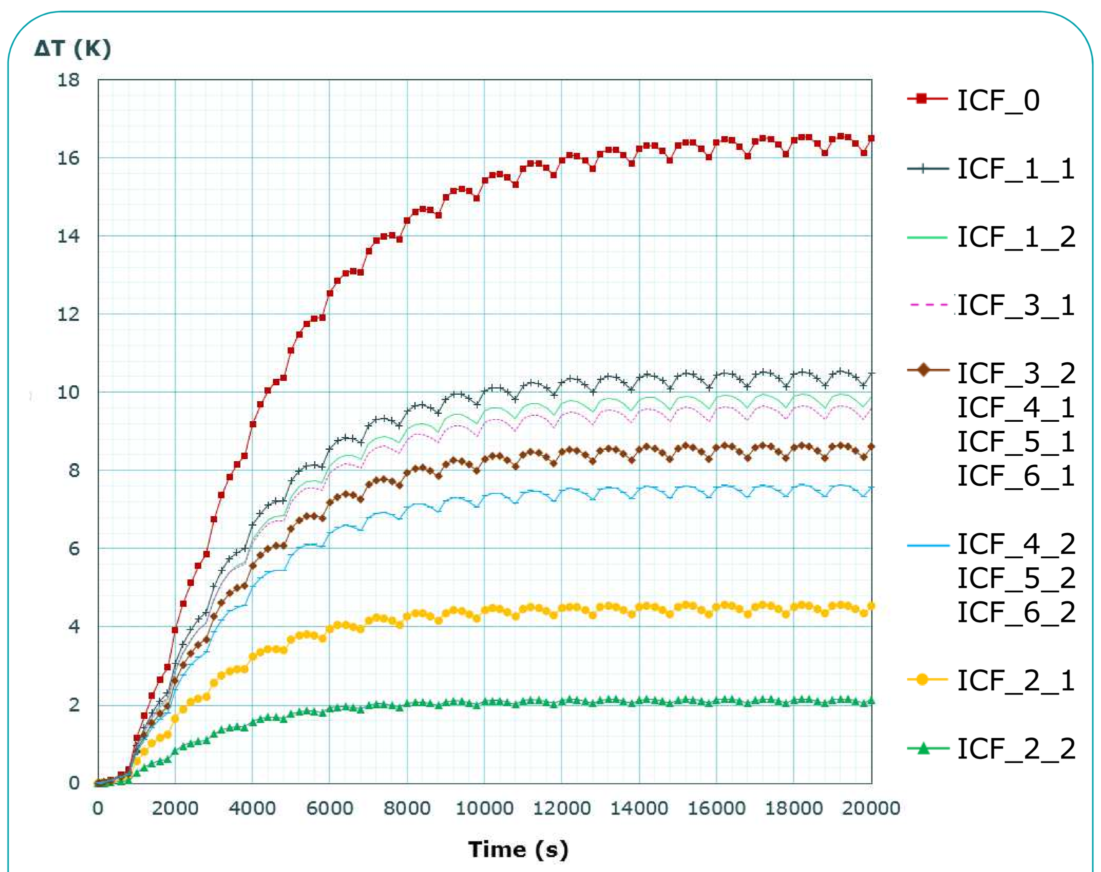
By involving internal cooling fins, the temperature of the cells stabilize earlier in comparison to case ICF_0 (no internal cooling fin). While the maximal cell temperature of case ICF_0 approaching 60 °C by 10 000 s, the involvement of ICF leads to maximal cell temperatures below 53 °C. By inserting eight ICF_2 cooling fins (case ICF_2_2), the maximal cell temperature is kept at 42 °C at 20 000 s, which full fills the demand of this study. Besides, the differences in average cell temperatures dropped to approximately 2 °C in case ICF_2_2, which is 14 °C lower than in case ICF_0 and therefore a satisfying result.

For the long term, the authors see the necessity to carry out thermal analysis of combined cooling systems, which involve both internal cooling fins and external cooling systems, for instance, water cooling and air cooling.



▲ *Figure 4: Temperature gain of the hottest cell in the battery module with and without internal cooling fins.*

Table 1: Cooling Fin Concepts	ICF_1	ICF_2	ICF_3	ICF_4	ICF_5	ICF_6
						
Cross Section (mm^2)	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



▲ *Figure 5: Temperature differences between the hottest cell and the coldest cell in the battery module with and without internal cooling fins.*

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