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Thermal Management of The E-Dumper Battery – Best Practice Designed by NTB

There are different cooling concept for Lithium-ion batteries available. The most common one is bottom cooling. Is there a better one to reach a homogenous temperature distribution inside a battery cell ?

To answer this question at NTB a novel test equipment exist, where the thermal behavior of Lithium-ion cells can be characterized [1]. By knowing the exact surface areas releasing the dissipated heat of a battery cell during charge and discharge the cooling system can be optimized accordingly.

In addition the temperature distribution of the cell surface was measured under defined load cases. Hereby the cooling system of E-Dumper battery could be optimized significantly.

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Motivation

To increase life-time, reliability and safety of Lithium-Ion Batteries (LIBs), the following circumstances have to be considered:

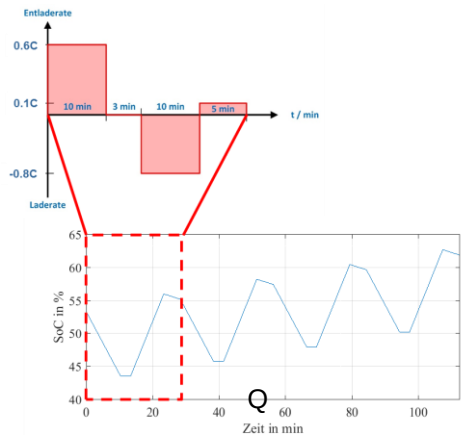
$$\textit{life-time/aging} = f(\vartheta,\ldots)$$
$$\textit{safe operation} = f(\vartheta,\ldots)$$
$$\textit{reliability} = f(\vartheta,\ldots)$$

For each of this temperature relations an upper and lower limit exist, which is not allowed to be exceeded or underrun, respectively [2].

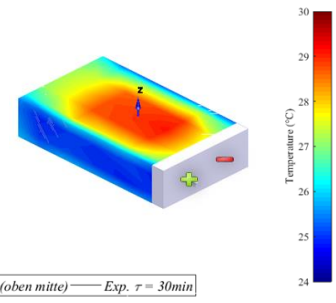
⇨ ***Where and how to cool or heat the LIB cell best ?***

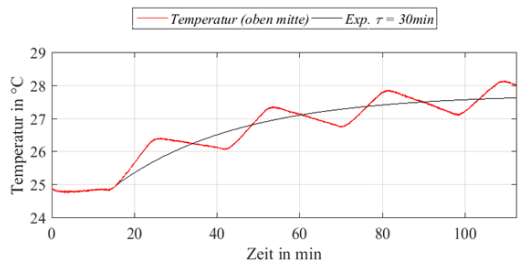
Common Bottom Cooling under Real Load ⇨ Improvement is Required

Real working loads of the E-Dumper during a daily shift can be summarized as follows:



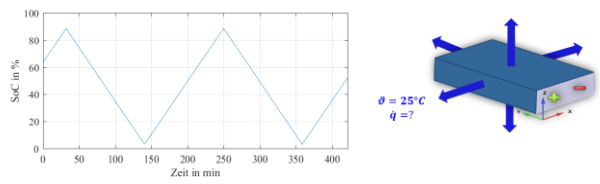
This average loads causes a strong inhomogeneous temperature distribution and a continuous heating up of the battery cells.



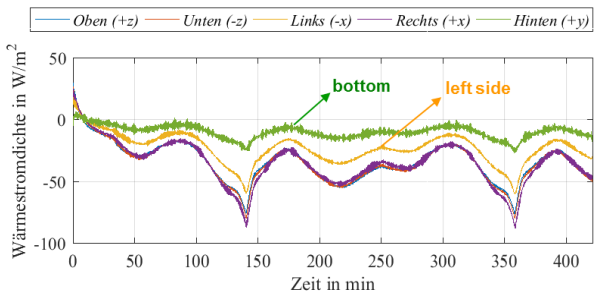


1St Step: Thermal Cell Characterisation

Under cyclic load and constant surface temperature the local heat release is measured.

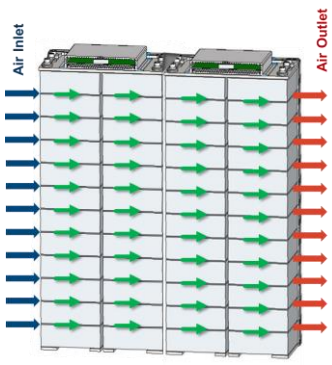


Min. heat release is detected at the bottom of cell surface. Max. heat flux can be measured at the two large surface areas of the battery cell.



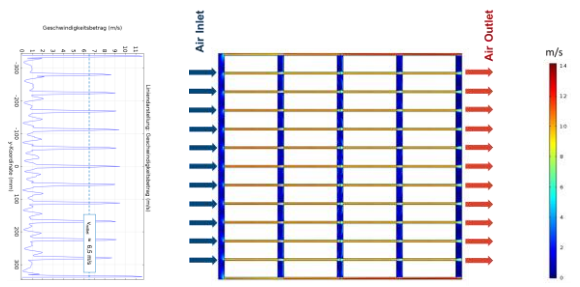
2St Step: Adequate Design of the Thermal Management System

To realize a cooling of the two large surface areas of the battery cell an horizontal air flow is needed.

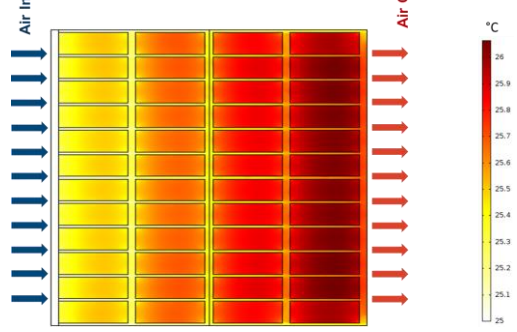


Most important to reach also homogeneous temperatures between different Li-ion cells inside a battery pack, the cooling air flow velocity has to be equal between different flow channels. If this is realized, the heat transfer from the cell surfaces to the air flow will be the same.

$$\dot{Q} = h \cdot A \cdot (\vartheta_{surf} - \vartheta_{air})$$



Along the air flow direction an temperature increase can not be prevented due to heating up of the cooling air.



References

[1] Rouven Christen, Gerhard Rizzo, Alfred Gadola and Max Stöck: "Test Method for Thermal Characterization of Li-Ion Cells and Verification of Cooling Concepts", Batteries, Vol. 3(1), Art. 3, 2017.

[2] T. Waldmann, M. Wilka, M. Kasper, M. Fleischhammer und M. Wohlfahrt-Mehrens: „Temperature dependent ageing mechanisms in Lithium-ion batteries - A Post-Mortem study", Journal of Power Sources, Bd. 262,P. 129-135, 2014.

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