Temperature propagation during cell stacking processes for lithium-ion cells

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Introduction

During the fabrication of high-end battery systems, Li-ion cells pass multiple production processes, such as laser welding, where the cells are exposed locally for several seconds to elevated temperatures.[1,2] By using the "Heat transfer in solids" interface and the CAD import module of COMSOL Multiphysics® a three dimensional model of a prismatic Li-ion cell was established, in order to simulate the temperature propagation under these conditions. Experimental input parameters such as heat capacity and thermal diffusivity were defined using Differential Scanning Calorimetry (DSC) and Laser Flash Analysis (LFA) in our laboratory.

Modeling Approach

The studies are performed by using heat transfer modelling with the following geometry and equations: [3]

- The components of the Li-ion cell were measured and virtually reconstructed in form of a 3D-CAD model.
- The thermo-physical properties of the cell components (anode, separator, cathode, current collectors) were directionally dependent averaged for the jelly roll according to the parameter attributes.
- Validation using temperature sensors at the collectors (A1,A2), in the center (M1-M3) and on the surface (O1-O3) of the jelly roll.

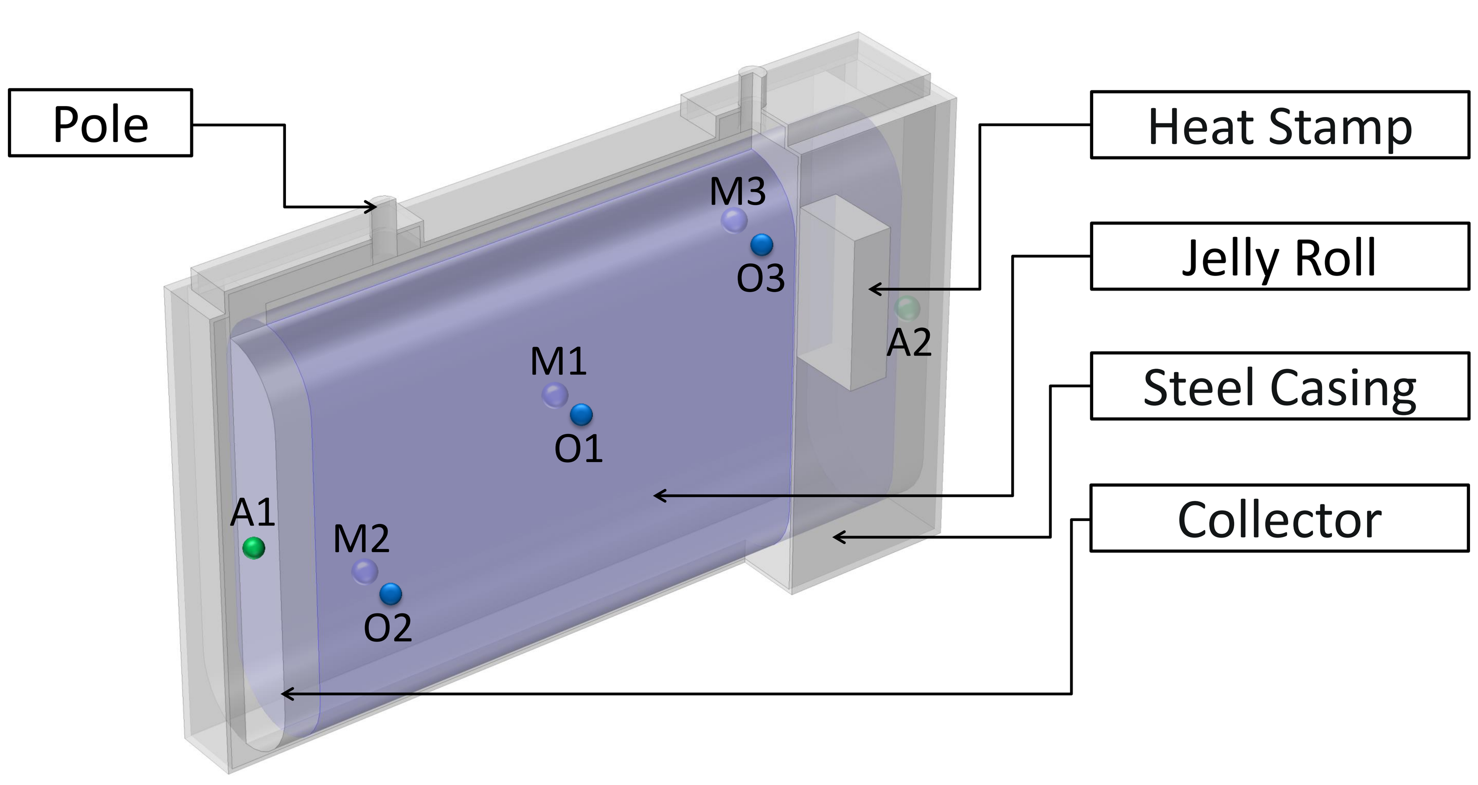

Fig.1: Three dimensional cell geometry of the simulated Li-ion cell with thermal sensor spots and heat stamp on the cell-housing surface .

- Heat transfer equation: heat generation and conduction

$$\rho\, C_p \frac{\partial T}{\partial t} = \mathrm{div}(\lambda\, \nabla T) + Q$$

- Material relationship of heat capacity, heat conductivity and density

$$\lambda(T) = \alpha(T)\rho(T)C_p(T)$$

Modeling with COMSOL Multiphysics®

- Numerical simulation is performed by solving the heat transfer equation and setting initial boundary conditions, representing natural convective cooling and a heat load as a space-homogeneous temperature function of time.

$$-\lambda\, \nabla T = h\,(T - T_{ext})$$
$$T = g$$

- Results: e. g. temperature profiles, critical temperature levels, heat propagation characteristics.

Simulation Results and Validation

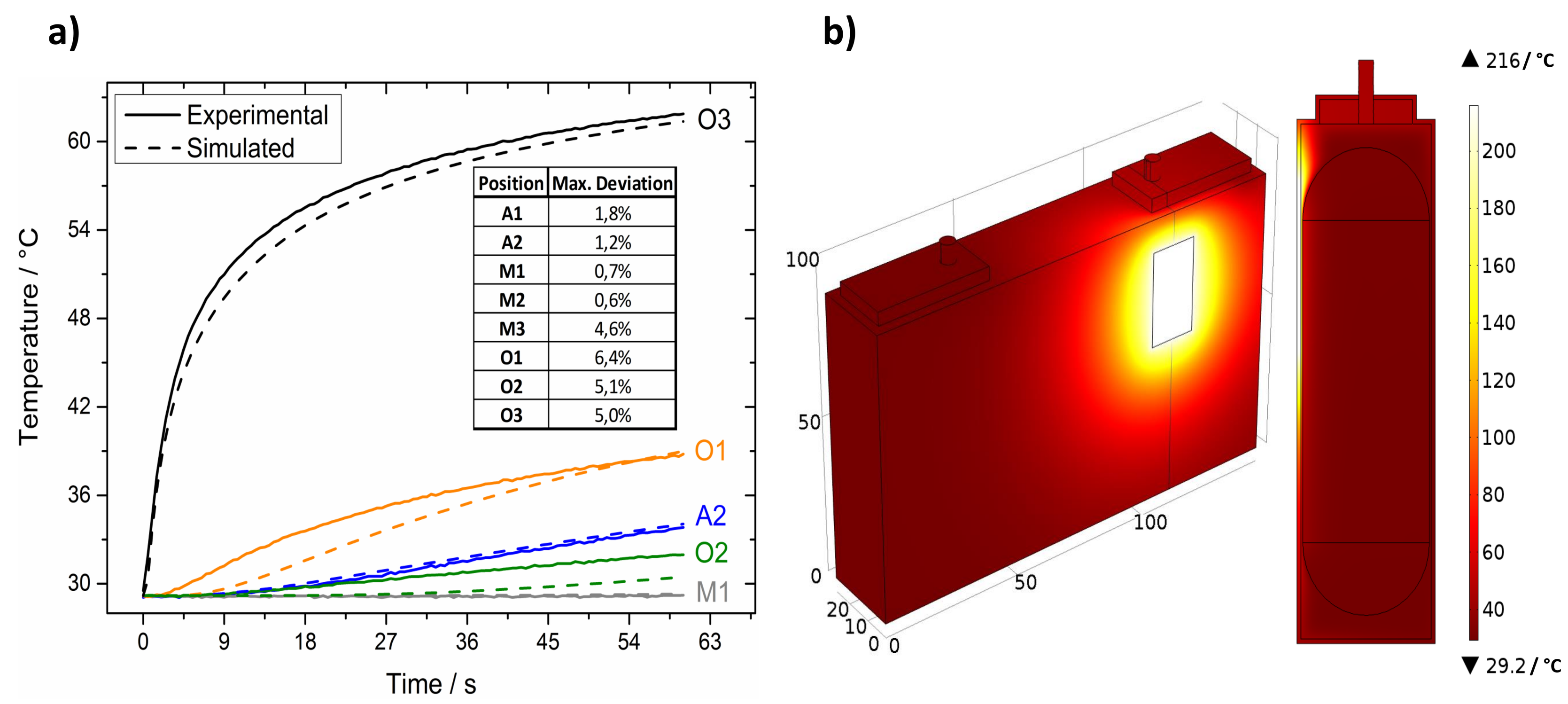

Fig.2: **a)** Simulated and experimental temperature profiles during thermal stressing for 60 s at a heat load of 50 W and **b)** temperature distribution [°C] in a prismatic cell after a thermal stressing for 60 s at a heat load of 50 W

Short-term thermal treatment

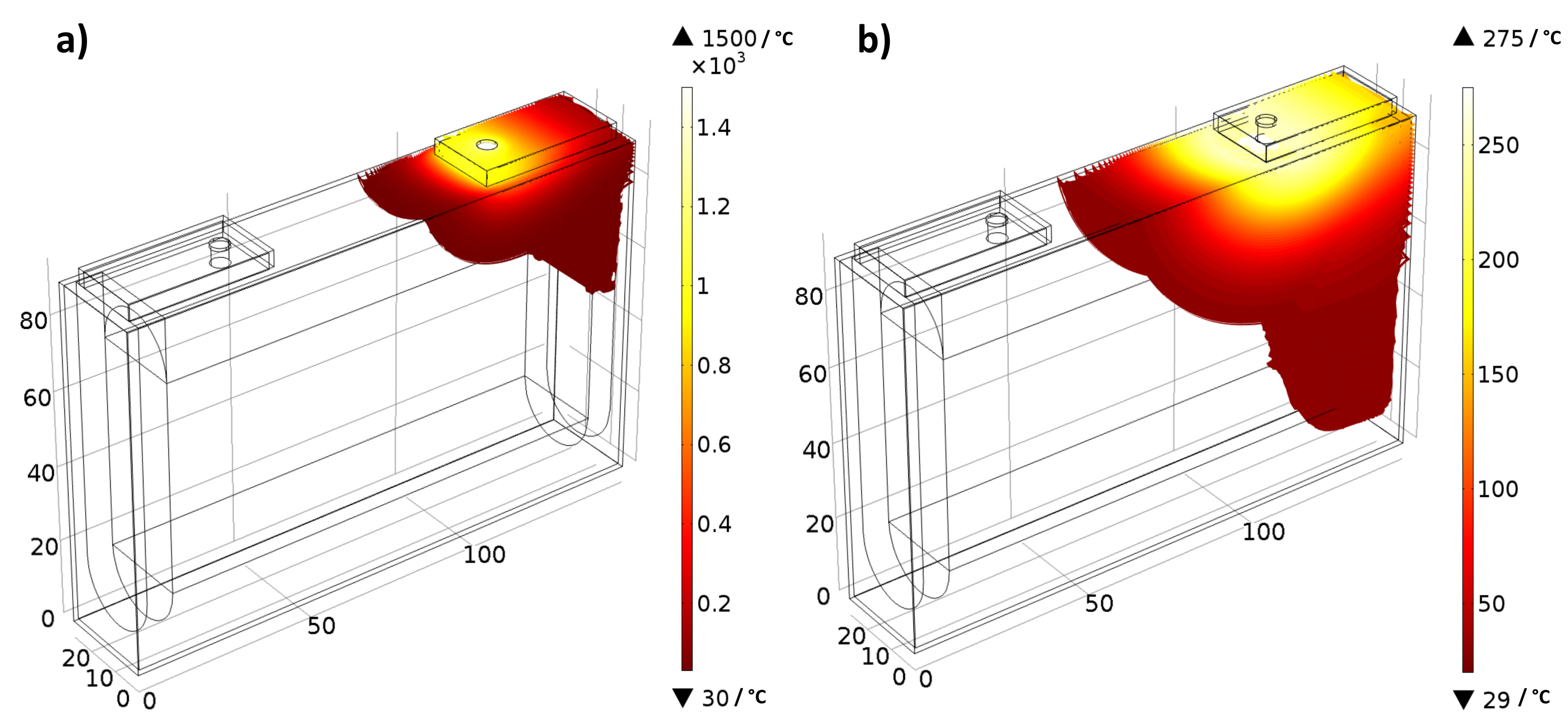

Fig.3: Temperature distribution [°C] to simulate laser contact welding on nickel alloy based collector poles at **a)** thermal stressing for 4 s at 1500 °C and **b)** 10 s after the thermal stressing

Conclusions and Outlook

- A thermo-physical 3D model of a commercial Li-ion battery was developed and validated.
- Visualization of the temperature distributions inside a Li-ion cell during cell stacking processes were simulated.
- Critical temperature levels depend on position, duration and intensity of the thermal stressing.
- Results show a maximum local temperature of 180 °C at the jelly roll after laser welding for 4 s at 1500 °C.
- Further studies on various stress scenarios that represent cell stacking processes at elevated temperature will be performed.
- The current model will be further developed in order to improve the model accuracy and address safety issues of Li-ion cells with different geometries.

References

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[3] Taheri, P. and Bahrami, M., *SAE Int. J. Passeng. Cars - Electron. Electr. Syst.* 5(1) (2012).