

Battery modeling: influence of current collector geometry on the behavior of large lithium-ion pouch cells

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Summary

In this work, current density and temperature distribution across the electrodes of a large Li-ion pouch cell are examined by using an extended two-dimensional polarization model. Different design studies are carried out under variation of geometrical parameters such as the size of the cell tabs and the thickness of the current collectors. Simulations are showing, that the cell can be optimized with a small increase in depth-of-charge imbalance by altering the thickness of the current collectors. The simulation is validated by measurement data of a commercial 40 Ah Li-ion pouch cell with nickel-manganese-cobalt-oxide chemistry.

Keywords: modeling, lithium battery, finite element calculation, state of charge, optimization

1 Introduction

Due to an uneven polarization in large battery cells, the geometry of the electrodes is crucial when designing a thermally and electrically optimized cell. Additionally, geometrical properties of the current collectors have significant influence on the uniformity of current and potential distribution in the electrodes [1]. A non-uniform current distribution can cause strong temperature gradients and an uneven state of charge [2,3], leading to high peak temperatures and an accelerated degradation of the cell. Due to the higher current density, a cell with small tabs produces higher ohmic losses in the current collector and a higher local temperature. On the contrary, bigger cell tabs may contribute to a higher heat flux into the cell connectors and lead wires resulting in an increased temperature gradient in the electrodes. In conclusion, an optimized electrode design produces less polarization losses, lower cell peak temperatures and smaller temperature gradients in the electrodes. These effects can be optimized by altering geometrical properties of the cell such as the size of the current collecting tabs and the thickness of the current collectors.

In the field of battery modeling, the complexity of the model corresponds to the specific design problem. From a practical point of view, the modeling approach can be categorized into empirical models and physics-based models. Physics-based models give access to physical and geometrical parameters at the electrode level, while providing accurate information about internal cell processes. On the contrary, the improved accuracy often comes with the price of high parameterization effort. Full distribution models, that take multi-scale and multi-dimensional electrical and thermal effects into account, need a considerable amount of computational time to solve the systems partial differential equations [4]. With regard to these considerations, much effort is put into reducing the order of physics based models while maintaining their unique ability to describe mass and charge transfer reactions. Empirical models are commonly parameterized by fitted polarization data, reducing the complexity of the model, but, in consequence, the link to fundamental physical parameters of the cell at the electrode level is lost. One of these types of modeling is based on the work of [5]. Here the transfer current between the current collectors is scaled by a specific cell conductance, which can be derived from linearized polarization data. Gu [6-7] determined an empirical equation for the specific conductance from measurement data of an experimental cell with small electrodes

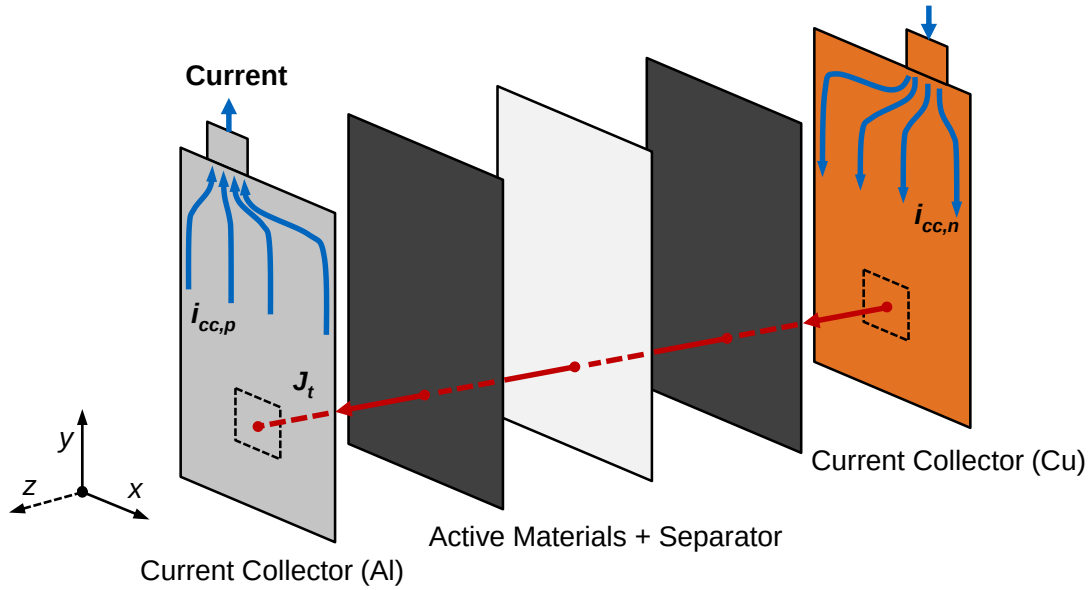


Figure 1: Schematic of simplified cell assembly consisting of current collectors, active materials and separator. The current density in the current collector and the transfer current density are indicated by the blue and red lines during a discharge process.

to minimize the ohmic drop in the current collectors. The equation was integrated into a resistive network model to calculate potential and current distribution in the cells' electrodes. Solved by numerical methods, Kwon [2] extended the work into a state of charge dependent dual foil model. This strategy was commonly adopted in later works, hence, the modeling approach is usually addressed as NTG [8] or NTGK model [9]. To describe the thermal behavior at the cell level, the model was unidirectionally coupled to 2D and 3D thermal models [2,10-14]. Bidirectionally coupled thermal models using an either ambient [15] or cell [16,17] temperature dependent conductance parameter, implemented by an Arrhenius type equation. Here [17] solved the governing equations analytically by assuming an uniform transfer current density. The derived electrical model can be coupled with an analytical thermal model, developed earlier by the same research group [18], leading to a fully analytical electro-thermal model of a pouch cell. By extending the modeling approach with a lumped double-layer capacitance, the accuracy of the model's dynamic behavior can be further improved [19]. In addition, [8,20] used equivalent circuit theory to further improve the dynamic behavior of the model. However, parameter estimation is based on either HPPC or pulse relaxation profiles leading to significant measurement and parameterization effort comparable to full equivalent circuit models. Furthermore, model accuracy under constant current conditions may be reduced due to polarization losses at relaxation phases of the parameterization current pulses.

In this paper, we present an efficient 2D electro-thermal model, which can be applied to study different cell designs and to foster the development of large-scale batteries. The work expands the polarization model mentioned above [8,19,20] to an simplified equivalent circuit model with one RC pair while preserving the simplicity of the original polarization modeling approach used by [2,10-14].

2 Mathematical model

The modeling approach of this work is used to investigate a conventional lithium-ion pouch geometry. As shown in Fig. 1, the stack is simplified as one single cell layer. To calculate the potential and current distribution in the negative (index = n) and positive (index = p) current collector a two dimensional model based on charge balance equations is applied. The model consists of a cell sub-domain, tab sub-domain with the in-plane dimensions "x" and "y" assuming that there is no significant potential drop perpendicular to the current collectors in the "z" dimension. Furthermore, it is considered that one cell layer consists of half of a negative current collector, negative coating, separator, positive coating and half of a positive current collector.

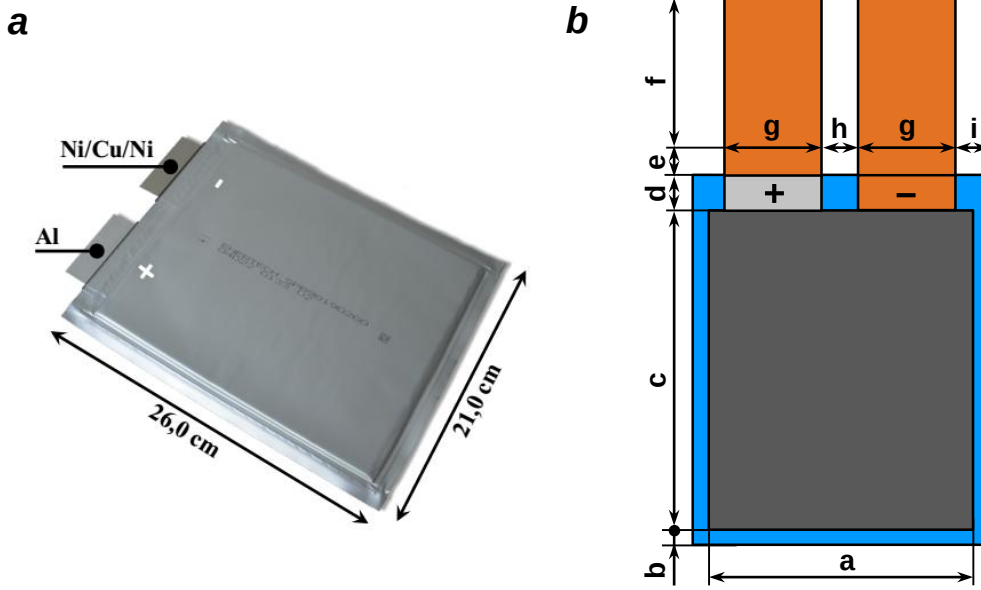


Figure 2: a) Experimental 40 Ah cell with pouch case. b) Schematic of cell geometry used in the electro-thermal model. The regions denoted by length scales “b-f” have different material properties and thicknesses (b – pouch casing, c – cell stack, d – tabs, e – terminals, f - connectors). The electrical model is solved in the regions of the cell stack and the tabs colored in black, grey and orange.

In the sub-domain of the current collector, the local potential distribution is described by Poisson’s equation:

$$\sigma_{cc,j} \frac{\partial}{\partial x} \left(\frac{\partial \varphi_{cc,j}}{\partial x} \right) + \sigma_{cc,j} \frac{\partial}{\partial y} \left(\frac{\partial \varphi_{cc,j}}{\partial y} \right) = \frac{n_j J_t}{0.5 \cdot L_{cc,j}} \quad (1)$$

Here $\varphi_{cc,j}$ is the local current collector potential and J_t is the local transfer current density which describes the transport of lithium ions passing through the separator. The unit vector n is perpendicular to the current collector and pointing in the outward direction. It is defined positive for the negative current collector and negative for the positive current collector. In the model, one repeating cell unit consists of half of a current collector for both electrodes, thus the thickness of the current collectors $L_{cc,j}$ is scaled by the factor 0.5. Furthermore, the thickness of the current collectors $L_{cc,j}$ and the electronic conductivity $\sigma_{cc,j}$ are assumed to be constant in the dimensions “x” and “y”. It is assumed that the in-plane current is carried only by the current collector due to its electronic conductivity, which is several orders of magnitude higher compared with the one of the coating. Gu [6] applied a similar approach in a resistive network model for a Zn/NiOOH cell, which has a layered electrode geometry comparable to the lithium-ion cell used in this work. The boundary conditions for Eq. (1) can be found in [17].

Table 1: Dimensions of geometry in x-y plane, corresponding to Fig. 2.

Geometry in x-y plane	a / mm	b / mm	c / mm	d / mm	e / mm	f / mm	h / mm	g / mm	i / mm
	177.9	16.05	216.9	27.05	21	129	32	60	29

Considering that there is no electrochemical reaction taking place in the cell tabs, Poisson’s equation simplifies to Laplace’s equation:

$$\sigma_{cc,j} \frac{\partial}{\partial x} \left(\frac{\partial \varphi_{cc,j}}{\partial x} \right) + \sigma_{cc,j} \frac{\partial}{\partial y} \left(\frac{\partial \varphi_{cc,j}}{\partial y} \right) = 0 \quad (2)$$

The relevant boundary conditions for Eq. (2) at the top of the negative and positive tab are:

$$\varphi_{tab,n} = 0 \quad (3)$$

$$n \cdot (-\sigma_{cc,p} \nabla \varphi_{cc,p}) = \frac{I_{app}}{A_{tab,p}} \quad (4)$$

To derive the temperature distribution of the investigated pouch geometry, a two-dimensional model based on heat flux, heat generation and heat exchange with its surroundings is chosen.

Table 2: Thickness and electronic conductivities of the cell components, corresponding to Fig. 2.

Component	Thickness / mm	Electronic conductivity / S m ⁻¹
Pouch casing	0.15	-
Cell stack	9	-
Positive current collector with tab (Al)	22.5 x 10 ⁻³	37.8 x 10 ⁶
Negative current collector with tab (Cu)	13.5 x 10 ⁻³	59.6 x 10 ⁶
Positive Terminal (with 2x connectors)	10.4	-
Negative Terminal (with 2x connectors)	10.3	-
Connectors (Cu)	5	-

The heat conduction for the geometry shown in Fig. 2b is derived following the principles of conservation of energy:

$$\rho C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} \left(k_x \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left(k_y \frac{\partial T}{\partial y} \right) + q_{gen} - q_{loss} \quad (5)$$

where ρ is the density, C_p is the specific heat capacity at constant pressure, T is the temperature, t is the time, and k_x , k_y are the effective thermal conductivities along the “x” and “y” dimension of each cell component. The generated heat q_{gen} is given as a sum of irreversible and reversible heating in the cell stack and the ohmic heating in the current collectors (see Fig. 1):

$$q_{gen} = \gamma_t J_t \left(U_{ocv} - (\varphi_{cc,p} - \varphi_{cc,n}) - T \frac{\partial U_{ocv}}{\partial T} \right) + \gamma_p \sigma_{cc,p} |\nabla \varphi_p|^2 + \gamma_n \sigma_{cc,n} |\nabla \varphi_n|^2 \quad (6)$$

where γ is the specific volumetric scaling factor defining the part of the volume where the heating occurs and $|\nabla \varphi_p|$, $|\nabla \varphi_n|$ are the magnitudes of the potential gradients vectors in the “x”, “y” dimensions accounting for ohmic heating. Considering that the transfer current density in the tabs and connectors is zero, heat generation in those regions is described as purely ohmic heating, thus the scaling factors and electronic conductivities are adjusted to material properties in those regions. Due to the high current rates applied in this work, reversible heating is neglected. The heat exchange with the cells’ surroundings is implemented as a sum of convective and radiative heat loss:

$$q_{loss} = \frac{h}{h_t} (T - T_{ref}) + \varepsilon \sigma_B (T^4 - T_{ref}^4) \quad (7)$$

where h is the heat flux due to convection, h_t is the thickness of the cell in the specific region, ε is the emissivity, σ_B is the Stefan–Boltzmann constant and T_{ref} is the reference temperature. The emissivity is set to a constant value of 0.95 due to the material properties of the matt black paint applied at the cell surface for the temperature measurements. Thermal parameters such as density, specific heat capacity and thermal conductivities for the components shown in Fig. 2 are derived from [14].

2.1 Approximation of cell polarization

The transfer current density J_t can be expressed as a function of the overpotential between opposing nodes of the negative and positive current collector with the same coordinates:

$$J_t(x, y) = f(\eta(x, y)) \quad (8)$$

This equation includes non-linear polarization terms arising from mass transport, charge balance and reaction kinetics in the electrode domain and potential gradients in the current collector domain. According to [5,21], cell polarization is following a nearly linear behavior over a wide range of applied current rates, thus can be approximated as

$$J_t(x, y) = -Y_{s,lin}(x, y) (\varphi_{cc,p}(x, y) - \varphi_{cc,n}(x, y) - U_{ocv,lin}(x, y)) \quad (9)$$

where $Y_{s,lin}$ is the linearized static electrochemical conductance per unit area and $U_{ocv,lin}$ is the linearized open circuit voltage (see Fig. 3). The electrochemical conductance $Y_{s,lin}$ can be interpreted as a scaling factor simplifying the non-linear current-potential characteristic of the cell. Both $U_{ocv,lin}$ and $Y_{s,lin}$ are described as a function of depth-of-discharge (DOD) in polynomial form [17]:

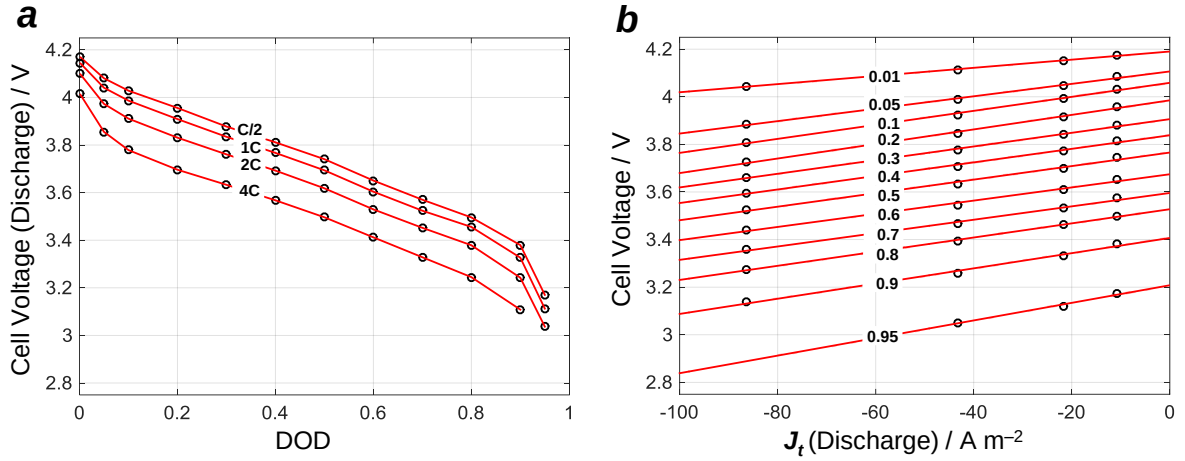


Figure 3: a) Measured voltage response during constant current discharge at 0.5C, 1C, 2C, 4C at 25 °C. b) Linear fit of the current-potential characteristic at different DOD derived from voltage response data.

$$U_{ocv,lin} = \sum_0^k a_k (DOD)^k \quad (10)$$

$$Y_{s,lin} = \sum_0^l b_l (DOD)^l \quad (11)$$

The parameters a_k and b_l are fitted to voltage data at a constant discharge rate at different DOD. Following this method one may argue that the potential drop in the current collector is already part of the electrochemical conductance data and is calculated twice in the model (see Eq. (1)). To the authors knowledge, only [6] addressed this issue by using a cell with small electrode size of 2.54 x 2.85 cm. In this work, the measured current-potential characteristic is corrected by the ohmic voltage drop in the current collectors derived from simulations.

In reference to [16,17,20], a temperature dependent electrochemical conductance $U_{ocv,lin}$ and open circuit voltage $Y_{s,lin}$ can be derived from fitted measurement data at different temperatures:

$$U_{ocv,lin} = U_{ocv,lin,ref} + a_T (T - T_{ref}) \quad (12)$$

$$Y_{s,lin} = Y_{s,lin,ref} \exp \left[b_T \left(\frac{1}{T_{ref}} - \frac{1}{T} \right) \right] \quad (13)$$

Here the constant parameters a_T and b_T can be derived from fitted data of $U_{ocv,lin}$ and $Y_{s,lin}$ at different temperatures [16]. The index ‘ref’ denotes the values of the quantity at a given reference temperature (e.g. 25 °C). In this work, the open current voltage is implemented in accordance to Eq. (7). A temperature dependency of the linearized open circuit voltage and conductance is neglected, assuming that the influence of temperature increase during the parameterization process is already part of these quantities. However, a temperature dependency of $Y_{s,lin}$ should be considered when the model is applied for simulation of dynamic drive cycles, even though results from [19] indicate that simulation results are still accurate without a temperature correction.

2.2 Implementation of dynamic behavior

Applying the methods as presented in sub-section 2.1, the modeling approach cannot describe the electrical behavior under short current pulses and dynamic cycling. When the applied current is cut off, the voltage jumps to its steady state value neglecting the transient behavior. According to [19], the transfer current density can be redefined to include faradaic and non-faradaic components resulting in a modified definition:

$$J_t = -Y_{s,lin} \left[(\varphi_{cc,p} - \varphi_{cc,n} - U_{ocv}) + \tau_{dl} \frac{\partial(\varphi_{cc,p} - \varphi_{cc,n})}{\partial t} \right] \quad \text{with } \tau_{dl} = C_{dl}/Y_s \quad (14)$$

where the first term of the equation corresponds to the polarization expressions in Eq. (6) and the second term describes a side reaction current consumed by double-layer effects.

Table 3 Coefficients of the polynomials $U_{ocv,lin}$, $Y_{s,lin}$ and $Y_{0,lin}$ in Eq. (10), Eq. (11) and Eq. (17), respectively.

Coefficients a_k	Value / S m ⁻²	Coefficients b_l	Value / S m ⁻²	Coefficients c_m	Value / S m ⁻²
a_0	4.192300	b_0	588.1562	c_0	945.8111
a_1	-2.363872	b_1	-6032.793	c_1	-296.1977
a_2	17.19207	b_2	5176.754	c_2	283.6154
a_3	-92.52489	b_3	-217678.1	c_3	-5526.744
a_4	272.3260	b_4	501583.6	c_4	3142.683
a_5	-439.4901	b_5	-643844.7		
a_6	362.6126	b_6	431417.9		
a_7	-119.1711	b_7	-117643.3		

In [19] the area specific double-layer capacitance C_{dl} (F m⁻²) is derived from the transient behavior at the beginning of the discharging process. As shown in Fig. 2a, this form can be described by applying equivalent circuit theory. Due to its character, Eq. (11) is comparable to an equivalent circuit model (ECM) with one linearized open circuit voltage U_{ocv} , one double layer capacitor C_{dl} and one linearized electrochemical conductance $Y_{s,lin}$.

To improve the transient behavior during cycling the ECM is expanded with a time dependent capacitor network. By solving the equivalent circuit shown in Fig. 2b the following equations can be found:

$$J_t = -Y_{0,lin}(\varphi_{cc,p} - \varphi_{cc,n} - U_{ocv} + u_1) \quad (15)$$

$$u_1 = J_t \frac{1}{Y_{1,lin}} - \tau_1 \frac{\partial u_1}{\partial t} \quad \text{with } \tau_1 = C_1/Y_{1,lin} \quad (16)$$

Here the quantity $Y_{0,lin}$ accounts for the ohmic potential caused by ion and electron transport through the electrodes and ion transport through the separator [22]. It is derived from short current pulses during parameterization process as a function of DOD in polynomial form (see Fig. 3):

$$Y_{0,lin} = \sum_0^m c_m (DOD)^m \quad (17)$$

Consequently, the quantity $Y_{1,lin}$ can be calculated from the linearized static electrochemical conductance $Y_{s,lin}$ at each DOD value:

$$Y_{1,lin} = \frac{Y_s Y_0}{Y_0 - Y_s} \quad (18)$$

In accordance to [19], the time constant τ_1 (s) is determined from the transient voltage behavior at the beginning of discharge to ensure that the capacitor describing mass transport is not saturated. It is found that the time constant has a nearly constant value of $\tau_1 = 39.1$ s at all applied current rates.

The DOD is defined for a given initial value DOD_0 as

$$DOD = DOD_0 + \frac{A_{cell}}{Q_0} \int_0^t J_t dt \quad (19)$$

where Q_0 is the cell capacity (As), t is the charge or discharge time (s) and A_{cell} is the electrochemically active area where the transfer current passes through.

3 Experimental measurements

A battery test system by BaSyTec is used for the discharge test of the cell. The test system is capable of currents and voltages up to 200 A (accuracy ± 400 mA) and 6V (accuracy ± 1 mV), respectively. To ensure a constant ambient temperature, the cell is placed into a temperature chamber with a size of 150 cm length, 64 cm width and 94 cm height. The temperature inside the chamber is logged by additional Pt100 sensors to guarantee an uniform temperature distribution. Additionally, the material used for the casing inside the chamber is a matt black foam with high emissivity to reduce reflexions from heat radiation and ensure thermal insulation. The temperature range and air flow inside the chamber can be varied from 15 °C to 45 °C and from 0 to 3 m s⁻¹, respectively.

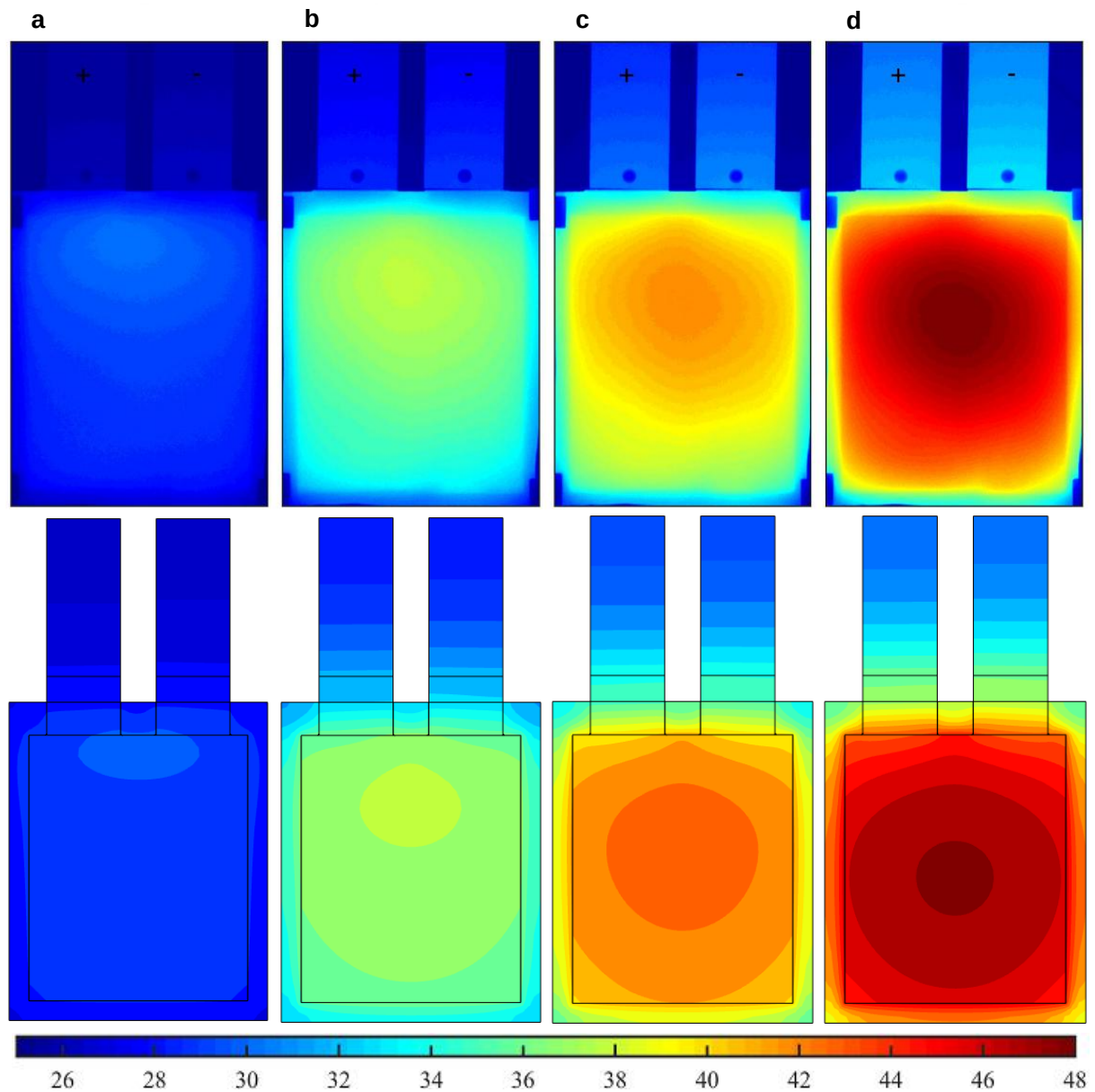


Figure 4: Temperature distribution (°C) from IR (infrared) images (top) and simulation (bottom) of the investigated 40 Ah pouch cell at a discharge rate of 4C and a) 12.5%, b) 38.5% c) 65% d) 93.5% DOD. Contours used in the simulation indicating regions with 1 K temperature difference.

Furthermore, the cross sectional area of the connectors and lead wires are big compared to the tabs of the cell, thus heat generated in these components at high discharge rates can be neglected. In this work, the temperature is set to a reference value of 25 °C and an air flow of 1 m s^{-1} which corresponds to the heat flux due to convection of $10 \text{ W m}^{-2} \text{ K}^{-1}$. To measure the surface temperature distribution of the cell a FLIR 655sc thermal infrared camera is used. The camera is externally triggered by the battery test system and provides 640×480 pixels resolution with a temperature sensitivity of 30 mK.

4 Model Analysis and Results

The equations and the associated boundary conditions carried out in chapter 2 are solved by using the finite element method. The finite mesh of the model consists of 4,028 quadrilateral mesh elements and 57,068 degrees of freedom. All equations are solved by means of the commercial software COMSOL Multiphysics 5.2. The investigated cell consists of 24 double coated negative current collectors and 25 positive current collectors resulting in a total number of 48 cell layers. All experiments and simulations are carried out at a reference temperature of 25 °C. As shown in Fig. 4, surface temperature distribution obtained by thermal infrared spectroscopy is well in line with the simulated temperature distribution at the applied discharge

current of 4C. At the beginning of discharge, the temperature peak is near the current collector tabs with a value of approximately 31°C at 10% DOD. During the discharge process, the temperature peak migrates into the middle of the electrode area with a value of approx. 48°C at the end of the discharge (see Fig. 4).

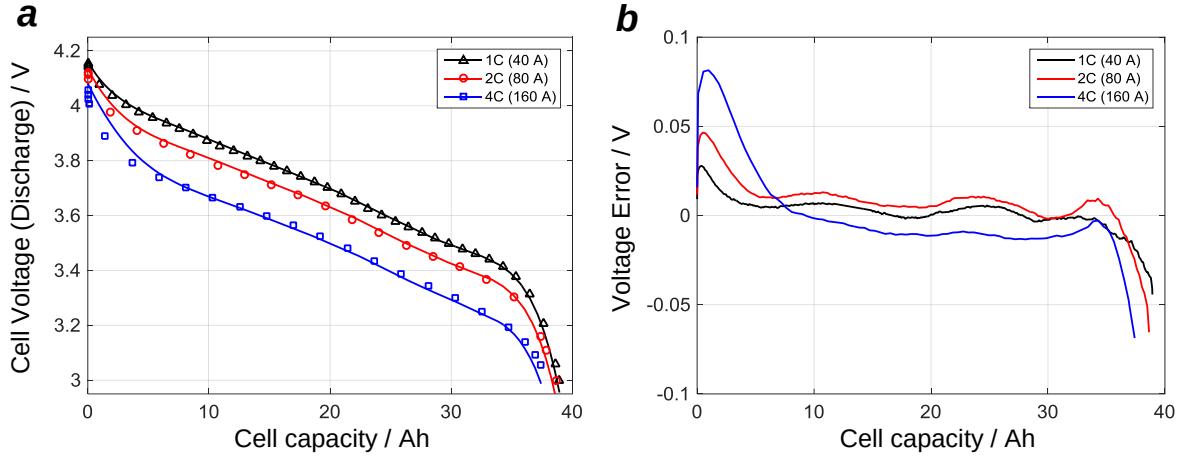


Figure 5: a) Measured and simulated voltage versus cell capacity during constant current discharge at 1C, 2C and 4C. b) The voltage error indicates good agreement with the measurement data. Due to the reduced accuracy of the polynomial approximation error increases at the beginning and the end of the discharge.

Throughout the discharge of the cell, the model is able to follow the measured voltage profile (see Fig. 5a). Voltage error between 15% and 85% DOD is < 20 mV, showing the validity of the modeling approach used in this work. However, due to the approximation error during model parameterization the accuracy at the beginning and the end of the discharge process decreases (see Fig. 5b). Furthermore, voltage error at the end of the discharge process can be explained because of the missing voltage value for the 4C discharge (see Fig. 5b).

Simulations are done on pouch cells with the tabs aligned symmetrically at one side of the cell. Two major design cases are investigated by varying the tab size of the negative and positive current collector from 60 mm to 30 mm. For each of the two design cases, three different current collector thicknesses are investigated by evaluating the temperature and SOC distribution at two cutlines passing through the electrode surface at a specific discharge time. To ensure a symmetric change of ohmic resistance, the thickness ratio of both current collectors is set to a constant value for the three different scenarios. In contrast to the simulation results shown in Fig. 4, the parts of the cell connectors not in contact with the terminals are neglected, assuming that the cell is directly connected with the lead wire in the terminal region.

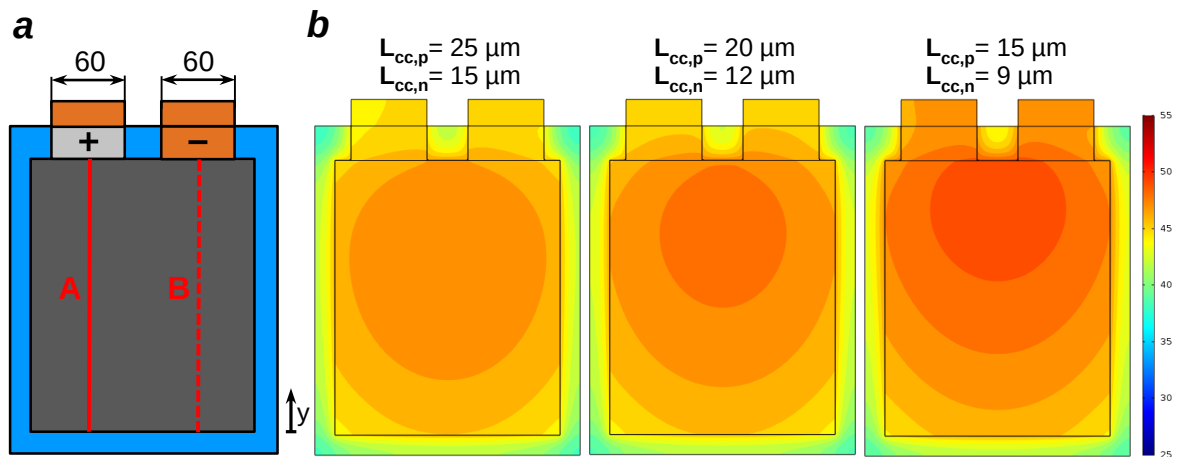


Figure 6: Design Case 1: a) Schematic of the cell with 60 mm tab size. Cutlines A and B passing through the center line of each tab. b) Simulated temperature distribution for 60 mm tab size and three different ratios of current collector thicknesses at the end of 4C discharge.

As shown in Fig. 6b, the temperature distribution is dependent on the current collector thickness. The first thickness ratio of the current collectors (25 μm /15 μm) is comparable to the initial setup used for model validation (see Fig. 4). It can be observed that the thermal mass of the cell connectors results in an additional

cooling effect, which increases the temperature gradients at the cell surface. Furthermore, the symmetric heating in both current collectors indicates that the ohmic resistance in the negative and positive tab are nearly identical. When the thickness of the current collector decreases, the ohmic overpotential and the heat generated in the current collectors increases. The combined overpotential loss in the current collectors increases from 20 mV (25 μm /15 μm) to 29 mV (15 μm /9 μm). The maximum temperature in the region of the cell stack increases from 48 $^{\circ}\text{C}$ (25 μm /15 μm) to 49.6 $^{\circ}\text{C}$ (15 μm /9 μm), resulting in a temperature increase of 1.6 $^{\circ}\text{C}$ due to the different current collector thicknesses.

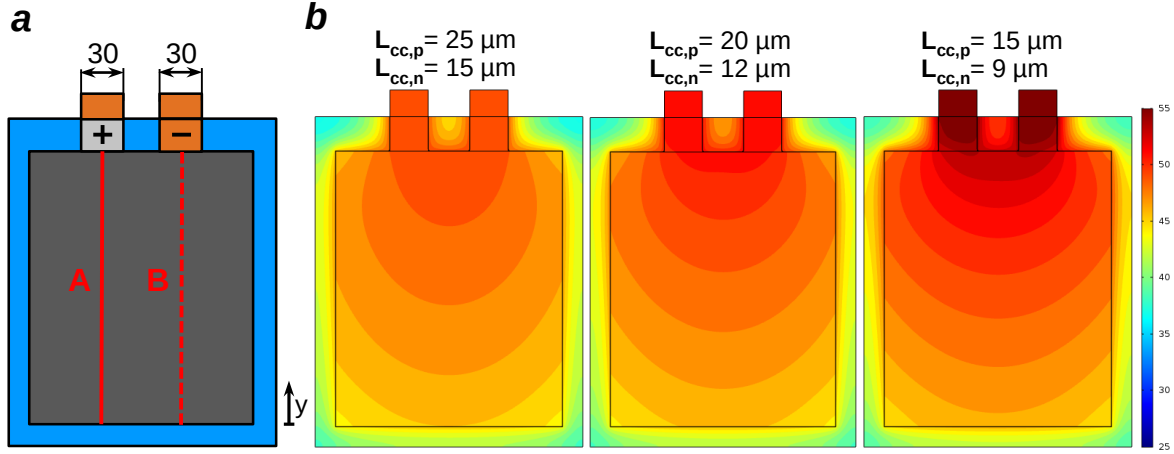


Figure 7: Design Case 2: a) Schematic of the cell with 30 mm tab size b) Simulated temperature distribution for 30 mm tab size, corresponding to Fig. 6.

For the design case 2 the tab size is set to a value of 30 mm. As shown in Fig. 7, the smaller tab size results in a higher temperature compared to a tab size of 60 mm. The maximum temperature in the region of the cell stack increase from 49.7 $^{\circ}\text{C}$ (25 μm /15 μm) to 54 $^{\circ}\text{C}$ (15 μm /9 μm), while the temperature peak is moving in the tab region. This indicates an increase in overpotential losses in the tabs compared to the region of the cell stack. Additionally, the smaller tab size leads to bigger temperature gradients at the cell surface even at high values of current collector thicknesses. The temperature increases from 6 $^{\circ}\text{C}$ (25 μm /15 μm) to 8.4 $^{\circ}\text{C}$ (15 μm /9 μm) in the region of the cell stack. The combined overpotential loss in the current collectors increases from 29 mV (25 μm /15 μm) to 36 mV (15 μm /9 μm).

The electrical current flowing towards or away from the tabs results in a faster change of electrostatic potential in this region. In consequence, the regions nearest the cell tabs are preferably discharged initially. A non-uniform transfer current is building up resulting in a state-of-discharge imbalance comparable to the temperature distribution in Fig. 6 and Fig. 7. Since material properties such as the electronic conductivity are temperature dependent, the imbalance is effected by the cell temperature. However, these effects are usually small and are neglected in this work.

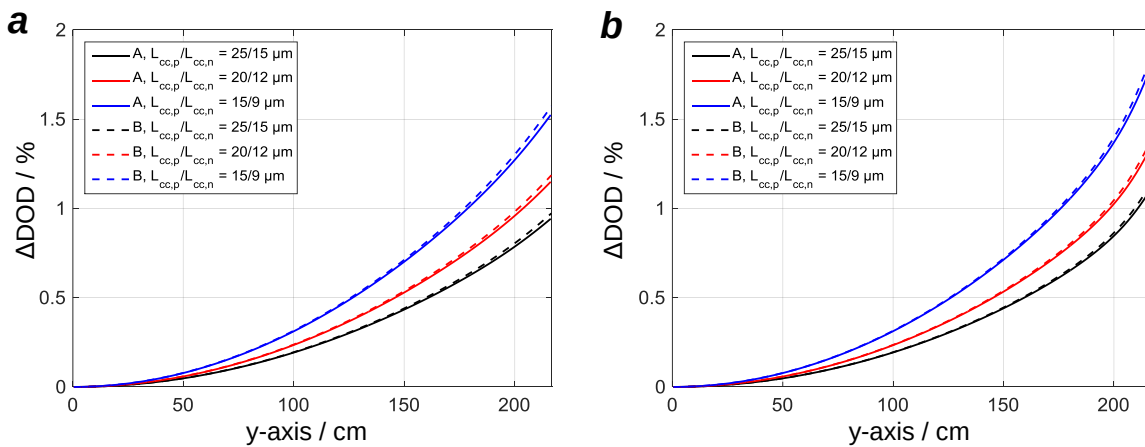


Figure 8: Evaluated change in DOD at the cutlines A and B for a) 60 mm and b) 30 mm tab size for three different current collector thickness ratios after 450 s of discharge (50% DOD). The tabs of the cell are at $y = 216.9 \text{ mm}$.

As shown in Fig. 8, the imbalance in the DOD distribution through the electrode is most dominant at the cell tabs at $y = 216.9$ mm. The maximum change in DOD increases from 1% (25 $\mu\text{m}/15$ μm) to 1.5% (15 $\mu\text{m}/9$ μm) with 60mm tab size and from 1.1% (25 $\mu\text{m}/15$ μm) to 1.8% (15 $\mu\text{m}/9$ μm) with 30mm tab size. The difference between the design cases is generally small with an increase of 0.3% of DOD imbalance for small values of current collector thickness. The DOD imbalance induced by changing the thickness of the current collectors is 0.5% and 0.6% for the cell with 60 mm and 30 mm tab size, respectively. Thus it appears, that the DOD imbalance of the cell is more dominantly effected from the thickness of the current collectors rather than the size of the tabs.

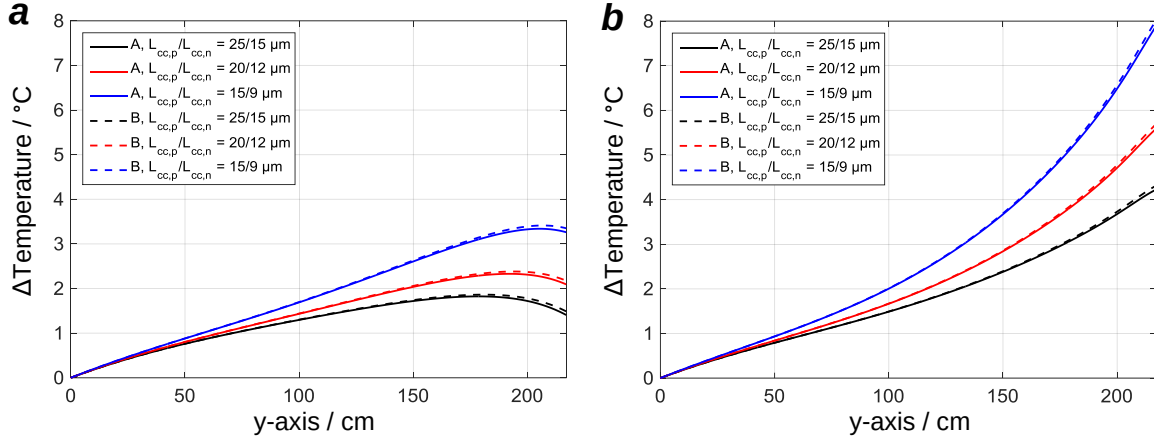


Figure 9: Evaluated temperature at the cutlines A and B for a) 60 mm and b) 30 mm tab size after 450 s discharge.

On the contrary, Fig. 9 shows a significant deviation at temperature distribution between the two simulated design cases. The variation of the current collectors thickness results in an increased temperature gradient from 1.5 °C (25 $\mu\text{m}/15$ μm) to 3.2 °C (15 $\mu\text{m}/9$ μm) with 60 mm tab size and from 4.2 °C (25 $\mu\text{m}/15$ μm) to 8 °C (15 $\mu\text{m}/9$ μm) with 30 mm tab size. These values imply, that a smaller tab size causes a more non-uniform temperature distribution across the electrodes compared to a smaller current collector thickness. As shown in Fig. 8 and Fig. 9, there is no significant deviation between the cutlines A and B, indicating that the cell has a very symmetrical cell design. The analysis shows, that the thickness of the current collectors can be reduced with a small increase in DOD imbalance and temperature. However, a change in tab size must be considered more adequately due to the high temperature response of the cell.

5 Conclusion

To enhance the understanding on the influence of different current collector designs, a polarization model of a 40 Ah pouch cell was developed. The model is accurate in predicting the cell behavior while preserving the simplicity of the polarization modeling approach. Furthermore, the model extends the original modeling approach and is able to simulate dynamic drive cycles. In this study, two different cell designs with a tab size of 60 mm and 30 mm are investigated under variation of the current collector thickness. The analysis shows, that the temperature distribution across the electrodes is highly dependent on the tab size. A smaller tab size leads to higher peak temperatures and a more non-uniform temperature distribution across the electrodes. On the contrary, a smaller tab size has a lower effect on the DOD imbalance (factor 2) compared to a smaller current collectors thickness. The simulation results show, that the cell design can be further enhanced by adjusting the thickness of the current collectors, in exchange for a moderate increase in DOD imbalance. A thinner current collector reduces the mass of inactive components resulting in a higher energy density of the cell. A study on the influence of these parameter under dynamic cycling conditions is ongoing.

Acknowledgments

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