Power tool battery packs: shortening intervals of operation and charging by improved cooling strategy

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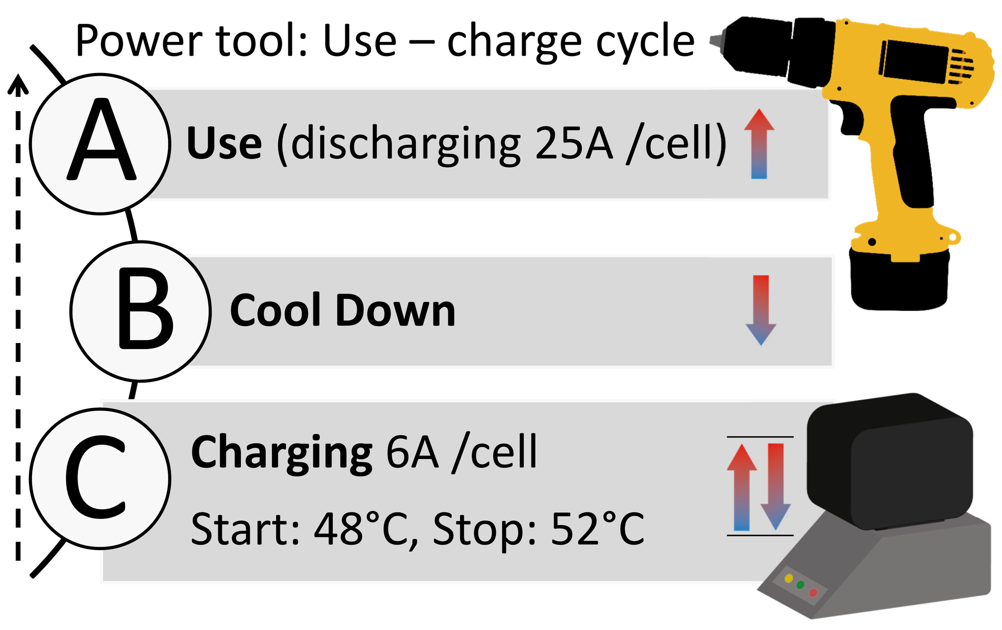
INTRODUCTION: After high duty use phases, battery packs reach temperatures up to 70°C. To prevent accelerated aging due to high temperatures in the cells in the following charging step, the pack manufacturers have to ensure that the cells in the battery pack do not exceed a certain maximum temperature. Reducing downtimes in between high duty use and charging as well as improving charging strategies (fitting the used cooling system) can significantly reduce the total use-charging cycle time and ageing risk.



COMPUTATIONAL METHODS: A Comsol model of an 18V power tool battery pack was developed. A special focus was on the interaction of cell pack performance and cooling system. It comprises battery models of commercial available 21700 cells as well as heat transfer models.

Battery Cell Model:

Comsol Lumped Battery Model, Input parameters were determined applying parameter estimation at measured charge/discharge cycles (different C-rates) and EIS measurements.

Heat Transfer Model (Cell Pack):
Cell: 10x Samsung INR 21700 40T

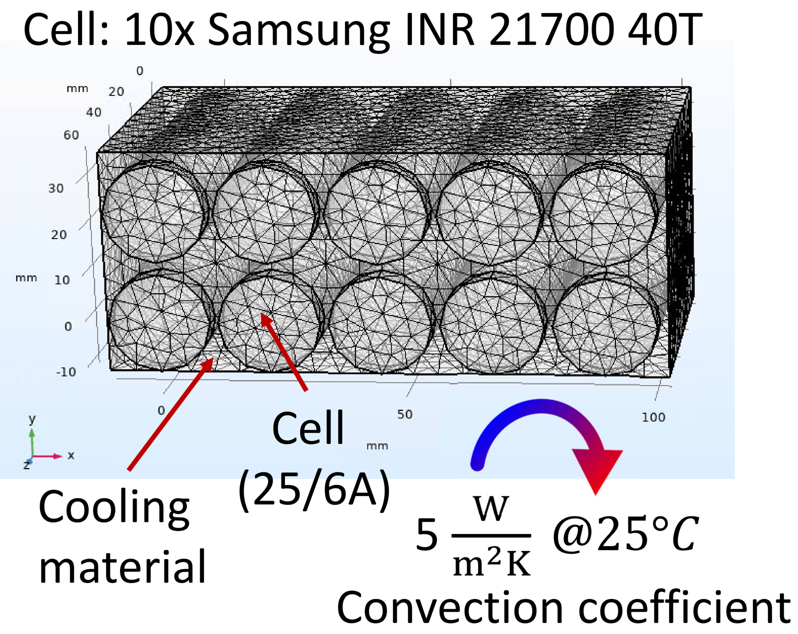


Table 1. Battery cell model input parameters

Input parameter	Value
Investigated cell	Samsung INR21700 40T
Cell capacity	4.0 Ah
Number of cells/pack	10x
OCV-curve	Experimental measured
Voltage losses:	
Ohmic overpotential	18 mV
Activation overpot.	0.97
Concentration overpotential	Part. diffusion, 1000 s, spheres
Current discharging	25 A / cell
Current charging	6 A / cell
Charging modes	CC + CV
Voltage range	2.5-4.2 V

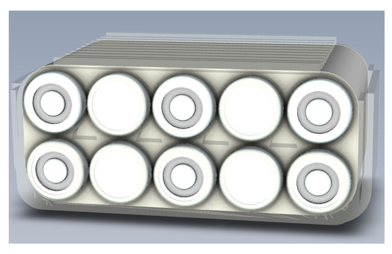


Table 2. Investigated cooling materials and their key properties

Material	Density [kg/m³]	Specific heat capacity [J/kgK]	Thermal conductivity [W/mK]	Melting point [degC]	Heat of fusion [W/kg]
Reverence (non convective air)	Comsol database „air“			-	-
Heat conductive polymer I	1540	1470	2.2	-	-
Heat conductive polymer II	980	3500	0.74	-	-
Latent heat storage material	1220	2100	0.4	39*	70 000*

*latent heat storage: Phase change at 39 degC

RESULTS I: Influence of cooling material surrounding the cells in the pack:

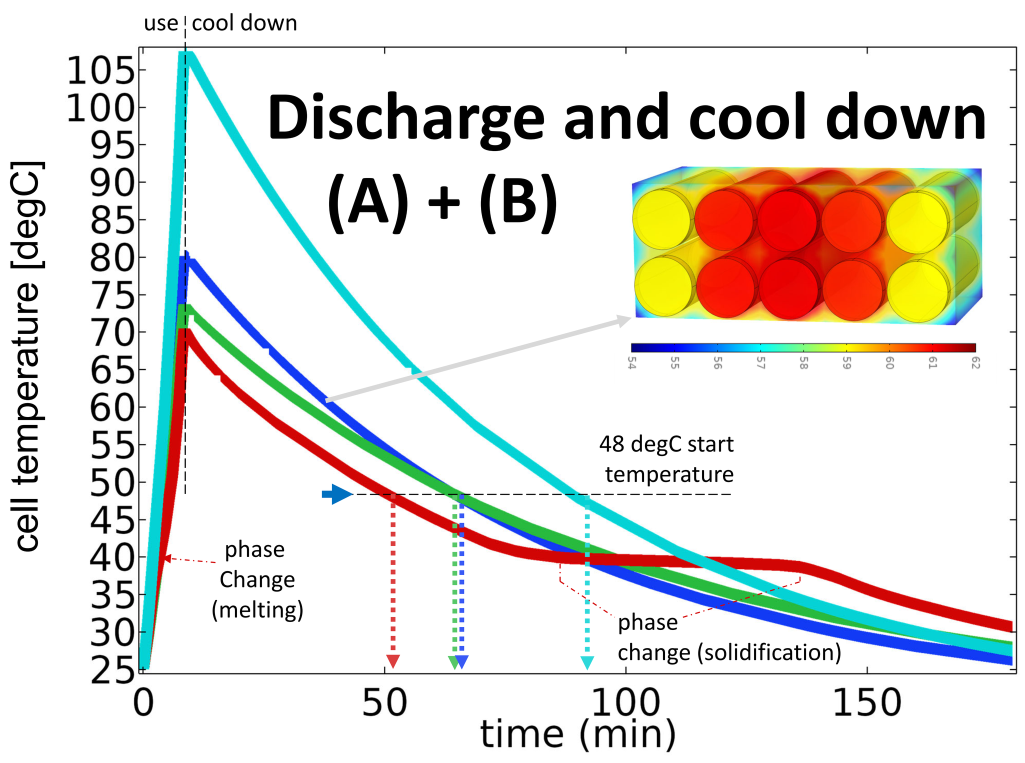


Figure 1. Use phase (6.25C=25A discharge) and cool down phase with different cooling systems.

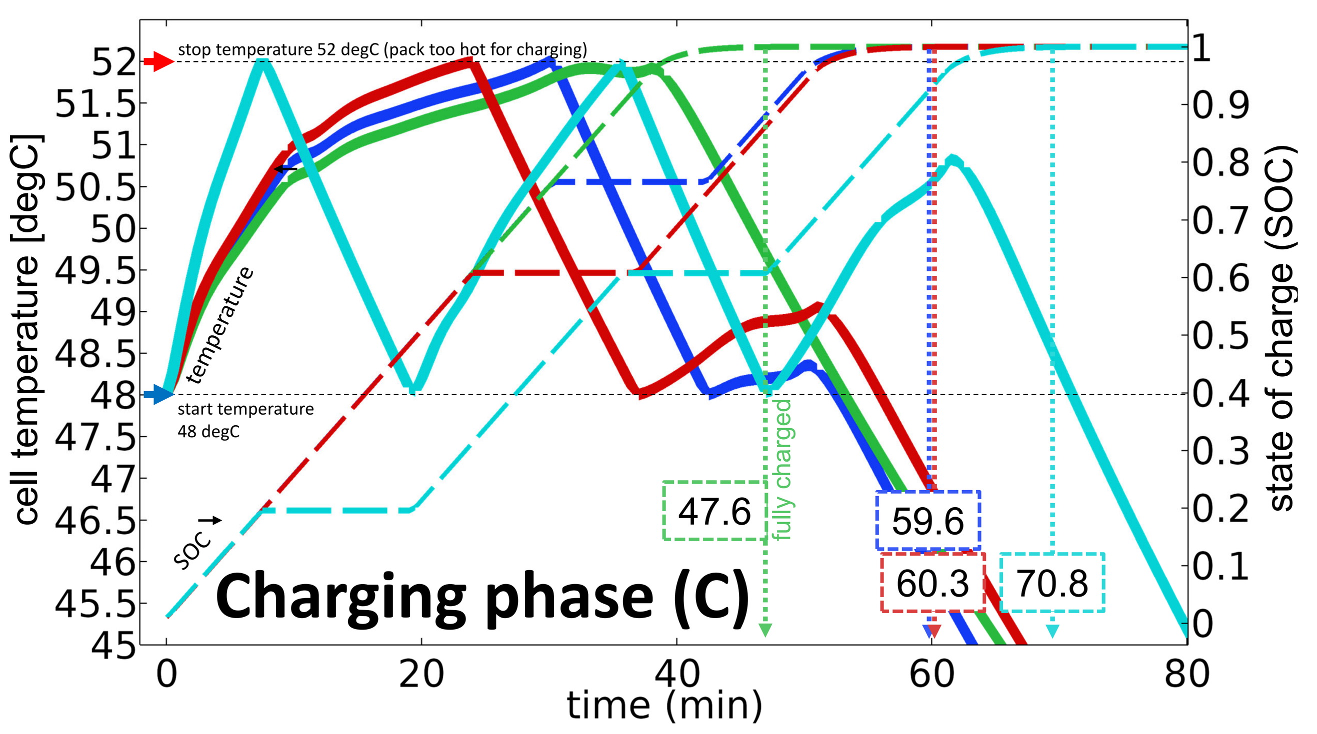


Figure 2. Charging (6A =1.5C) with different cooling systems. Charging starts as the battery pack has cooled down to 48 degC (start temperature) and is stopped if the temperature reaches 52 degC.

- Simulation allows to review the behavior of the different battery pack designs over the whole use – charge cycle (A, B, C).
- „Latent heat storage material“ is advantageous during discharge due to the energy stored during phase change - however, this applies for the first cycle only.
- High heat capacity of „heat conductive polymer II“ lead to the shortest charging interval in the investigated case.
- Compared to the reference scenario, a shortening of up to 33% (30% for the whole cycle) was achieved using heat conductive polymer II in the shown use case.

RESULT II: Influence of ambient conditions - Surrounding temperature, ventilation and start temperature:

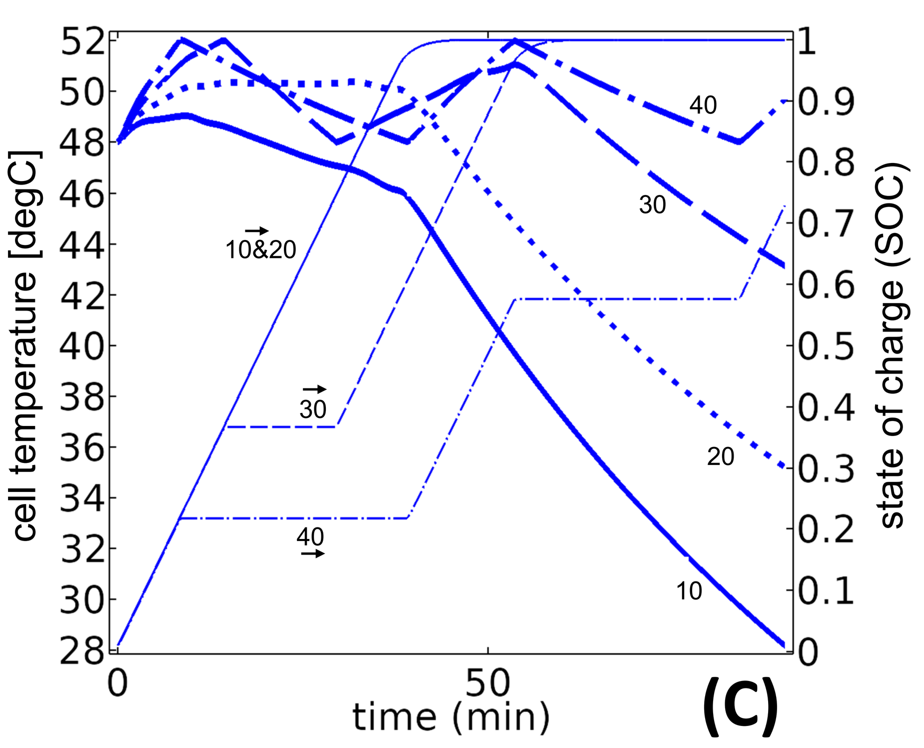


Figure 3. Charging with heat conductive polymer I: Variation of ambient temperature (10, 20, 30, 40 degC).

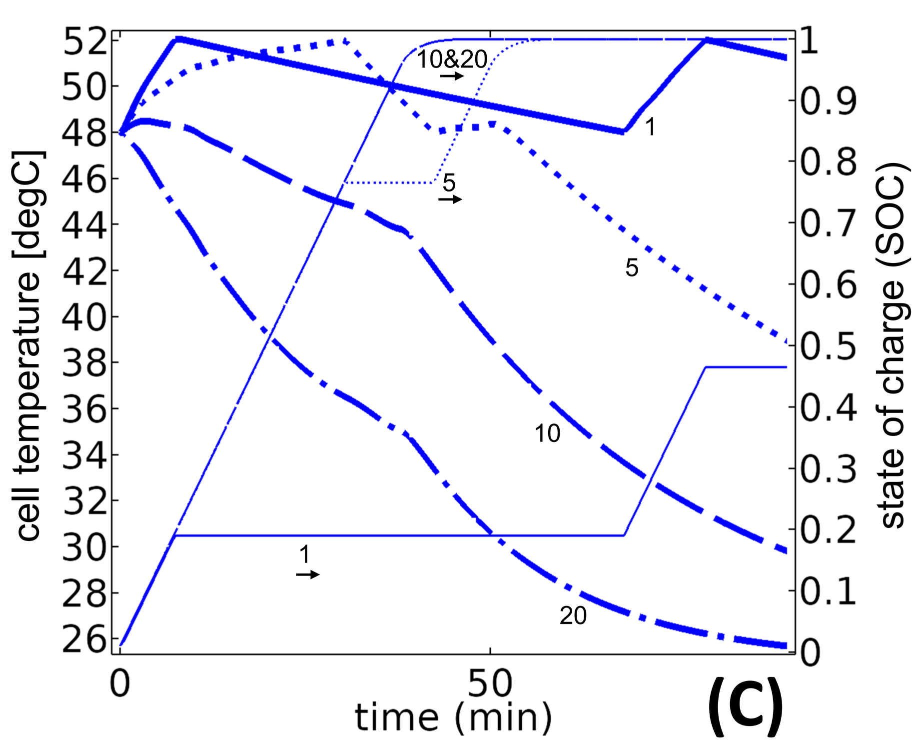


Figure 4. Charging with heat conductive polymer I: Variation of convection coefficient (1, 5, 10, 20 W/m²K).

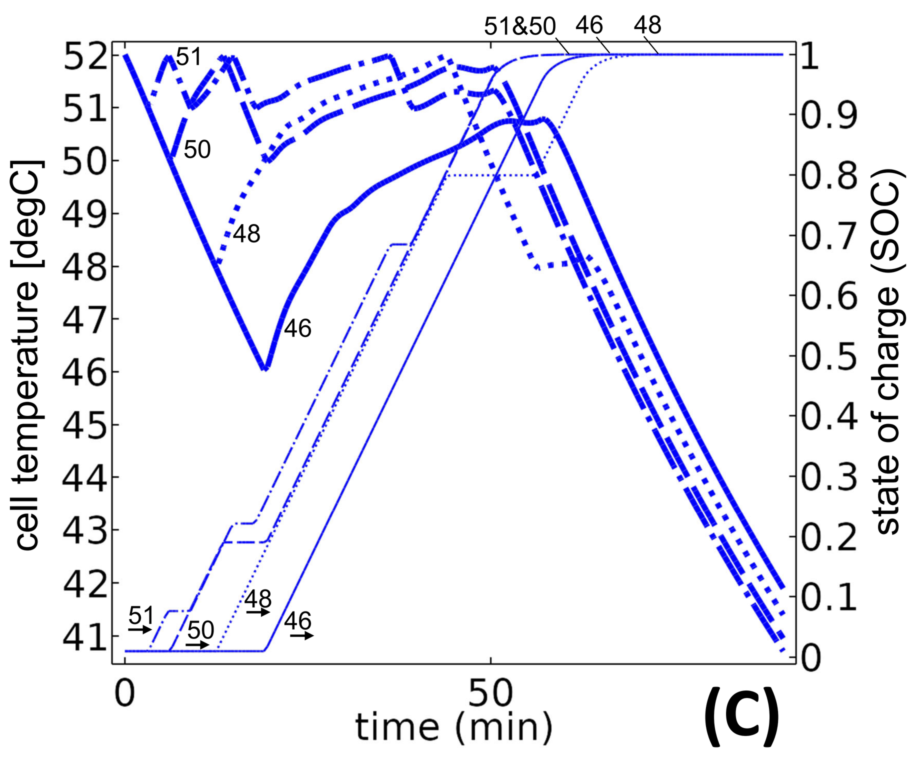
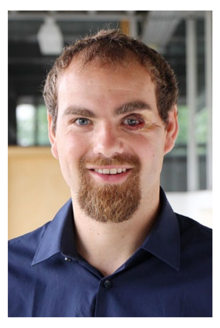


Figure 5. Charging with heat conductive polymer I: Variation of start temperature (51, 50, 48, 46 degC).

- Ambient temperature and ventilation (convection coefficient) highly influence the performance of the cell pack.
- Other parameters, like e.g. the „start temperature“ can be modified to further reduce charging time.
- Using the simulation, the power tool battery pack design and management can be optimized to fit use conditions and customer needs.



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CONCLUSIONS: Reviewing different cooling materials a significant reduction of the charging time can be demonstrated. Parameter variation study highlighted the high influence of ambient temperature, ventilation and charging control parameters, which have to be taken into account designing the battery pack. Simulation was successfully applied for cooling system optimization.

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