Multiscope optimization

of metal cased EV pouch cell stack

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Scope and optimization setup

Optimization target: Achieve optimal battery pack temperature and even temperature distribution

$$min\left[\alpha_1\left(T_{max}-T_{opt}\right)+\alpha_2\left(T_{max}-T_{min}\right)\right]$$

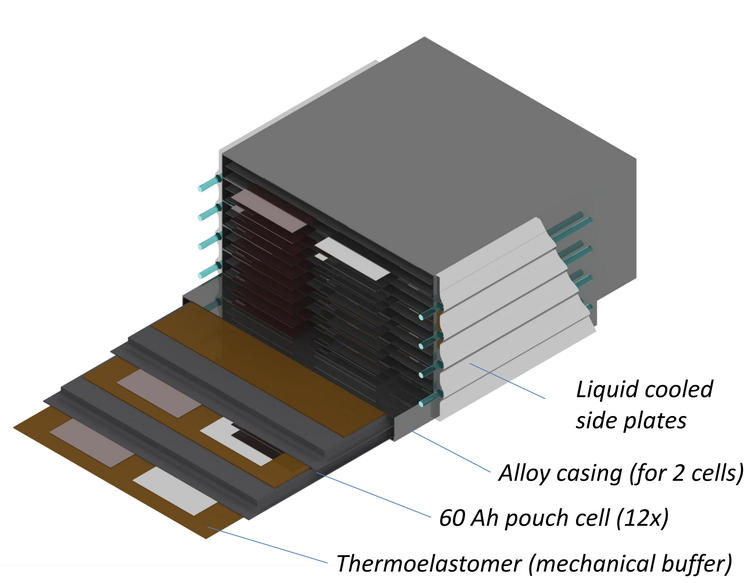
Boundary conditions: Satisfying mitigation of single cell failure (2nd load case)
Fixed coolant mass flow, inlet temperature and coolant temperature rise

Constraints: Space and weight limitations, min/max material thickness
Variables of design: Geometric layout/thickness of casing and thermoelastomer
Simplifying assumptions: Uniform cell material, uniform ohmic heat generation only, heat dissipation solely by coolant, isotropic heat transfer

Simulation setup: ANSYS 14, 2M nodes, CFD simulation for coolant channels

Basic thermal energy balance:

$$\int_{T_0}^{T_1} mc_p\,dT = \int_{t_0}^{t_1}\dot{Q}_{gen}\,dt - \int_{t_0}^{t_1}\dot{Q}_{diss}\,dt \qquad \dot{Q}_{gen} = I^2 R$$



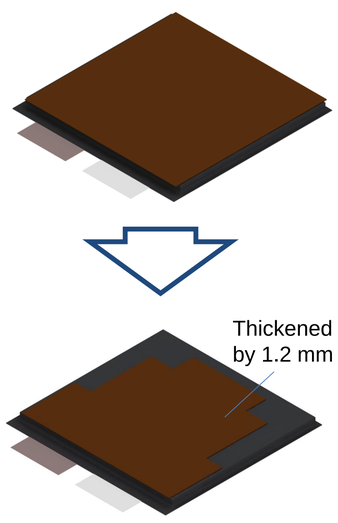
Heat generation assumptions			
1	Volumetric heat generation (reg. cell)	[kW/m³]	20.0
	Total heat generation in stack (reg. operation)	[kW]	0.085
2	Assumed volumetric heat generation (damaged cell)	[kW/m³]	300.0
	Total heat generation in stack (distressed)	[kW]	0.283

Cooling system specifications		
Coolant medium	water	
Fixed coolant mass flow rate	[kg/s]	0.05
Fixed coolant inlet temperature	[K]	293
Max ΔT coolant (boundary condition)	[K]	0.7

Material data assumptions		
Thermal conductivity cell-material (uniform)	[W/mK]	2.2
Specific heat capacity cell material (uniform)	[kJ/kgK]	1.2
Thermal conductivity thermoelastomer	[W/mK]	1.25
Specific heat capacity thermoelastomer	[kJ/kgK]	0.8

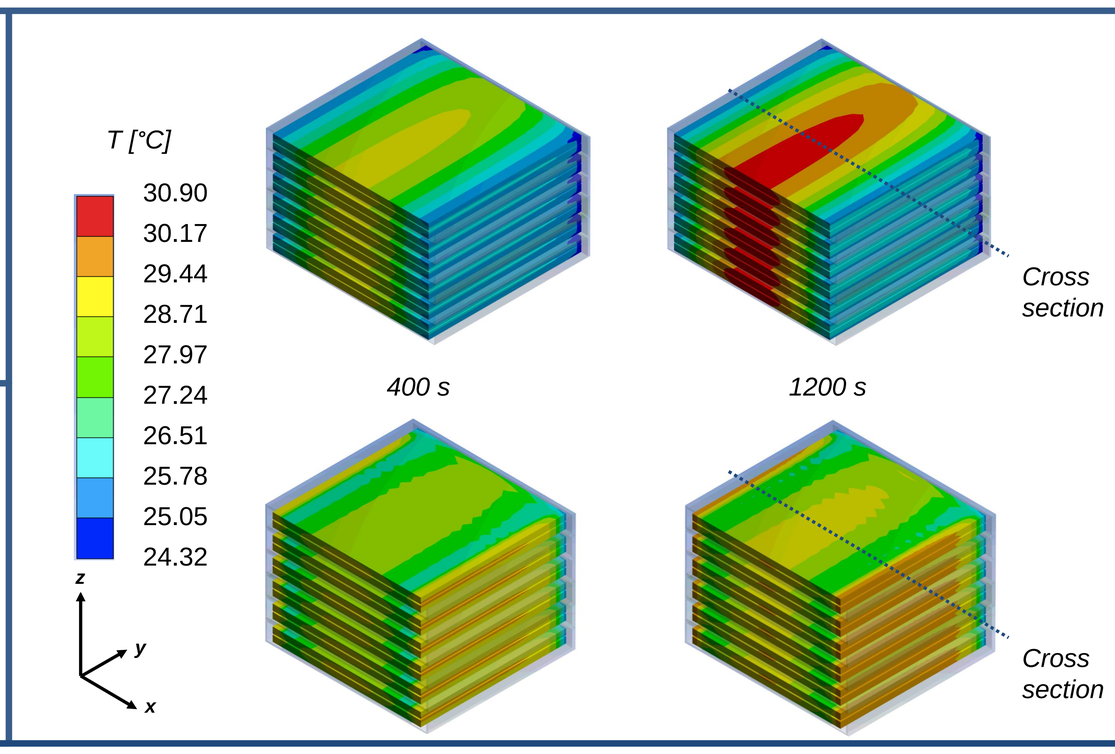
Results: Transient temperature distribution and geometry

Geometry variation

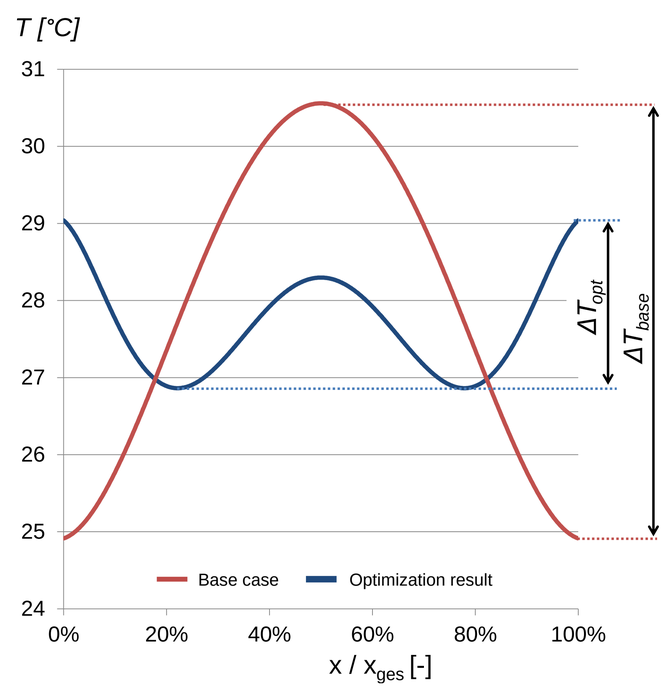


Total increase in weight: ~3.8 %

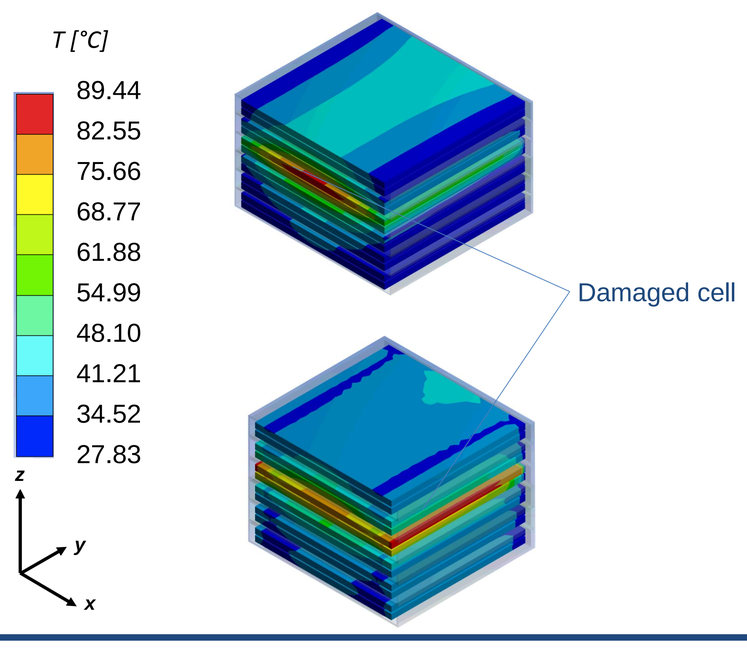
1 Regular operation, 20 minutes 180A charge



Temperature profile in cross section after 1200s



2 Distressed condition, thermal runaway of single cell



Conclusion and outlook

- Evaluation of 1,800 parameter combinations and creation of response surface
- Significantly reduced temperature spread of **2.1 K (- 64 %)** achieved by modified geometry and slightly higher material thickness (weight: + 3.8%)

  ➡ **Profound positive effects on current distribution and therefore aging effects**
- Accelerated occurrence of thermal steady state condition

Outlook :
- Build-up of physical prototype and validation of results by experiments
- Scale-up to battery pack level
- Further optimizations incl. additional variables and more detailed 3D heat gen. model

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