Evaluation of the Thermal Behavior of a 48V EV Battery with Passive Cooling

European GT Conference

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01 Introduction

02 Cell Calibration with GT-AutoLion

03 Thermal Model of the Battery Pack

04 Results

05 Conclusion
Introduction

• Rheinmetall Automotive is traditionally strong in the market of conventional drive trains
• Expansion of the traditional product portfolio with products for electric and hybrid drive trains
  • become a competent partner for electric drives, battery packs and power electronics

Motivation:
• Development of a simple tool for the evaluation of (scalable) battery pack concepts
• Fast reaction for customer inquiries

Requirements:
• Low calibration effort based on 3D CFD
• Cell Temperature error should not exceed 1K on average
• Gradient of the individual cell temperatures across the battery pack must be consistent
Simulation Workflow

- Cell Calibration
- Geometry Translation into Thermal Masses Model
- Calibration for stationary Cell Temperature Distribution

- Geometry Preprocessing
- Model Parametrization for Thermal Distances

- GT AutoLion
- GEM3D
- GT-SUITE

✓ Comparison of stationary and transient results with 3D CFD
✓ Comparison of cell model with test results
✓ Validation with test results
✓ Calculation of temperature distribution for real drive cycles

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GT-AutoLion | Cell Description

Cell Characteristics:
- Prismatic Cell
- Stacked Electrodes
- LiFePO4 / Graphite
- 72 Ah Capacity
- 3.2V Nominal Voltage
- 2C max. Constant Current

Create AutoLion model to simulate cell behaviour:

Available Data for model creation and calibration:
- CT-Scan
- Official Datasheet
- Capacity Test for 0.05C (Discharge)
- Capacity Test for 1/3C, 1C and 2C (Discharge)

GT-AutoLion | Calibration Workflow

- **GT-AutoLion Template**
  - CT-Scan
  - Official Datasheet

- **OCV Calibration**
  - Capacity Tests for 0.05C

- **Cell Dynamics Calibration**
  - Capacity Tests for 1/3C, 1C and 2C

- **Optimization**

- **GT-AutoLion Template Parameters**
  - Contact Resistance
  - Diffusivity Multiplier
  - Heat Transfer Coefficient
  - Capacity Loading | N/P Ratio
  - First Charge/Discharge Capacity
  - OCV@100% SOC
  - Geometry Parameters
GT-AutoLion | Calibration Results

- Calibration results for capacity discharge tests OCV|1/3C|1C|2C
- Maximum error about 1% for voltage values
- Capacity fit for all cases (except 2C)
- No calibration of charging tests so far

✔ Template can be integrated into complete Battery System Model
✔ Heat flow from cells can be extracted and fed into Thermal Model

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Thermal Model (TM) | Battery Setup

- 48 Volt Application
- Battery Capacity 15kW-h
- Two chambers (symmetrical)
- 64 prismatic battery cells
- Passive cooling

Cell Fixing - Plastic
Profile → Caoutchouc
Profile → Aluminum
Prismatic Cell → Lithium Ion
Busbar → Copper
Backfilling Material (Compound) → Synthetic Resin
Case → Aluminum
Synthetic Resin
**TM | Geometry Preparation and Modelling**

- Preparation of the CAD geometry in SpaceClaim
- Simplification of the CAD model
- Definition of a thermal resistance between the cells instead of a thermal mass for the casting compound
- Consideration of the anisotropy of the battery cell
- Control of the heat flows in the battery pack

- Anisotropic material properties
- Coordinate direction

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Intermediate material

Thermal resistance between all cells

Sectioning of the casting compound into 5 thermal masses
TM | Battery Pack with Thermal Masses

126 thermal masses
Model with nearly 1000 possible calibration Parameter for “DtMC”

Optimization:
17 Parameter for “DtMC” in use to keep it “as simple as possible”

“DtMC”: Distance to Mass Center

CFD Analysis

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TM | Model Calibration

- Calibration of stationary load points with results from 3D CFD for different cases
  - Variation of stationary cell heat source
  - Variation of stationary ambient conditions
  - Optimization for “Case Sweep and Cross-Case Studies”
  - **Goal**: average cell temperature calibration error ≤ 1K
  - **Result**: max. ave. error about 0.25K / symmetry between chambers

- Transient results for a 7-Day-Cycle with calibrated model
  - Changing BC’s for HTC, temperature and heat source
TM | Battery Pack with Thermal Masses and GT-AutoLion

- Electrochemical integration with GT-AutoLion → validated model
- Build up of the battery cell arrangement and electrical flow
- 4 cells in parallel and 16 cells in series (4p16s)
- Transfer of dissipated heat from battery cell and ave. temperature from thermal mass

Dissipated heat rate from the cells to the thermal masses
Temperature from thermal masses to the cells
Current profile

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**Results | 1C Discharge Battery Pack**

**Boundary Conditions**
- Measurement for 1C Discharge
- Battery cell initial temperature 31-33°C
- Ambient temperature 25°C
- Start-SOC = 0.85

**Results**
- The gradient of the temperature characteristic is similar
- Note: model calibration only with 3D CFD!
- Simulation results for the 1C discharge match the test results very well
- For the case of battery charging, there are currently deviations between simulation and measurement

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**Conclusion**

- GT-AutoLion Cell Calibration successful according to recommended workflow by GT
- Small Error for discharging curves after calibration
- GT suitable for thermal management modeling
- Easy build-up of a battery model with passive cooling
- First verification with battery pack measurements shows good matches
- The model fulfills the defined requirements
- Further investigations are necessary
Thanks to

GT

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