Development of Computer-Aided Design Tools for Automotive Batteries

Steve Hartridge, CD-adapco

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Project ID: ES118

Overview

Timeline

Started - August 1st 2011
Finish - July 31st 2014
Currently ~22% completed

Budget

- Total project funding $2.74M
  - (3 Years)
  - $1,370,313 DoE
  - $1,370,313 CD-adapco team

Barriers

Barriers addressed

- Excessive cost & time of cell & pack design processes
- Enabler for design exploration
- Limited existing methods for analysis

Targets

- Widespread use of standardized battery CAE software
- Acceptance of simulation alongside and complimentary to test work

Partners

- Battery Design LLc
- Johnson Controls
- A123 Systems Inc
- NREL
- ORNL

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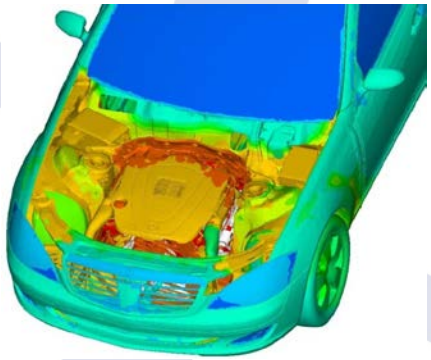
Funding provided by Dave Howell of the DOE Vehicle Technologies Program .
The activity is managed by Brian Cunningham of Vehicle Technologies.
Subcontracted by NREL, Kandler Smith Technical Monitor

Objectives (Supporting DoE's CAEBAT Activity)

- To produce electrical and thermal simulation models applicable for spirally wound lithium ion cell designs, both cylindrical and prismatic
- Validated such models at the cell and module level with test work
- Understand and identify the dominant design parameters in the electrical and thermal response of spirally wound lithium ion cells
- Include the created simulation models into the readily available 3D multi-physics code STAR-CCM+, for combined flow, thermal & electrochemical simulation



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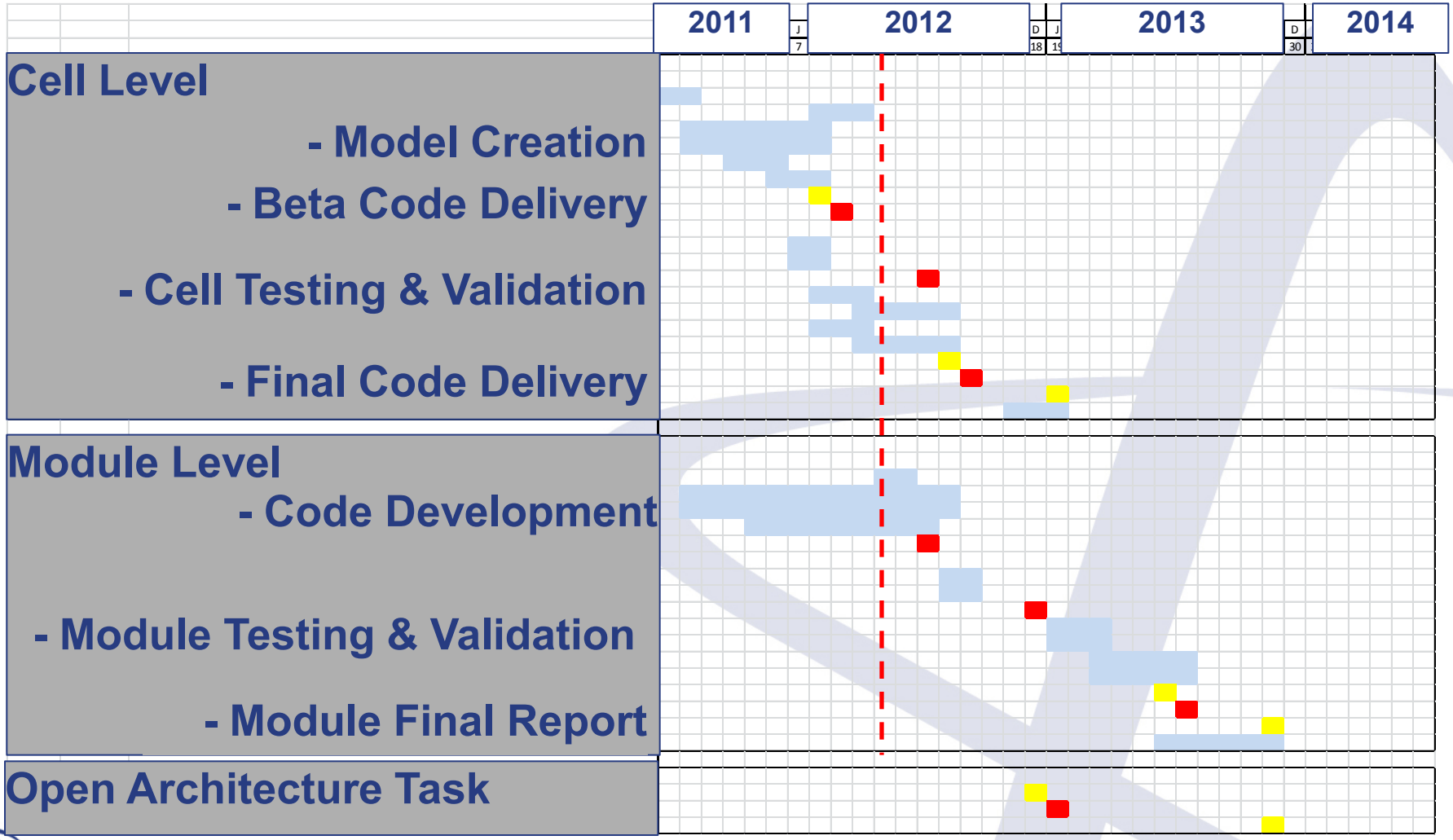
Milestones & Timing Plan



Milestones Completed

Project started – August 1st 2011

Month/Year	Milestone
February/2012	Completion of spirally wound cell model and architecture
March/2012	Delivery of first version of cell modelling code
April/2012	Completion of cell level testing, both cylindrical and prismatic form factors
Sept/2012	Completion of cell level simulation and validation
Oct/2012	Module level coding complete
Jan/2012	Open Architecture support

On Track

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Technical Approach

- **Combine the newly created model into two complimentary products**
  - Battery Design Studio, cell level design simulation code
  - STAR-CCM+, finite volume computational multi-physics code
- **Combination provides a flow, thermal and electrochemistry toolset which is accepted by many industries and users**
  - CD-adapco has circa. 8000 users of its code
  - Build on CD-adapco/Battery Design's position in the field of battery modelling
- **Validate the created method on cylindrical and prismatic wound cell types as well as on a control pouch cell design**
  - Johnson Controls Inc – Cylindrical (VL6P & VL41M)
  - Johnson Controls Inc – Prismatic (PL27M & PL6P)
  - A123 Systems – Pouch cell


A123 Pouch


PL27M

VL6P

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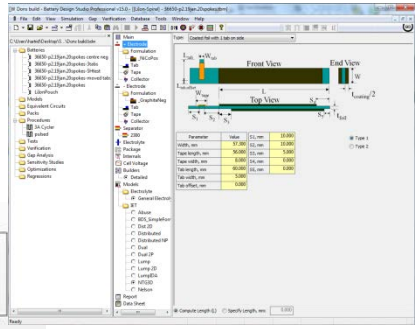
Simulation Method

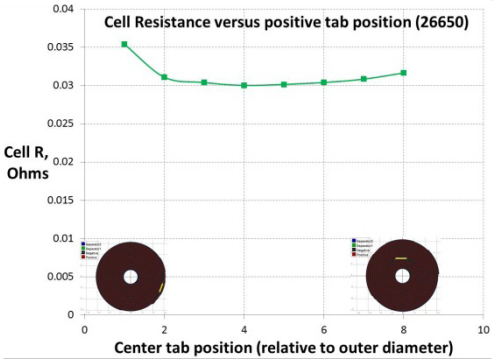
Spirally wound method at cell level

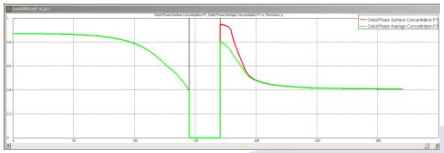
1) User definition of the cell properties

2) Design exploration of the appropriate quantities



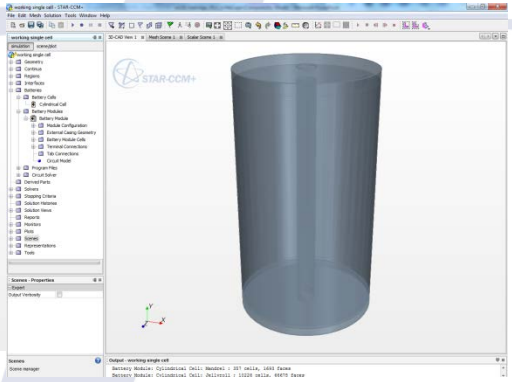
Current density on electrode

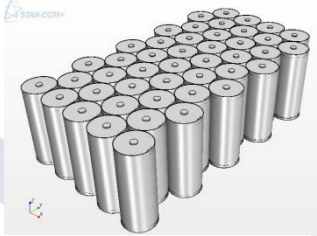


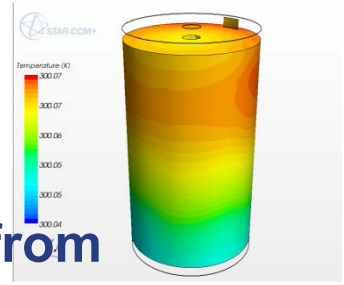


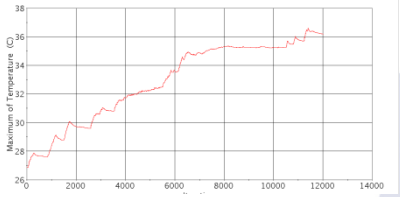
Solid Phrase concentration across electrodes

3) Seamless transfer of cell definition









4) Coupled flow, thermal & electrochemistry analysis

STAR-CCM+ v7

Distance from negative collector, μm

Spirally wound method at 3D module level

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Cell Level Testing for validation – on going

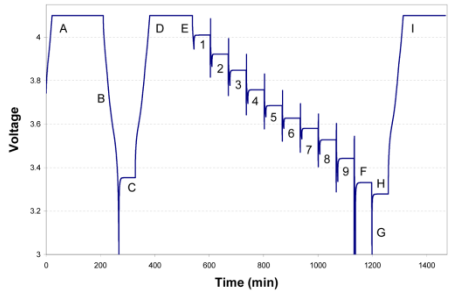
Cylindrical/Prismatic Cell testing

Testing for model creation

Open circuit tests

Constant current tests over range of temps

High pulse power characterisation tests over range of temps



Validation

Load based on US06 drive cycle scaled appropriately

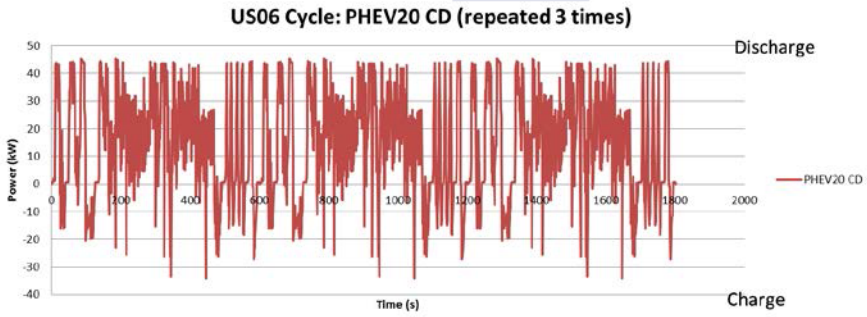
Pouch Cell testing

Model Creation

Parameters supplied by A123

Validation

US06 derived drive cycle



Simulation work – Next 6-9 months

Cylindrical/Prismatic Cells

- Electrochemistry parameters and cell CAD received
- Electrochemistry model created and parameter fitment on going
- Single cell validation of electrical and thermal results in progress

Pouch cells

- Equivalent circuit parameters received and implemented
- Cell model created and simulating test chamber/conditions

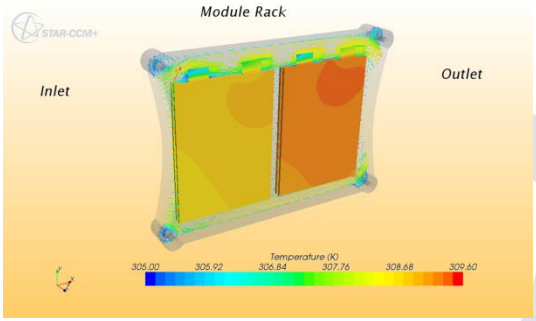
Module Level Testing & Validation – Next 6-9 months

Module Testing

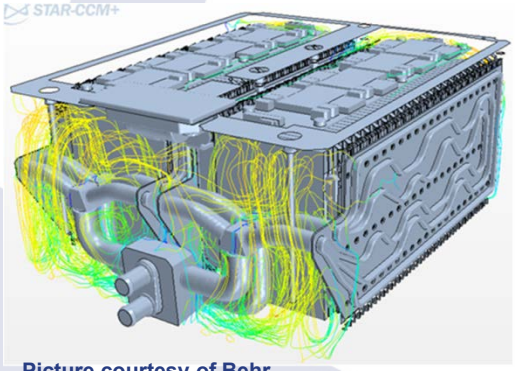
- 12 cylindrical cell module
- 6 prismatic cell module
- 21 pouch cell module
- Drive cycle tests

Module Simulation

- Create the appropriate modules in created code
- Use the validated cell level electrochemistry models
- Validate module level electrical and thermal results
- Previous work shown



Examples of previous work



Picture courtesy of Behr

Summary

- CD-adapco's team is pleased to be part of DoE's CAEBAT programme to further battery modelling techniques
- NREL's technical oversight has been helpful
- Since beginning the project a spiral cell simulation architecture & method has been implemented in to two commercially available codes
  - Battery Design Studio
  - STAR-CCM+
- Cell and pack level test plans have been defined and cell level testing has begun at both JCI & A123
- A simulation model replicating the validation cases, utilising the above methods, has been created for spiral cells. Work continues to complete this work for the validation cases
- Regular quarterly meetings with all partners have been conducted

Future Work

- Within the spiral cell architecture & methodology a rigorous exploration of solver methods to expedite solutions will be explored
- The electrochemistry model will be further enhanced to cope with detailed property changes during the winding process
- Detailed electrolyte properties for contemporary electrolytes will be included in the model
- Further testing and numerical improvements will be added to the spiral models through the application of the code to the above problems
- Continue regular quarterly meetings and progress reviews
- Release of the first version of software to NREL fro comment