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ANSYS产品咨询:

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GM / ANSYS / ESIM / NREL:
先进仿真技术加速
电动汽车动力电池开发

ANSYS CHINA

朱祥德

电池是新能源汽车发展的关键技术之一

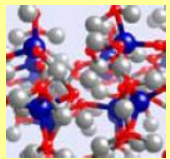
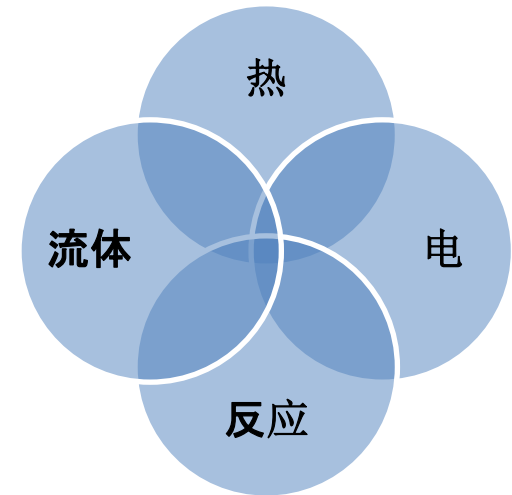
- 2012年3月，美国总统奥巴马宣布“电动汽车普及大挑战——到2022年生产每户美国家庭都能负担的起的插电式电动汽车(PEVs)”



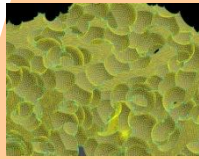
Image credit: “FY 2013 Annual Progress Report”, Energy Storage R&D, Vehicle Technologies Office, U.S. Department of Energy

电池开发中面临的主要挑战

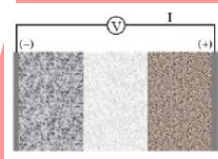
- 费用
 - 性能（能量密度及功率密度）
 - 耐用性和使用寿命（考虑在不同环境和使用周期）
 - 安全性（考虑恶劣环境）
-
- 复杂的多尺度、多物理场系统
 - 快速发展的材料和设计理念
 - 现有软件工具不专业针对电池



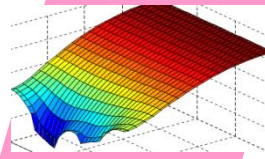
Molecular



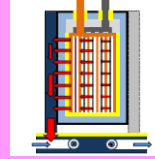
Particle



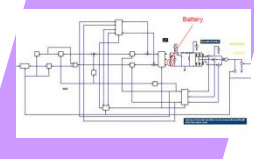
Electrode



Cell



Pack



Vehicle

CAEBAT 项目——背景

- 发起人: 美国能源部车辆技术办公室
 - 通过高风险/高回报的研究项目来推进车辆技术创新

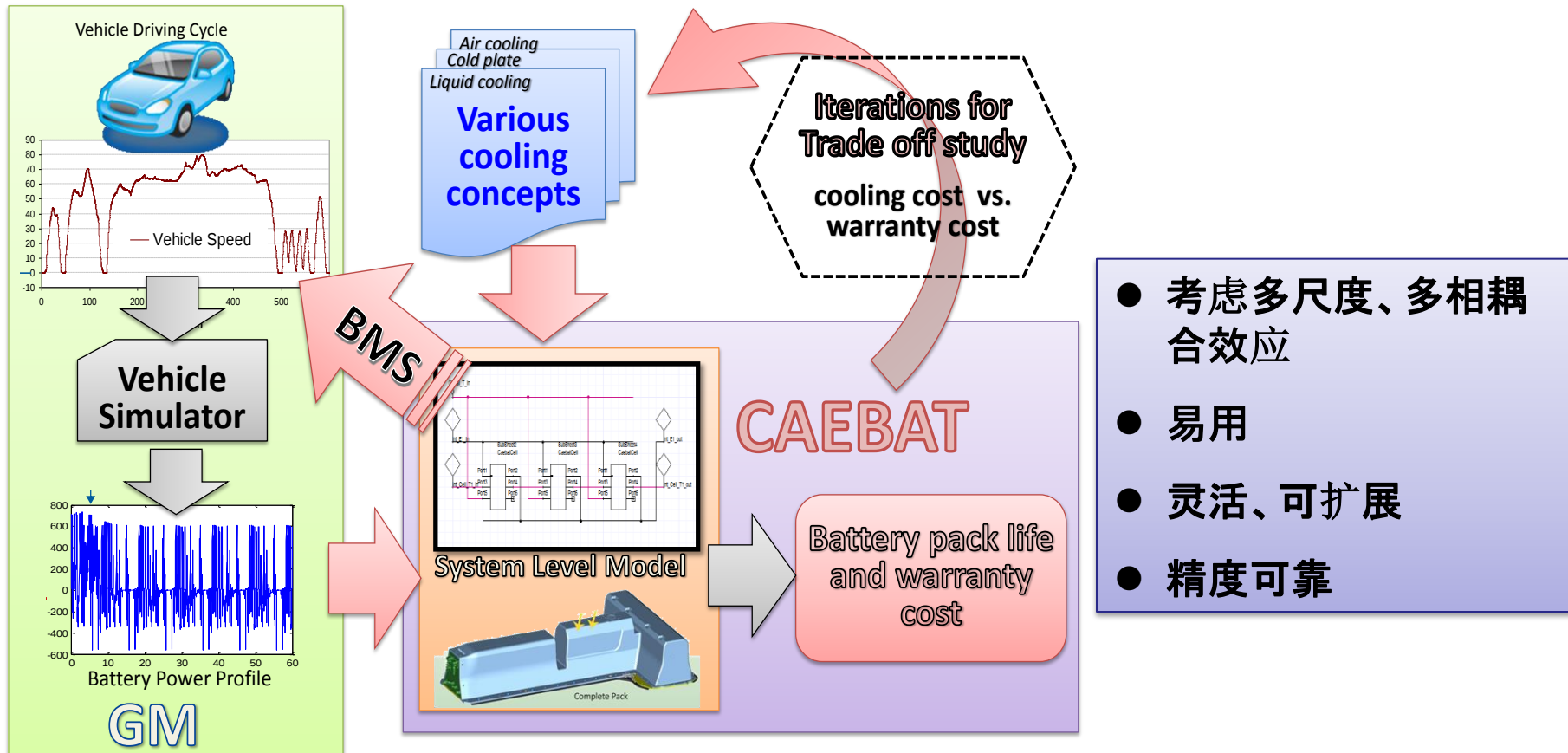
Computer Aided Engineering of Electric Drive Vehicle Batteries

- 先进的仿真技术是加速创新技术的关键
- 目标: 开发并验证高精度、高效率、模块化、灵活、易用的电池仿真软件
- 项目组成员(2011–2014)



CAEBAT项目——目标

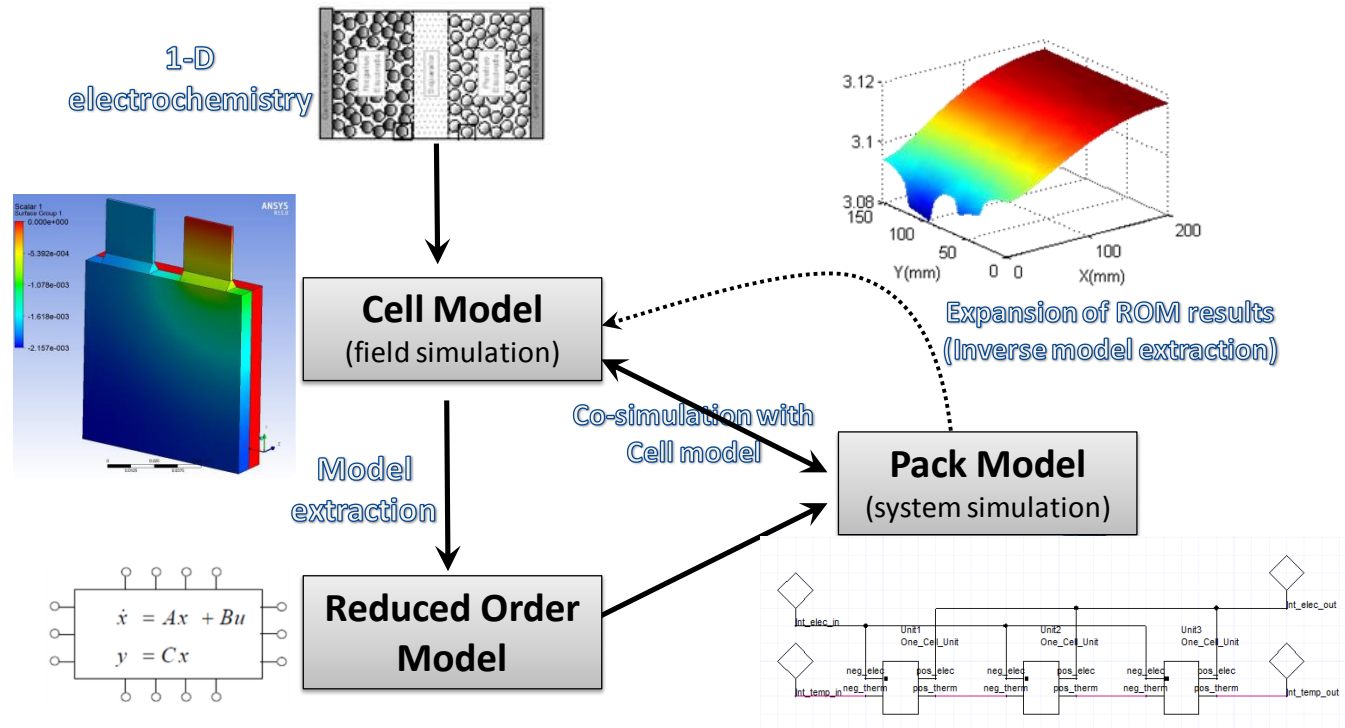
- 缩短设计周期，提高性能、安全及寿命，并降低成本



能够提供综合平衡了冷却成本和电池包寿命及保修成本的解决方案

CAEBAT项目—方法

- 结合CFD方法、系统仿真、多尺度耦合及降阶模型(ROM)

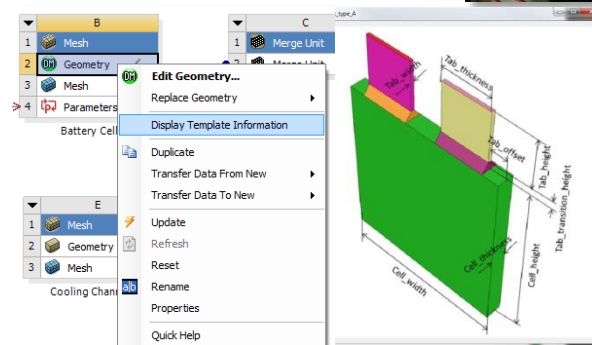
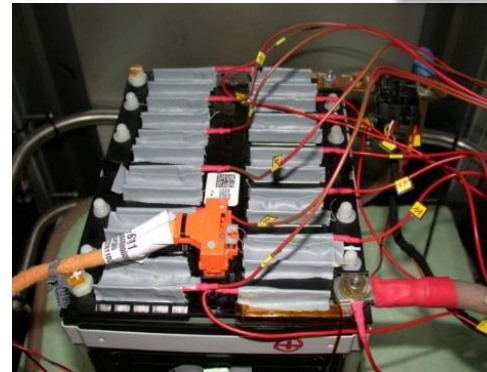
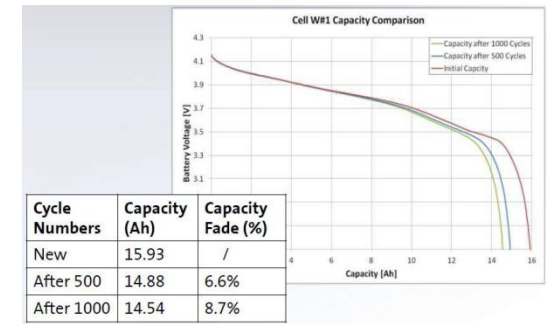


- 基于已有的手段：

- ANSYS Workbench, Fluent, Simplorer
- Interoperability via Open Architecture Software (OAS)

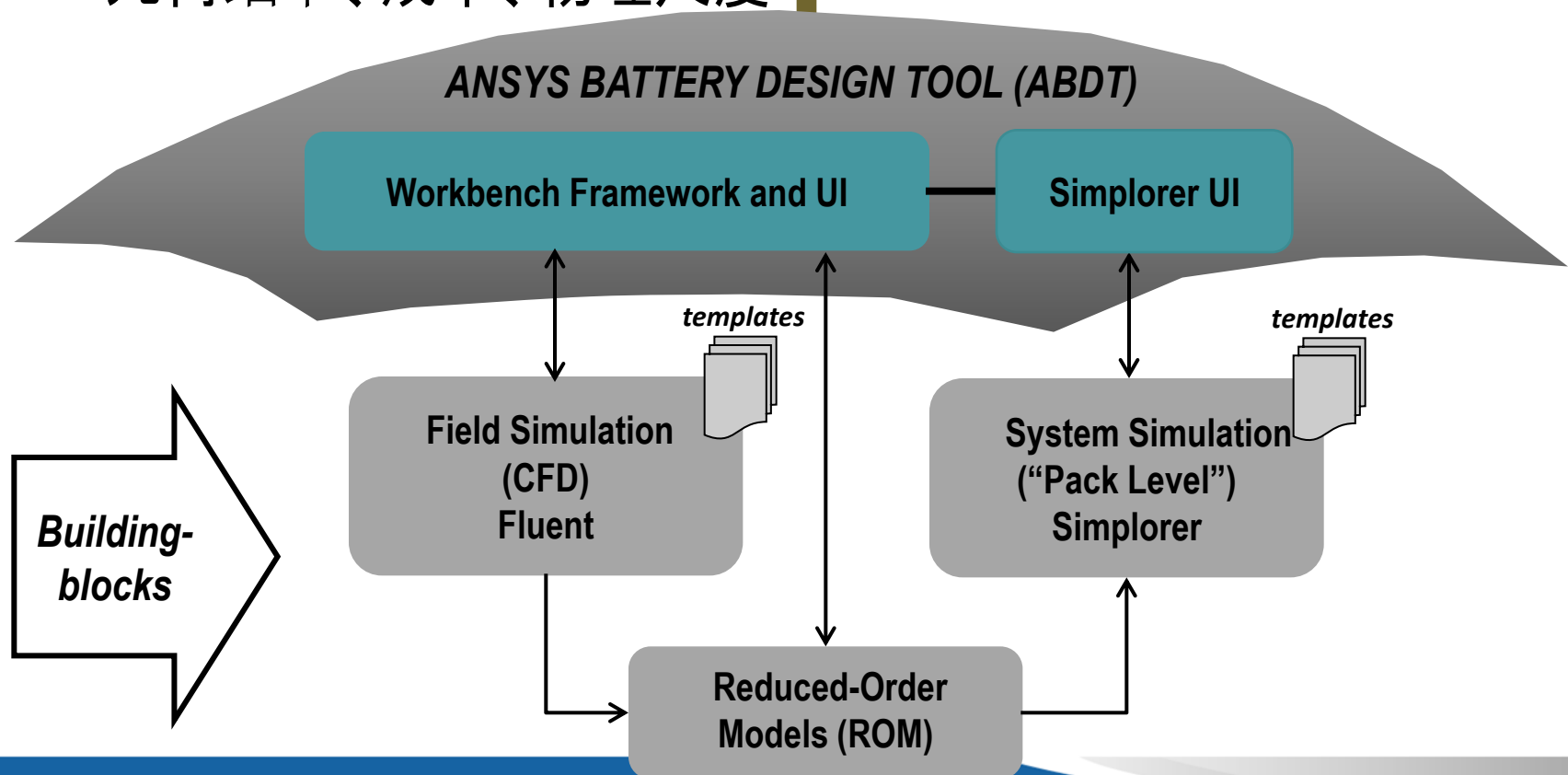
CAEBAT项目—方法

- 不同方法和模型之间的耦合 (NREL, ESim)
- 实验验证及校核 (GM)
- 可持续的行业推广 (ANSYS)



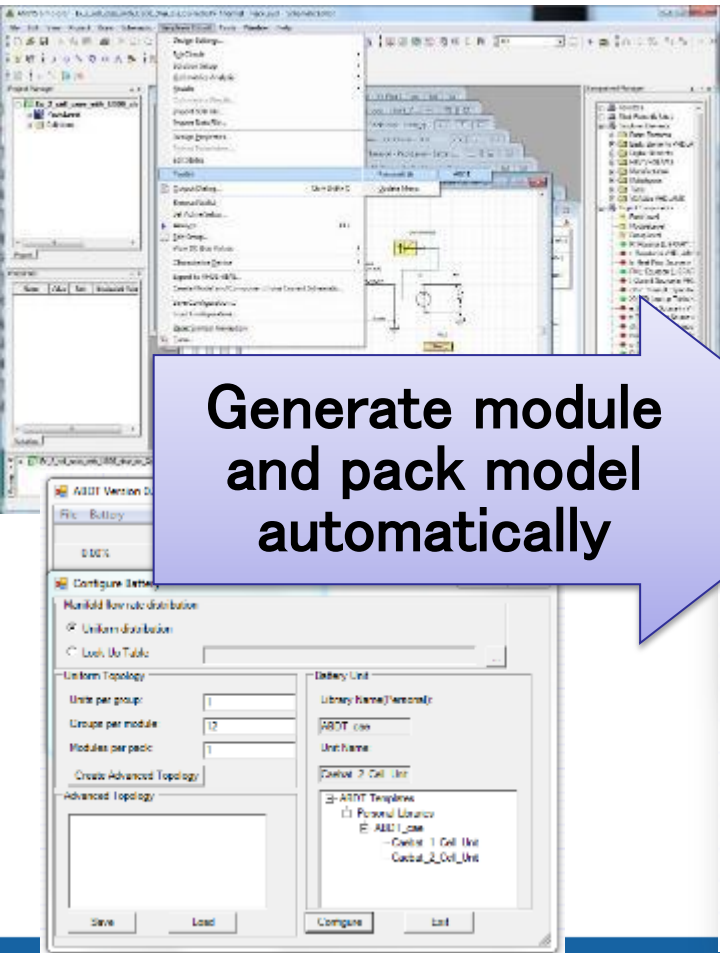
CAEBAT项目—成果

- ABDT是一个针对电池的垂直应用，可以让非专家用户在不同设计阶段、针对不同设计目标进行大量仿真分析
- 几何细节、成本、物理尺度



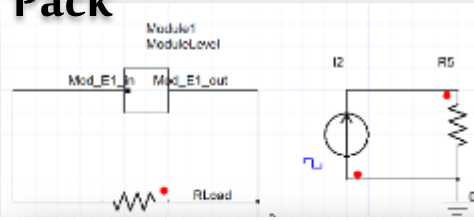
CAEBAT项目一成果

ABDT User Interface

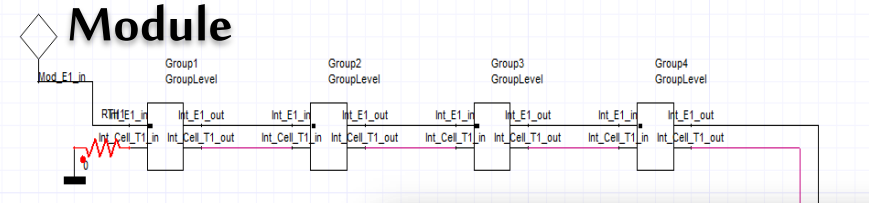


**Generate module
and pack model
automatically**

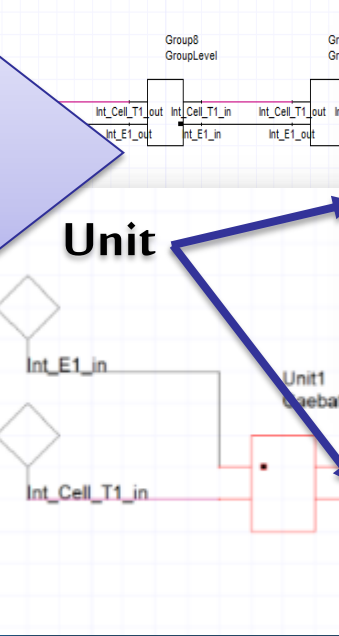
Pack



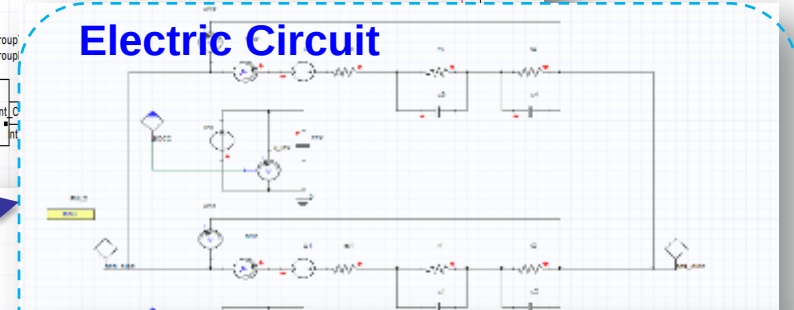
Module



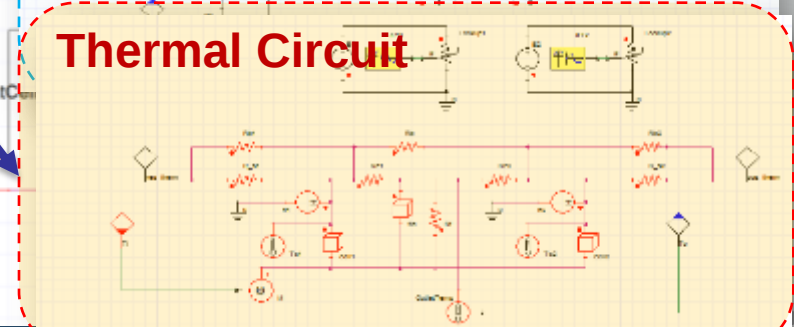
Unit



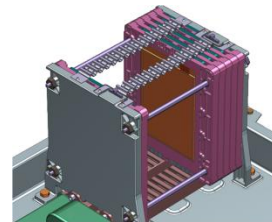
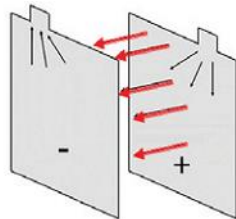
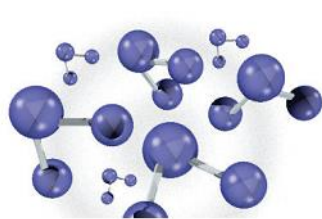
Electric Circuit



Thermal Circuit



完整的锂离子电池仿真方案

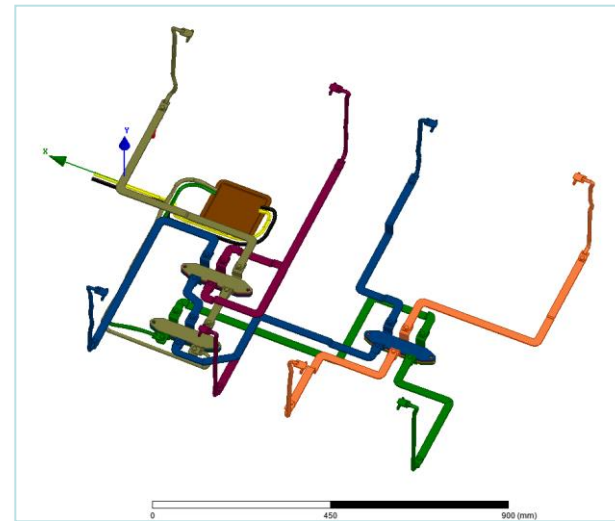
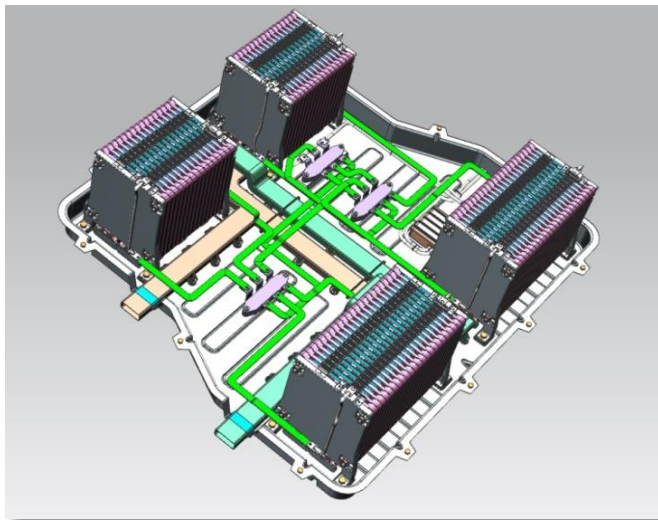
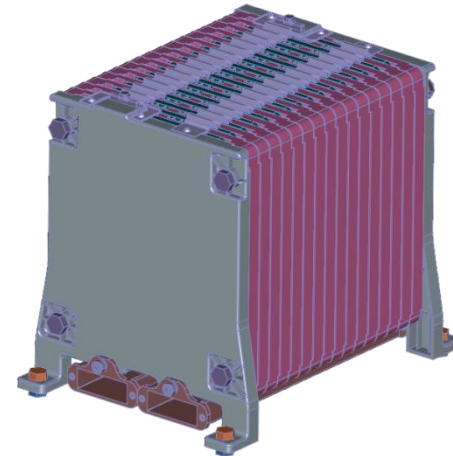
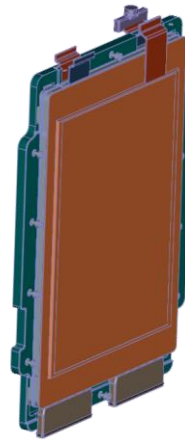
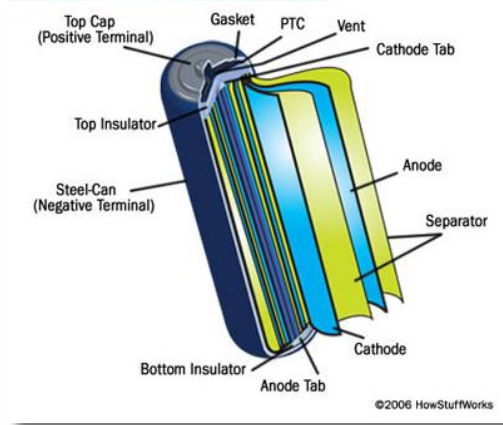


小尺度

大尺度

分子	电极	电池	模块/包	系统集成
材料	布局 过程 寿命 SEI	充电 放电 热 安全	热管理 持久性 NVH EMI/EMC	系统集成
	Electro-chemistry	ECM CFD FEA	ECM CFD ROM FEA	ECM ROM

完整的锂离子电池仿真方案

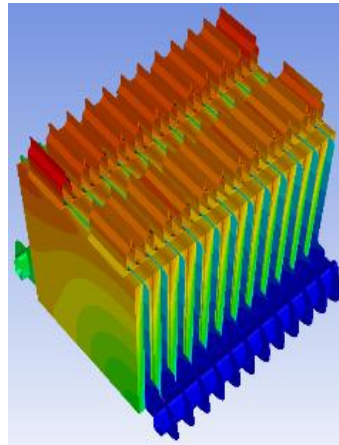


案例：电池模块整体三维CFD仿真

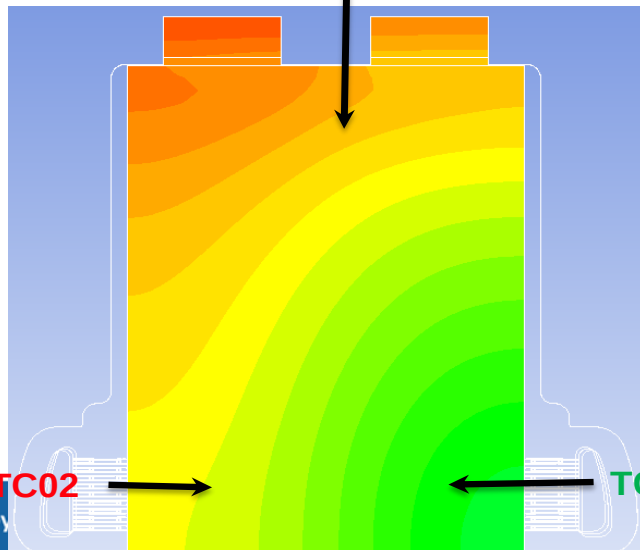
24 cell 原型



温度分布



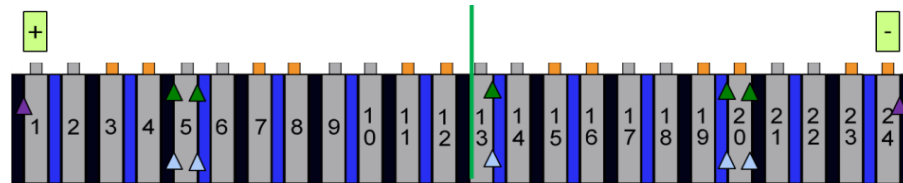
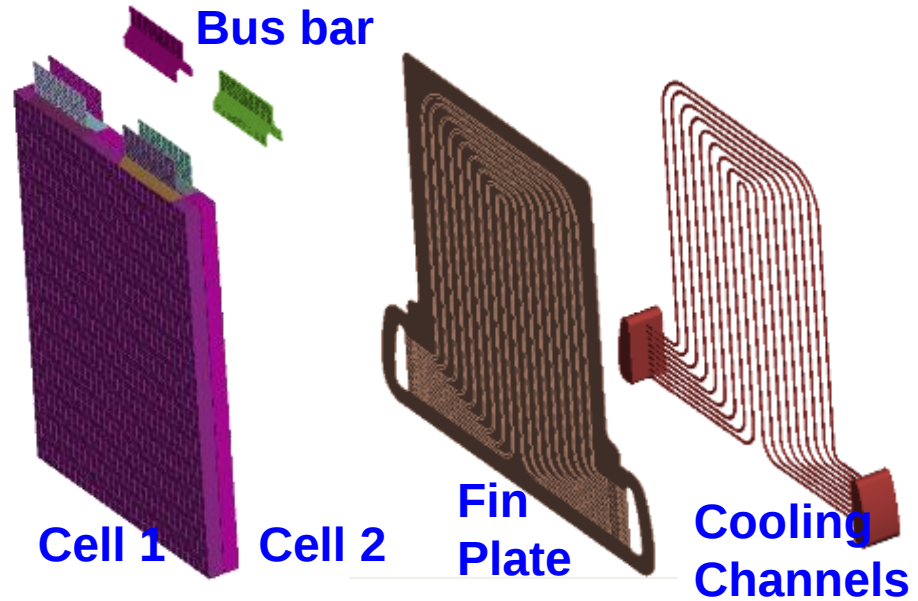
TC01



TC02

TC03

Bus bar



	TC #01	TC #13	TC #02	TC #15	TC #03	TC #14
Diff, °C	0.8	0.7	0.3	-0.6	-0.7	-0.7

电池模块包含24个电池芯，将整体三维CFD仿真数据同实验数据进行对比，工况为高频脉冲充放电

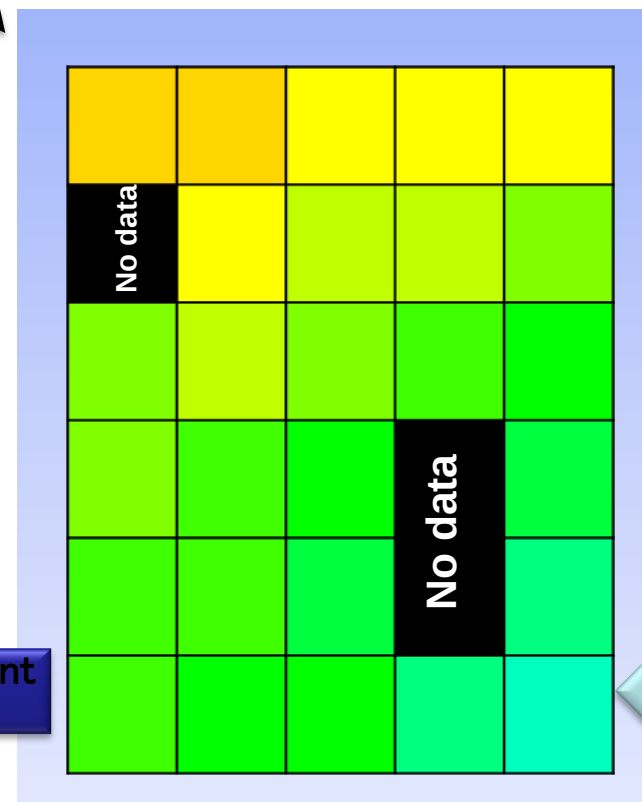
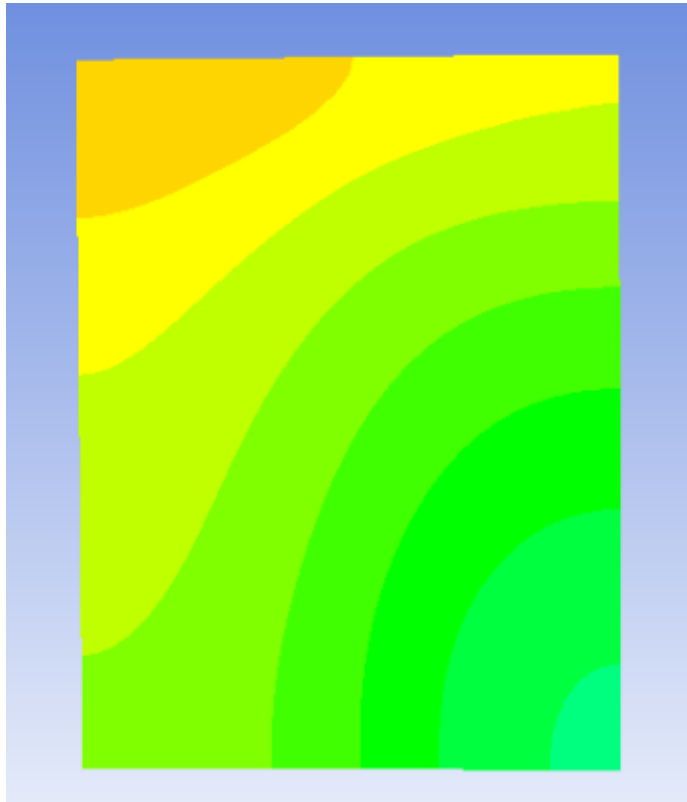
案例：电池模块整体三维CFD仿真

Top
View



整体三维CFD仿真

实验数据

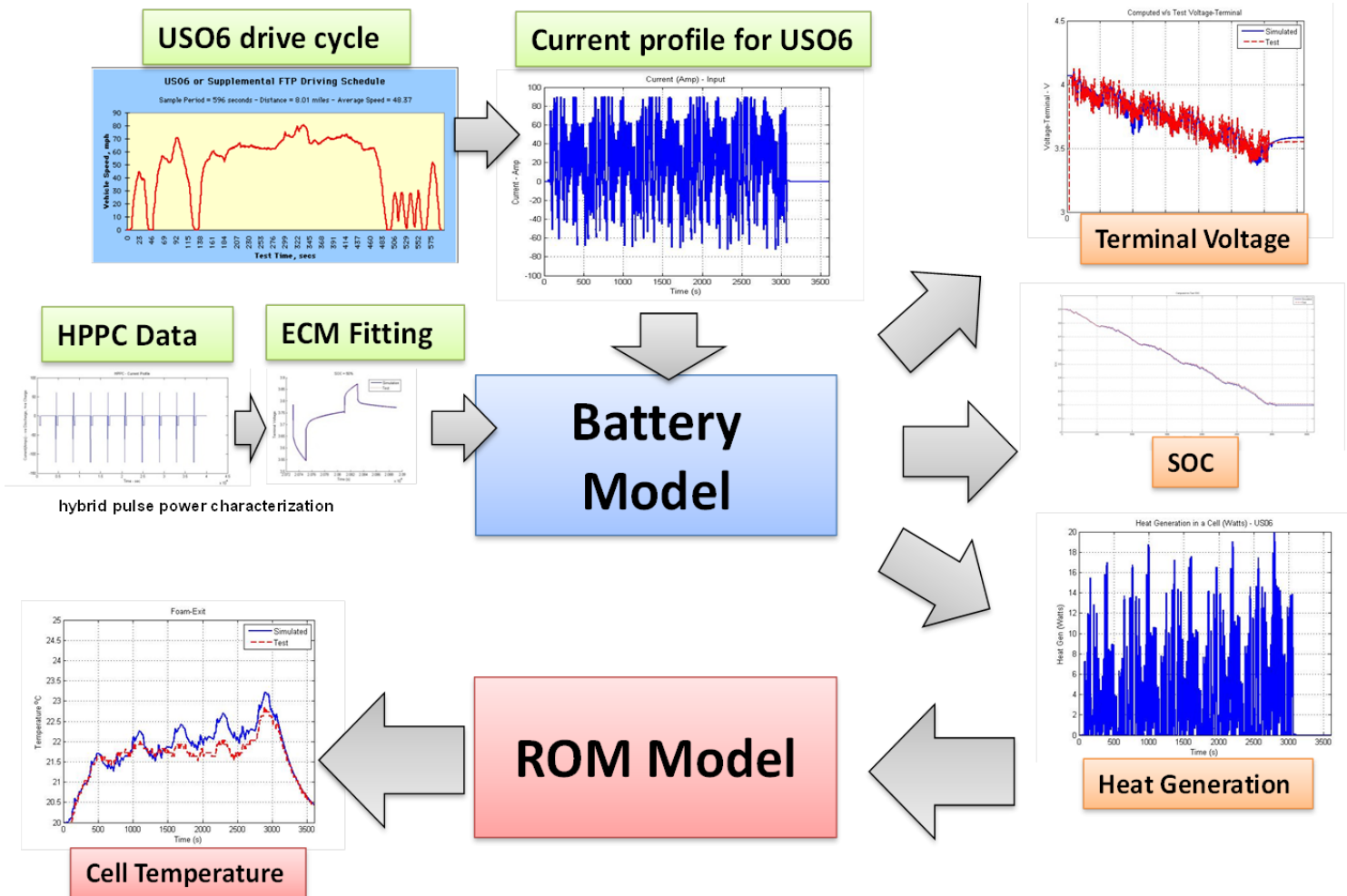


Coolant
out

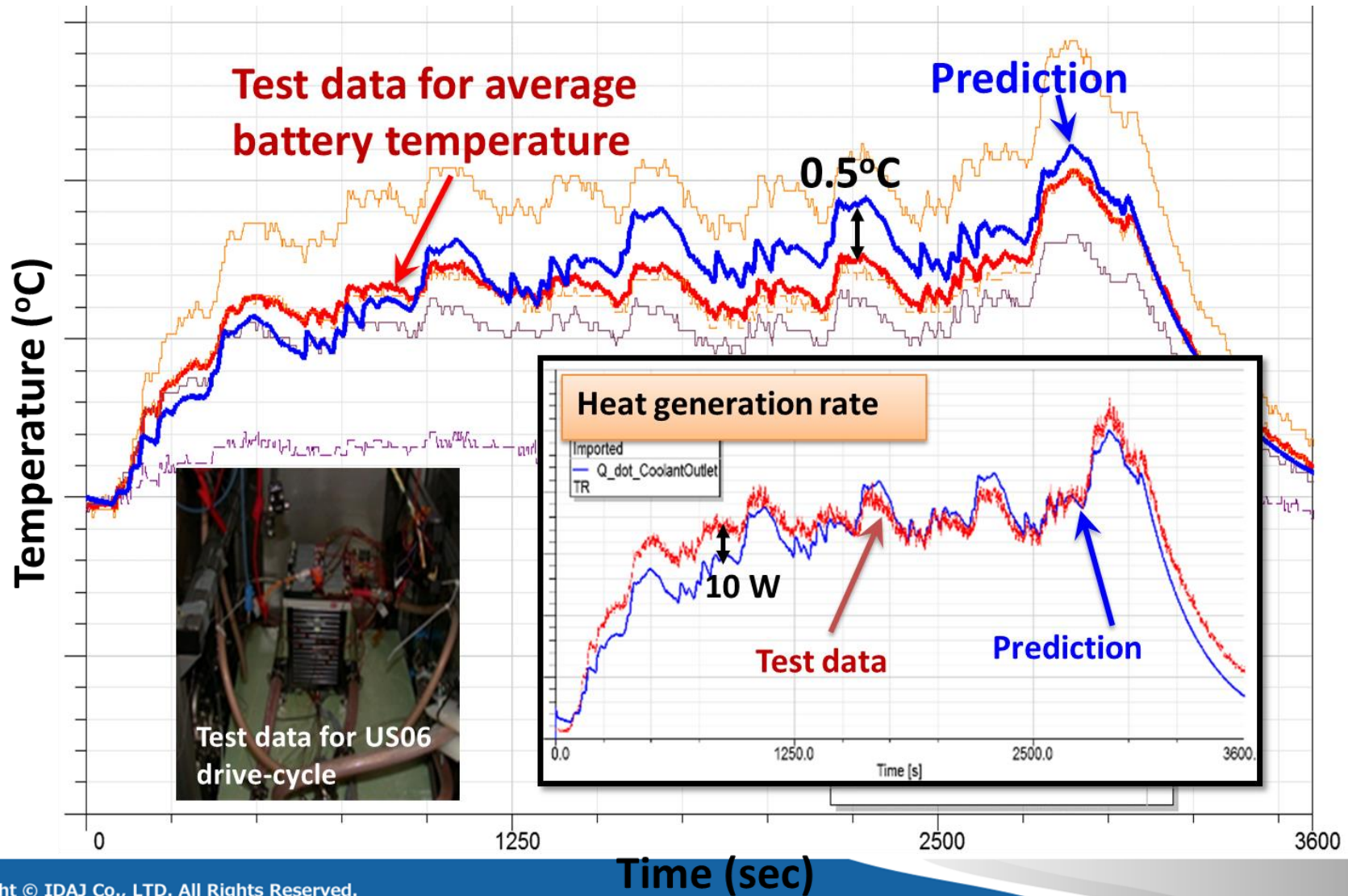
Coolant
in

仿真与实验最大误差在1度以内

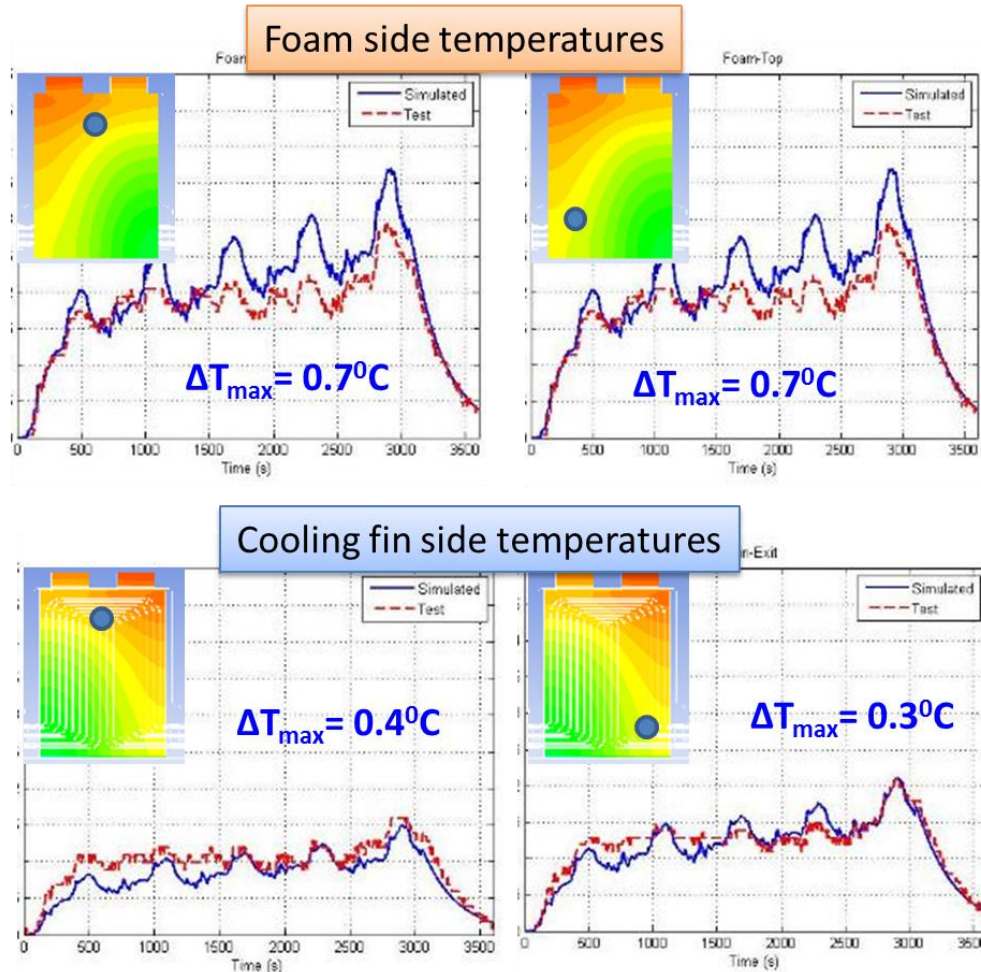
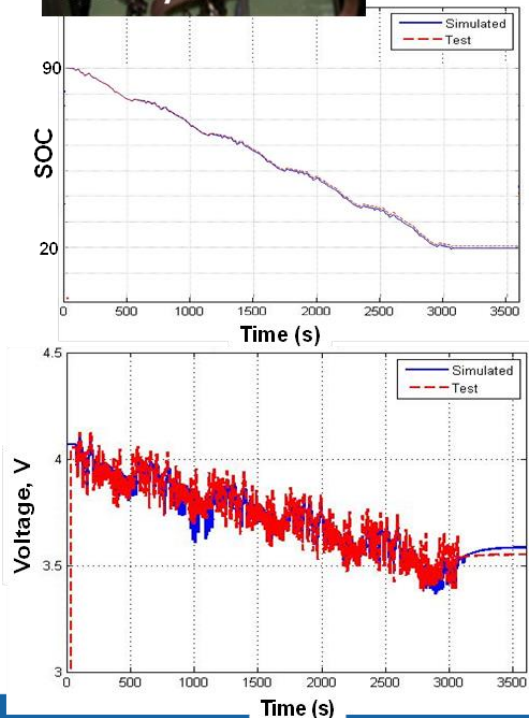
电池模块模拟方法



案例：电池模块系统仿真结果-US06工况

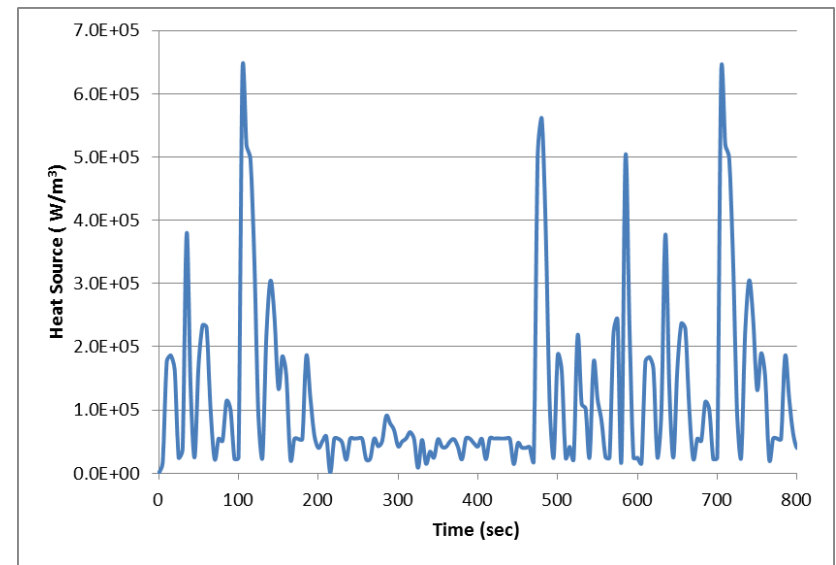
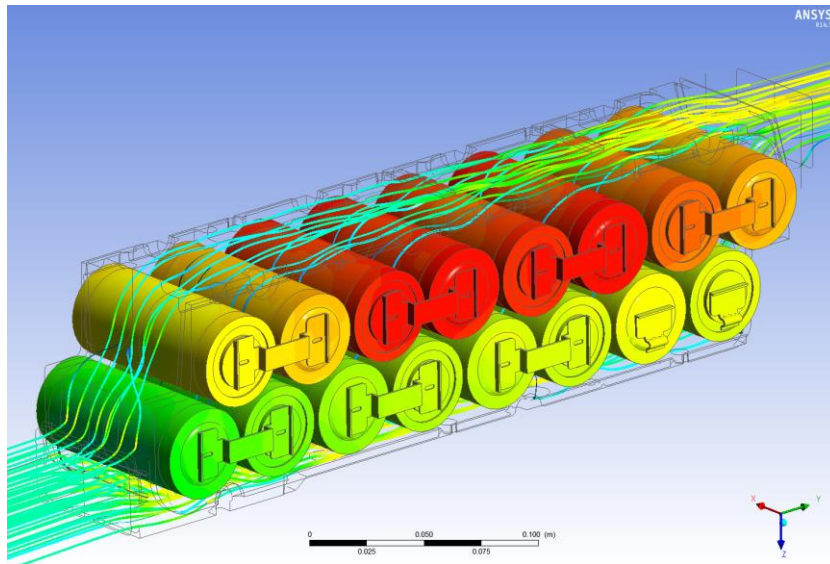


案例：电池模块系统仿真结果-US06工况



案例: ROM电池包瞬态热分析

- 采用SVD+LTI ROM模型对含16个单体电池的电池包进行瞬态热分析



Heat source used

X. Hu, S. Asgari, I. Yavuz, S. Stanton, C-C Hsu, Z. Shi, B. Wang, H-K Chu, "A Transient Reduced Order Model for Battery Thermal Management Based on Singular Value Decomposition," ECCE 2014.

案例: ROM电池包瞬态热分析

Step 1. CFD建模

Step 2. 阶跃响应分析

- FLUENT

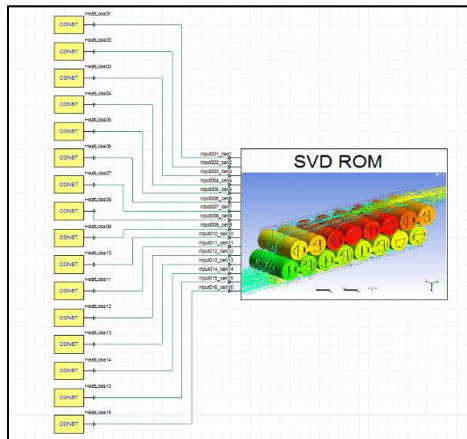
Step 3. 抽取SVD ROM模型

- Simplorer

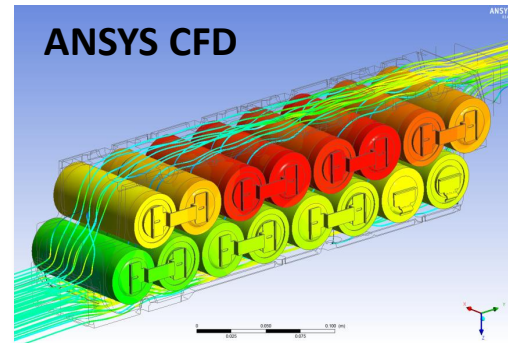
Step 4. 瞬态热分析

- Simplorer

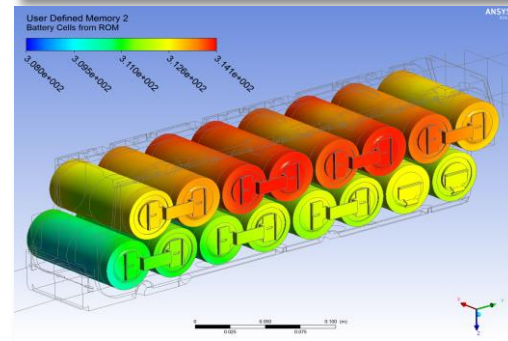
4



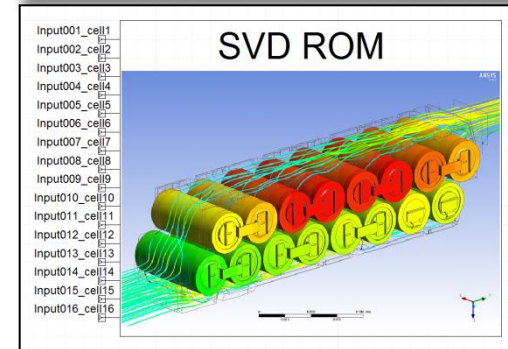
1



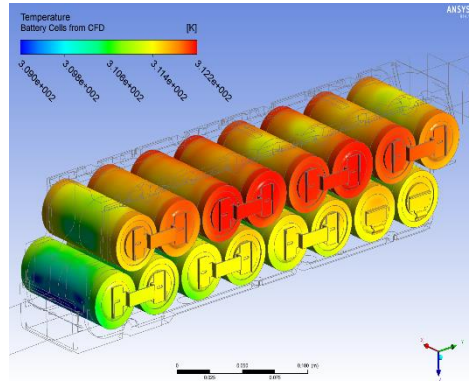
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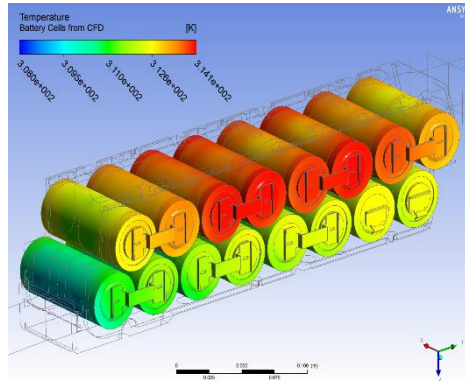
3



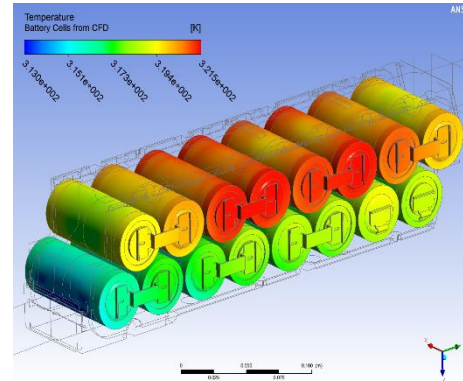
案例: ROM电池包瞬态热分析



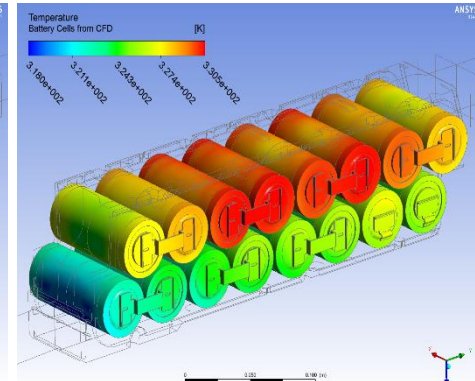
CFD (200 sec)



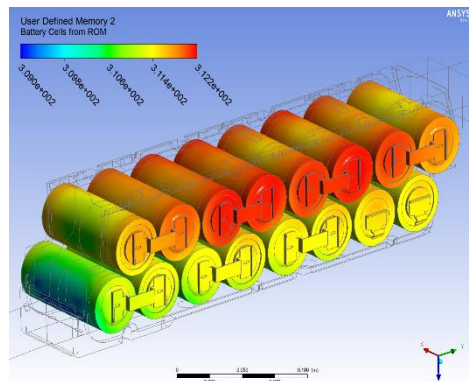
CFD (400 sec)



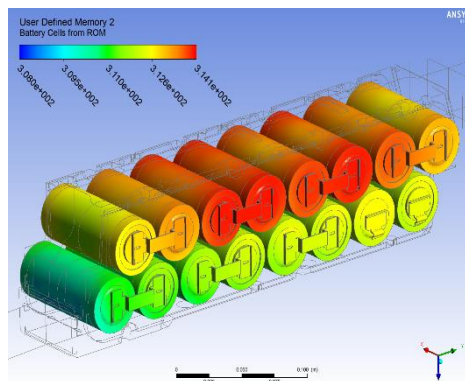
CFD (600 sec)



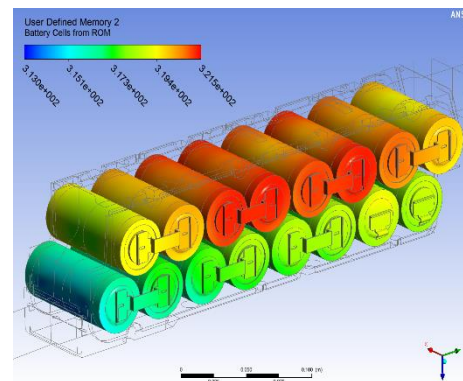
CFD (800 sec)



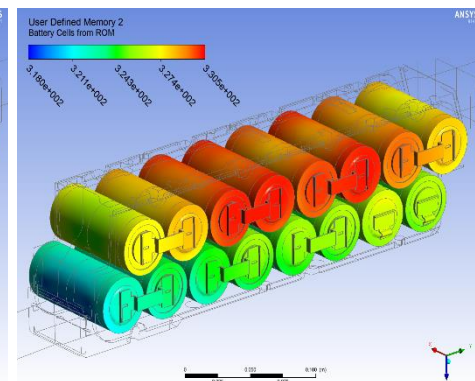
SVD+LTI ROM
(200 sec)



SVD+LTI ROM
(400 sec)

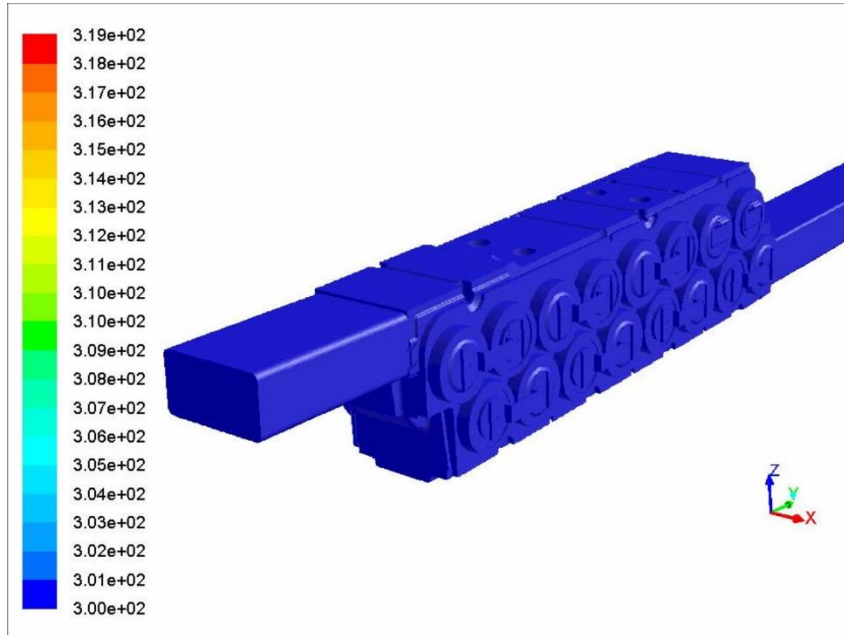


SVD+LTI ROM
(600 sec)

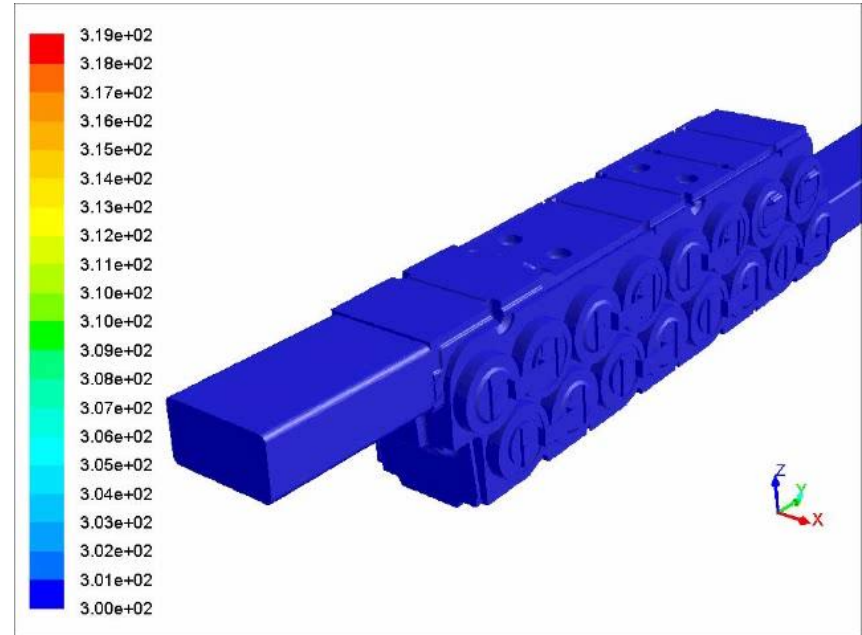


SVD+LTI ROM
(800 sec)

案例: ROM电池包瞬态热分析

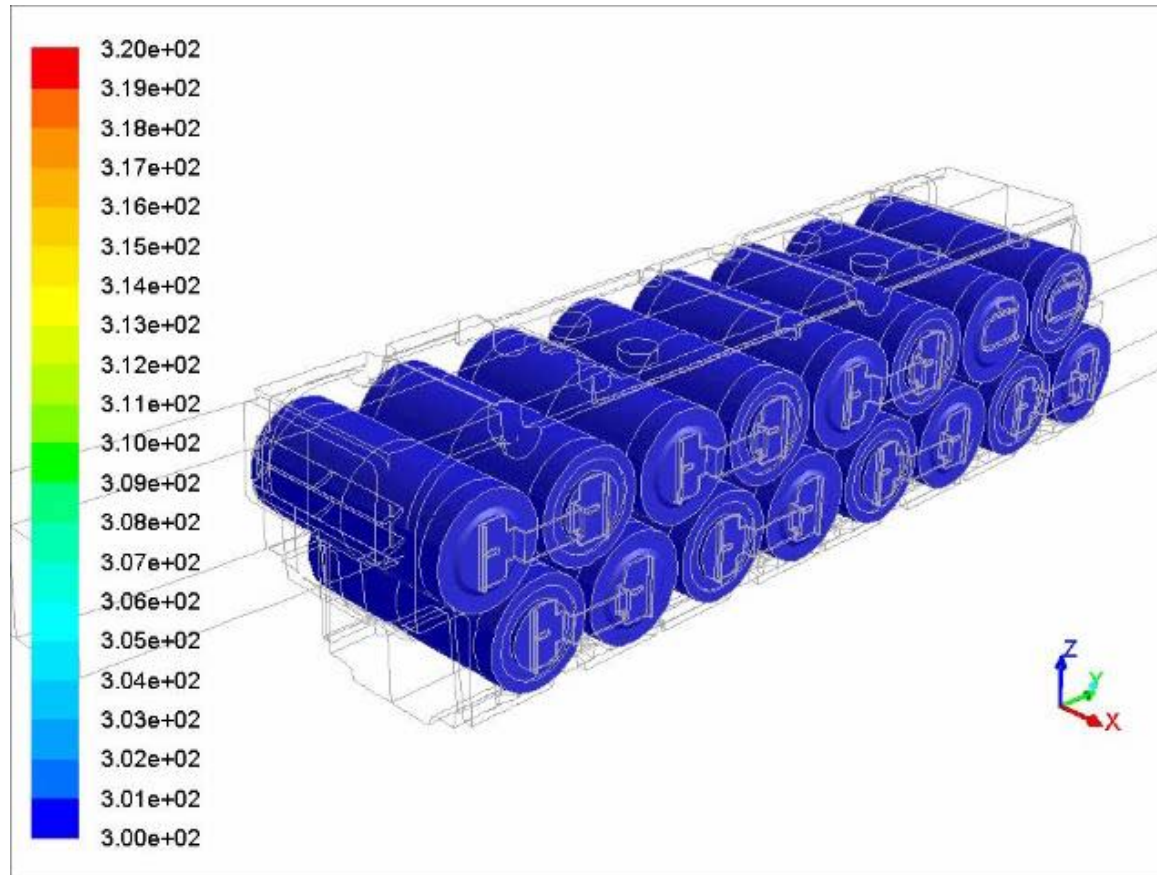


Temperature calculated from CFD.
7 hr simulation time with 6 CPUs.



Temperature calculated from SVD ROM.
0.5 hr simulation time with 1 CPU.

案例: ROM电池包瞬态热分析



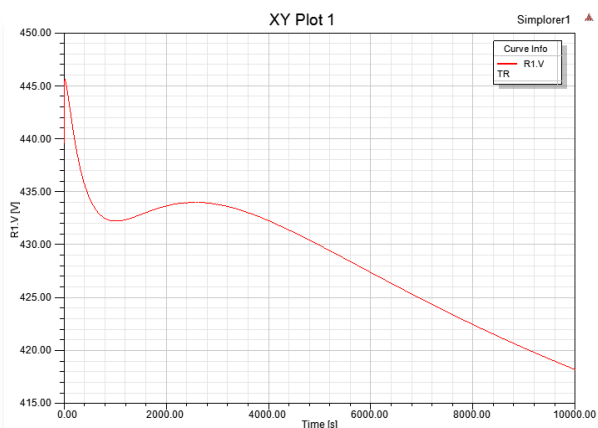
Temperature calculated from SVD ROM.
0.5 hr simulation time with 1 CPU.

案例: ROM电池包瞬态热分析

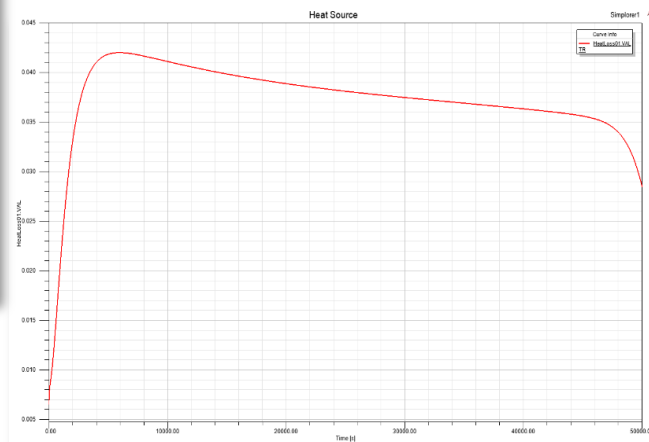
CFD mesh size	3,025,067
Number of steps in step response run	180
Size of matrix A	$3,025,067 \times 180$
Number of snap shots used for SVD calculation	180
SVD calculation time	5 minutes
SVD calculation memory usage	8.1 G
SVD ROM extraction time	5 minutes
CFD validation simulation time on single CPU	5 hours
SVD ROM simulation time on the same single CPU	a few seconds
Using SVD ROM results for an animation on one CPU	10 to 30 minutes

案例: ROM电池包热-电一体化分析

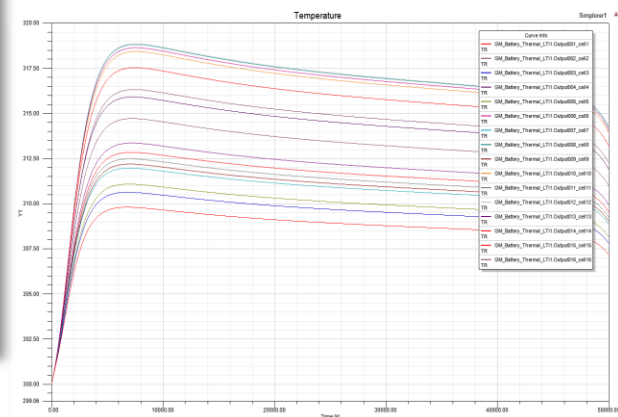
- ECM 求解单体电池的电热特性, 并传递给ROM模型
 - LTI ROM 求解平均温度, 并传递给ECM模型
 - SVD+LTI ROM 求解温度分布
- 在FLUENT中进行后处理



单体电池电压



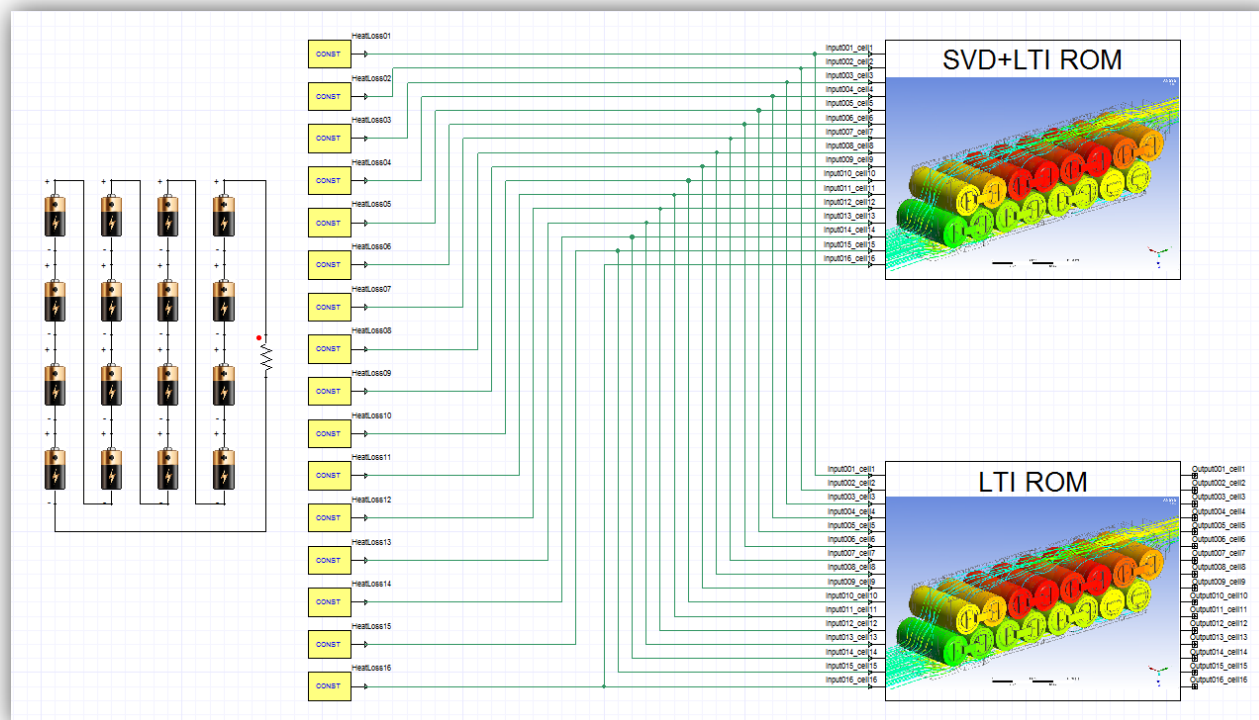
单体电池发热量



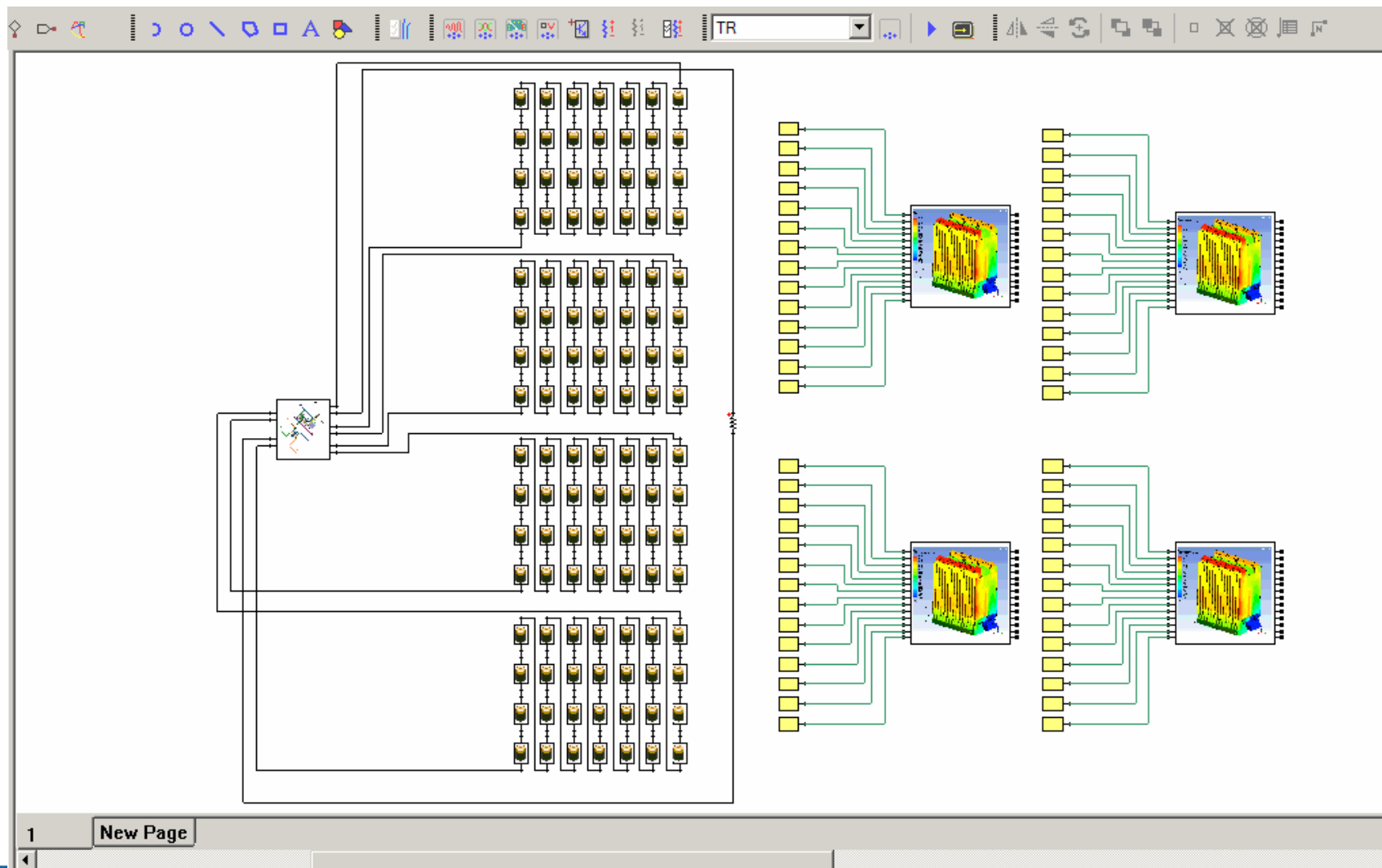
单体电池平均温度

案例: ROM电池包热-电一体化分析

- ECM 求解单体电池的电热特性, 并传递给ROM模型
- LTI ROM 求解平均温度, 并传递给ECM模型
- SVD+LTI ROM 求解温度分布
——在FLUENT中进行后处理



案例: ROM电池包热-电一体化分析



电池结构分析内容

1. External Short Circuit Protection
2. Overcharge Protection
3. Over Discharge Protection
4. Fire Resistance – Short/Long Duration
5. Thermal Shock
6. Over/Under Temperature Protection
7. Water Intrusion Test
8. Vibration/NVH
9. Crush/Impact Test
10. Drop Test
11. Durability analysis

Electrical and Electronics Integrity

Thermal and Fluid Flow Integrity

Structural Integrity

Major Global Standards: SAE , UN 38.3, JIS, FMVSS, ECS

电池结构分析模板

No.	Structural Integrity Standard Test Process	ANSYS Solutions
1	Effect of body weight on Support [SAE J2380]	Present Work
2	Pre-stressed natural frequency analysis [SAE J2380]	Present Work
3	Pre-stressed Random Vibration analysis in Vertical, longitudinal and lateral direction [SAE J2380]	Present Work
4	Random Vibration fatigue analysis	Work in Progress
5	Drop Test from 2 meter at an angle [SAE J2464]	Present Work
6	Thermal Stress analysis [SAE J2464]	Present Work
7	Impact/Crush analysis [SAE J2464]	Work in Progress
8	Shock Spectrum analysis in Vertical, longitudinal and lateral direction [SAE J2464]	Work in Progress
9	Nail Penetration analysis [SAE J2464]	Work in Progress

总结

- 电池是一个涉及多尺度-多物理场耦合的复杂产品
- ANSYS可以提供完整的电池仿真方案, 可以进行电极-电池-电池包-系统集成的全尺度仿真, 也可以进行电化学反应-热-流体-结构-电磁的多学科耦合仿真。
- ANSYS的精确分析果可以电池的结构设计(包括电极, 极耳, 集流体, 铺层等), 热安全性设计, 电池包设计, 系统集成设计以及相应的优化提供参考依据。

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