ELECTRIC, CONNECTED AND AUTONOMOUS VEHICLES SESSION
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MULTI-DOMAIN BATTERY SIMULATION FOR ELECTRIC VEHICLES

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The **IDEAL** World | From Chemistry to Systems

- **MATERIALS**
- **CELL**
- **PACK**
- **VEHICLE**
Strategy | Total Coverage from Chemistry to Systems

- **Molecular**: Molecular level material and chemical modeling
- **Cell**: Aging, Thermal, Electrical, El.-Chem.
- **Module & Pack**: Battery Management System
- **Vehicle**: 3D DESIGN | ENGINEERING | PHYSICS

- **1D**
- **3D**
Dassault Systèmes Solutions for Battery Simulation

Molecular

Cell

Module & Pack

Vehicle

Battery System Modelling

Battery Management System Design

1D & 3D Co-Sim

System Model Characterization

1D

3D

Battery Materials Design

Battery Cell Engineering

Battery Module & Pack Engineering

Full Vehicle Integration

Battery System Modelling

1D & 3D Co-Sim

Battery Management System Design

System Model Characterization

1D

3D

Battery Materials Design

Battery Cell Engineering

Battery Module & Pack Engineering

Full Vehicle Integration
Dassault Systèmes Solutions for Battery Simulation

- Molecular
- Cell
- Module & Pack
- Vehicle

Battery System Modelling

1D
- Battery Materials Design
- Battery Cell Engineering
- Battery Module & Pack Engineering

3D
- Full Vehicle Integration
- Battery Management System Design

Battery System Modelling
Solutions | Battery System Modeling

Molecular

1. Electrical Behavior Modeling

Cell

2. Thermal Behavior Modeling

Module & Pack

3. Aging Behavior modeling

Vehicle

4. System Analysis
Solutions | Battery System Simulation
Solutions | **Battery Cell Engineering**

- **Molecular**
  - Physical Design Definition

- **Cell**
  - Electro-Chemical Performance
  - Thermo-Electrical Losses
  - Thermal Management

- **Module & Pack**
  - Strength | Stiffness | Durability

- **Vehicle**
  - Degradation & Ageing
  - Safety
  - Reduced Order Modelling
Cell Engineering | Safety (Multiphysics)

**Mechanical Abuse**
- Abusive loads, large deformations: axial, bend, crush
- Plasticity and fracture of casing
- Crash scenario loads, nail penetration
- Tightness assessment, contact electrical resistance

**Internal Short Circuit (ISC) Onset**
- ISC onset: separator tearing
- ISC onset: electrolyte leaking
- Mechanically-induced thermal runaway onset

**Thermal Runaway (3D – Cell Scale)**
- Temperature-induced side reactions initiation
- SEI decomposition
- Exothermic anode-electrolyte reaction, electrolyte decomposition, separator decomposition
- Massive short circuit, rapid temperature increase

**Thermo-Electrical Abuse**
- External short circuit overheating
- Li-ion diffusion bounded peak current estimates
- Overcharge: cathode collapse (de-intercalation), oxygen release, electrolyte decomposition, pressure build-up
- Overdischarge: pole reversal overheat
- Dendrite growth driven by copper collector dissolution

**Results Analytics**
- DOE with stochastic input, manufacturing defects
- Likelihood of unsafe behavior

**Managed Engineering Data**

**Inputs**
- CAD models of the cell
- Characterized material properties
- Experimental cell test data (thermal, mechanical)

Solutions | **Battery Module & Pack Engineering**

- **1. Electro-Mechanical Physical Design**
- **2. Thermo-Electrical Management**
- **3. Strength | Stiffness | Durability**
- **4. Safety**
- **5. Reduced Order Modelling**
**Battery Pack Engineering - Thermal**

**Heat losses (3D)**
- Uses electrical behavior outputs from Battery System Modelling
- Computes energy losses in each cell via 1D or 3D modeling techniques (see battery cell engineering)
- Assesses other losses in bus bars, ECMs, etc.
- Applies computed heat fluxes in 3D models

**3D Thermal Management (Steady-state)**
- Uses RANS VOF technology, interoperable with CAD, multiple turbulence models
- Leverages automated hex dominated meshes
- Models interactions between fluid flow and thermal field in solids using a monolithic solver
- Models liquid or air-cooled, cold plate, channels..

**Managed Engineering Data**

**System identification**
- Choose inputs and outputs, run virtual tests
- Generate LTI reduced order models via LTI and SVD technology; to be used in vehicle level analysis.

**Solar Soak**

**3D Thermal Management (via Transient)**
- Uses LBM technology for fluid flow and FE for thermal solution in the solids via co-simulation for short transient periods
- Extracts HTCs and fluid ref temperatures for subsequent use in standalone solid thermal solve only
- Accounts for environmental conditions

**Inputs**
- CAD models of the module/pack
- Characterized material properties
- Experimental cell test data (thermal, mechanical)

**Solutions**

**1**

**Heat losses (3D)**

**2**

**3D Thermal Management (Steady-state)**

**3**

**Managed Engineering Data**

**4**

**System identification**

**1**

**Heat losses (3D)**

**2**

**3D Thermal Management (Steady-state)**

**3**

**Managed Engineering Data**

**4**

**System identification**

**1**

**Heat losses (3D)**

**2**

**3D Thermal Management (Steady-state)**

**3**

**Managed Engineering Data**

**4**

**System identification**
Solutions | Full Vehicle Integration

1. Vehicle Dynamics
2. Crashworthiness
3. Thermal Management
Solutions | Full Vehicle Integration - Thermal