SIMULIA

3DEXPERIENCE

BUILDING THE FOUNDATION FOR HIGH-PERFORMING BATTERY SYSTEMS

Collaboration and simulation bring faster, safer and more powerful battery cell engineering

DASSAULT SYSTEMES

TO BUILD HIGH-PERFORMING BATTERIES, YOU NEED HIGH-PERFORMING CELLS

A battery is the beating heart of every EV—and battery cells are its lifeblood. Every aspect of the vehicle's performance, from safety to driving range, acceleration and charging time, depends on its battery cells. Longevity is also essential. Since an EV's battery accounts for about one-third of its price tag, the vehicle's value and the cost of ownership are directly affected by how long that power pack will continue to perform well, without needing to be replaced. If the cells aren't up to the job, then the battery won't be either.

Creating battery cells is a complex multi-physics engineering process. Traditionally, the design process involves transferring and translating data between different computer systems, with months of physical testing adding time and cost. However, as the requirement for high-performance EV batteries evolves rapidly, these repetitive, time-consuming methods are too cumbersome to keep up. Fast, efficient innovation is the only way to seize the opportunities of this rapidly growing market.

By harmonizing all the relevant data in one place, organizations can achieve automated, simulation-ready modeling across the battery cell design cycle. This whitepaper will explain how Dassault Systèmes Battery Cell Engineering solution—powered by the **3D**EXPERIENCE® platform—empowers cell designers to characterize the behavior of materials from molecular to macro-scale, yielding detailed and accurate predictions around safety, performance and aging.

THE CHALLENGE OF BATTERY CELL ENGINEERING FOR EVS

To deliver powerful, safer and long-range EVs quickly to market, carmakers need bigger, better battery packs, fast. To build those battery packs, they need better, more powerful battery cells.

Each battery cell must be engineered to safely deliver critical aspects of the EV's performance, including its driving range, charge/discharge time, acceleration, efficiency, cost and longevity. If the battery cell isn't engineered to meet all these needs, the vehicle will be a non-starter. To deliver on all these goals, cell engineers need a detailed understanding, not only of how the cell behaves in the laboratory, but also how different conditions will affect it during vehicle operation.

Continuous innovation is crucial to grasp the opportunities offered by this exciting market—and that brings some challenges. Cell designers must explore new chemistries and form factors without existing information to draw from. That brings the need for extensive testing to discover everything about the cell's behavior—from how time and temperature will affect its performance and lifespan, to what will happen if it is damaged. Design changes will likely be necessary to optimize the results, bringing yet more testing in their wake. Traditional approaches use physical prototypes throughout the testing phase—which typically takes 8-10 months. This is too slow and costly to meet the aggressive market demands for reliable electric vehicles within budget.

Cell designers also work in an increasingly complex industry. Established cell manufacturers face competition from startups, who may be breaking new ground with solid-state or sodium ion cells. Joint ventures with the auto industry are also becoming more common as carmakers look to develop their own battery technology. Developing a cell, manufacturing it at scale and putting it into vehicles can involve several different organizations, each needing its own level of performance detail about how the cells behave.

Simulation technology should help to improve the efficiency of all these processes. But battery cell engineering is a multi-physics, multi-discipline process. A lot of the available simulation solutions simply can't handle the levels of detail required, and that limits the tests the engineers can run. In addition, when teams of modeling and simulation experts spend valuable time piecing together information from separate systems, errors and omissions can be introduced. Any adjustments to the design can also mean that big chunks of modeling work must be done again.

To overcome all these challenges and meet every stakeholder's requirements, organizations need a better way to manage multi-physics data so they can model and simulate battery cell behavior.

BENEFITS OF A COLLABORATIVE SIMULATION APPROACH

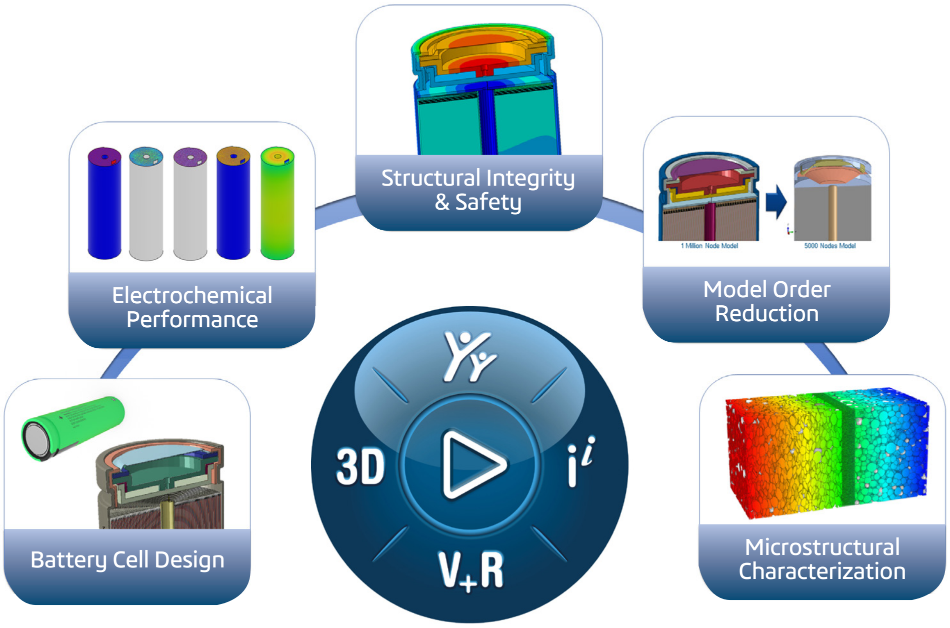
When all battery cell data can be accessed and managed in one place, engineers can innovate more quickly and cost-effectively. The **3D**EXPERIENCE® platform combines this approach with advanced capabilities in geometry, mesh associativity and engineering templates to create a seamless and efficient approach to battery cell design. It allows everyone involved to work with the same data model, in the appropriate context for their role, eliminating silos and the delays.

3D modeling and simulation, built on this harmonized data, can incorporate advanced multi-physics methodology to characterize the behavior of materials, from molecular to macro-scale. Cell engineers, for instance, can use simulation to evaluate the electrochemical, thermal and mechanical behavior of the cell. In addition, model order reduction allows for simulations at the Module & Pack level. This is particularly useful for individuals seeking a more comprehensive understanding, such as electric vehicle manufacturers who require knowledge about energy density, thermal management, cooling strategy, and structural integrity. This information helps them identify the most cost-effective cell for various vehicle models.

By enabling automated, simulation-ready modeling, this collaborative approach dramatically reduces the need to build and test physical prototypes. It makes it possible to combine modeling and simulation—an approach known as **MODSIM**—and automate repetitive processes so that engineers can focus on optimizing their designs. In doing so, it also allows the organization to assess performance variations beyond the scope of traditional physical tests. This gives engineers the freedom to explore new chemistries, particle and electrode architectures, and to simulate a wider range of usage scenarios to ensure optimal safety, performance and longevity of their cell designs.

3DEXPERIENCE POWERS BATTERY CELL ENGINEERING

Battery Cell Engineering on the **3D**EXPERIENCE platform combines SIMULIA multi-physics simulation with key capabilities from BIOVIA and CATIA. Together, these resources support the design, exploration and validation of battery cells using 3D virtual models.



The **3D**EXPERIENCE platform unifies data to provide multi-scale and multi-physics workflows for battery cell engineering.

Everything, from microstructure to detailed design and analysis, is done in the same virtual space, while model order reduction makes sure the relevant information can be passed on for higher-level engineering analysis. SIMULIA's standardized simulation templates help organizations to left-shift the process so that cell designs are tweaked, simulated and perfected early on, ensuring a more consistent, error-free and accelerated design cycle.

The highly detailed 3D Newman model on the **3D**EXPERIENCE platform is crucial for performing realistic simulations of the cell's thermal, electrochemical & structural behavior. These simulations provide high-quality predictions about how the cell will perform and age under different loading conditions.

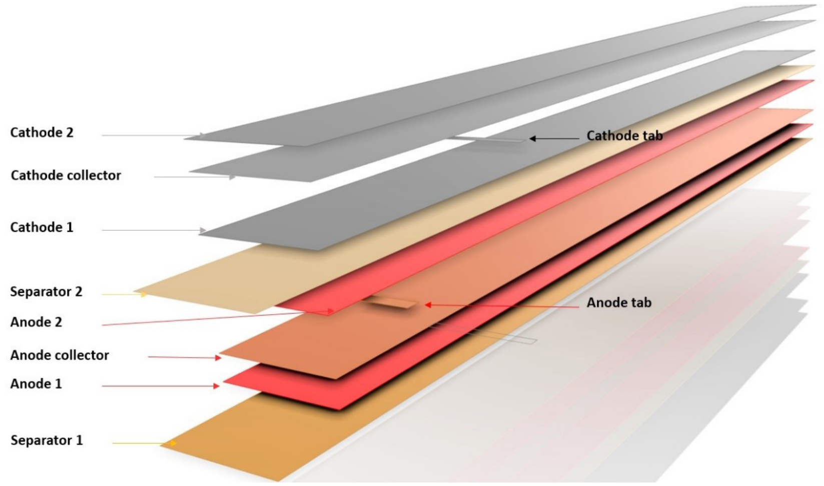
SIMULIA's microstructural simulation capabilities enable deep analysis of material characteristics within the electrodes and the effects of manufacturing processes, such as calendaring. Additionally, structural simulation is used to test the cell's behavior under conditions such as thermal stresses, mechanical indentation, or nail penetration, allowing engineers to design for optimal safety throughout the cell's lifespan. Furthermore, these cells can be homogenized through model order reduction methods to perform module and pack-level simulations.

From sketch to simulation

To run any type of simulation you need a detailed, parametric model which is based on a mesh and includes all the cell's functional components. Creating these manually is a challenging and time-consuming task, especially for complex cylindrical or "jellyroll" battery cell formats.

3DEXPERIENCE Battery Cell Engineering tools make it possible to simplify that process by using the CATIA Layered Product Designer application to develop detailed, realistic 3D designs and mesh them to create simulation-ready models.

This process begins with a sketch of the unrolled stack layers, including their respective dimensions and offsets. The lengths, widths and offsets of the layers can be used to define parameterization at this stage.

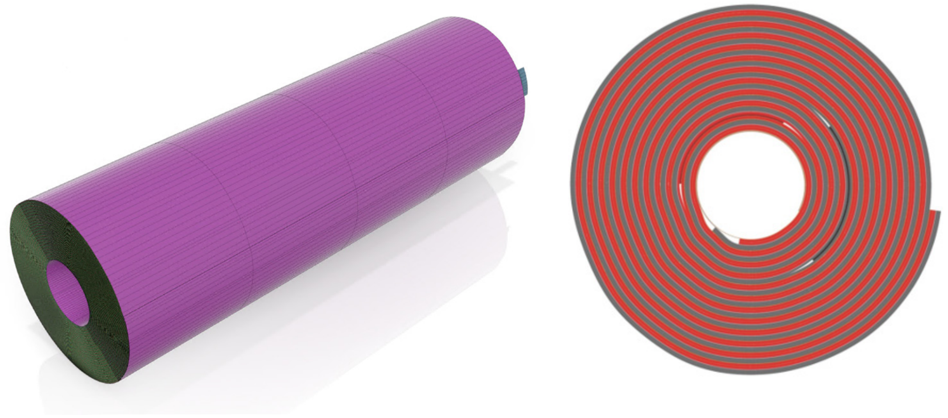


A flat, unwound model of stack layers.

Once the stacks are created, they are rolled into a cylindrical shape. Next, this "rolled shape" 3D geometry is abstracted, including details such as the number of divisions through the thickness, the mesh step size and the sag. These properties are essential to generate a clean and usable mesh for flat, rectangular and circular shapes. The mesh is automatically created on top of this abstraction using CAD data.

The result is an extremely fine mesh that creates a detailed, simulation-ready 3D model. After simulation, every aspect of the cell, such as temperature distribution or material properties, can be visualized in 3D.

Any design changes are automatically reflected in the mesh because all the CAD and CAE data is unified. Now the model is ready for simulation.

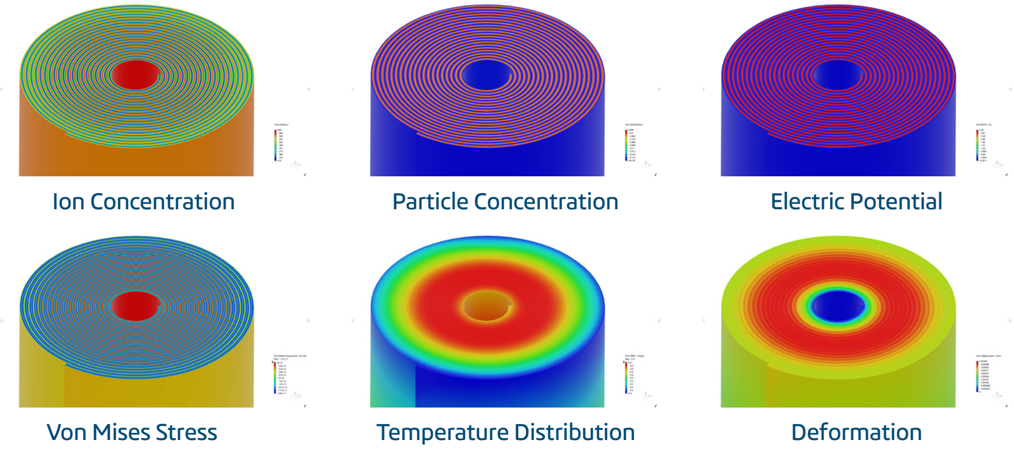


A rolled jellyroll with realistic offsets and transitions.

Ensuring efficient performance

A battery cell's electrochemical performance determines how effectively it charges, stores and releases energy, and how efficiently and reliably it will perform in different circumstances. Traditionally, it takes many physical tests to understand these complex, multi-physics interactions.

The Battery Cell Engineering solution includes a 3D Newman porous electrode theory (PET) model, which simulates the performance of the cell in real-world scenarios. This model is used by engineers to study the charging and discharging processes of lithium-ion battery cells. When the battery is being charged, lithium ions are extracted from the positive electrode (cathode), leading to a reduction in the volume of the active particles. The ions then move through the electrolyte and migrate to the negative electrode (anode), where they are incorporated into the active particles, causing an increase in volume. This movement of ions generates heat during the flow of current in the solid and liquid phases, as well as in the solid-liquid interface, and in the electrolyte. During discharging, this process is reversed. Engineers can analyze factors such as charge/discharge behavior at different charge rates, under different mechanical and thermal conditions. They can also assess and predict behaviors such as thickness deformation and stress caused by swelling.

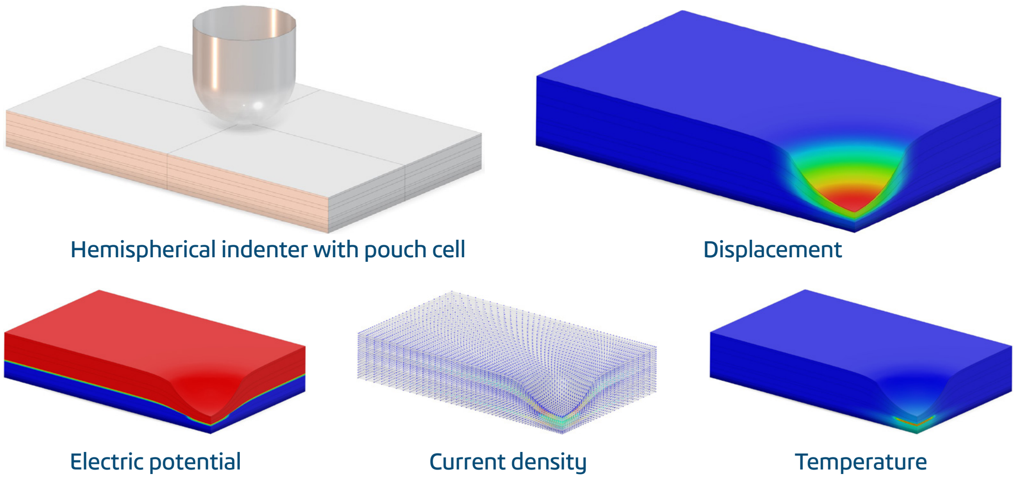


In this example, thermal electrochemical mechanical simulation is used to get detailed insights about temperature, electric potential, ion concentration, stress and deformation.

Safe and durable cells

Safety is still top of mind for anybody shopping for an EV. Every driver needs to know that if something happens—whether it's a crash impact, internal short circuit or a thermal runaway event causing the battery cell to overheat—they will have time to get themselves and their passengers to safety. It's up to the cell engineers, and the battery pack and vehicle designers who use those cells, to prove that their products are safe.

Rigorous, virtual testing with the Battery Cell Engineering tools allows engineers to analyze countless real-world scenarios that may impact the safety of the cells they develop, with high-accuracy. They can then optimize their designs in the virtual world before validating them with physical tests. Cell designers get detailed insights on these vital safety properties by performing highly complex multi-physics and nonlinear simulations to provide vehicle and battery pack makers with the higher-level information they need to put the safest cells at the heart of their products.



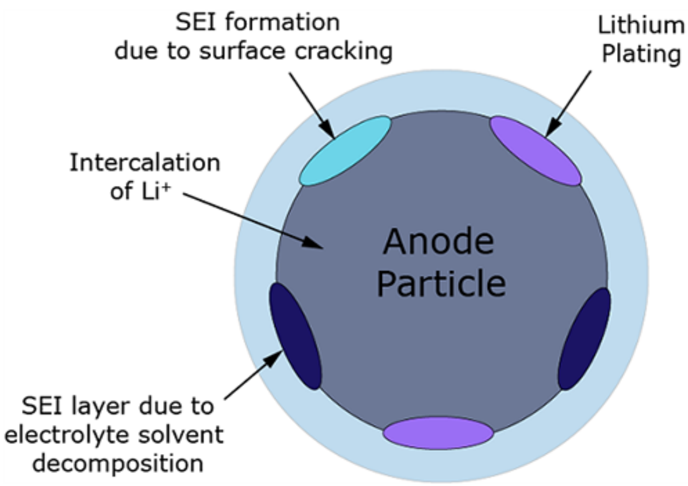
Rigorous simulated testing of the battery cells provides detailed analysis of how they will behave in real-world scenarios.

Longer-lasting batteries

A typical internal combustion engine vehicle lasts for many years without having to replace major parts, and users expect the same longevity from their EV. Since an EV's battery accounts for about a third of its price, it is integral to the vehicle's value. Buyers are especially concerned that it should serve them—and support the car's resale value—for many years.

Batteries age over time (calendric aging) and through repeated use (cyclic aging). Calendric aging occurs, for example, when a battery is stored out of use. Here, factors like the cell's state of charge and the storage temperature will influence the way its capacity fades. Meanwhile, a battery that is used regularly will undergo cyclic aging as it loses capacity through continuous charging and discharging cycles.

The Battery Cell Engineering solutions on the **3D**EXPERIENCE platform provide comprehensive workflows to simulate these aging processes. This makes it possible to model the following primary battery aging mechanisms:



Aging mechanisms in lithium-ion battery.

- Formation and growth of the solid electrolyte interface (SEI) due to electrolyte decomposition and deposition on the electrode surface.
- SEI growth in cracks at the particle surface.
- Decrease in porosity and active surface area due to SEI growth.
- Metallic lithium plating on the particle surface.
- Dissolution of the cathode.

The first four of the above mechanisms happen at the anode, while the last degradation mechanism happens at the cathode

POWERING THE FUTURE OF EVs

Every aspect of an EV's performance—from safety to performance, longevity and cost—depends heavily on its battery cell technology. In this complex and rapidly accelerating industry, multi-scale and multi-physics simulation is the only way to deliver safe, innovative and affordable cells. Dassault Systèmes Battery Cell Engineering solutions bring robust, automated workflows that help cell designers—from traditional players to startups—to become a driving force for the EV revolution.

HIGH-PERFORMANCE BATTERY CELLS DRIVE EV SUCCESS

Innovate faster

High-fidelity multi-physics analysis helps engineers to design battery cells faster and smarter.

Collaborate better

Enhance battery cell engineering teamwork through the **3D**EXPERIENCE platform, enabling real-time data access, integrated tools, and improved communication for more efficient design and safety assessments.

Design safer

Dassault Systèmes toolset makes it possible to predict the behavior of battery cell materials in mechanical and thermal abusive events, and design to avoid catastrophic results.

Ensure longevity

Detailed simulation of different calendric and cyclic aging processes allows engineers to improve cell longevity.

Optimize performance

PET Newman modeling empowers designers to assess and predict the cell's behavior in real-world conditions.

Drive affordability

Simulation dramatically reduces the need for physical prototypes and testing, lowering the cost of cell innovation and helping to make EV batteries more affordable.

We hope this whitepaper provided valuable insights on high-performing battery systems. Contact our experts now to learn more and thrive in your EV revolution journey.

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