DRIVING THE DIGITAL FUTURE OF ELECTRIC, CONNECTED AND AUTONOMOUS VEHICLES

**COVER
STORY**
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On the Cover: Saeid Emami, technical specialist, Romeo Power
Photo by Narrative Studios

3DS SIMULIA

THE FUTURE OF THE CAR

Recently, I was invited to the Financial Times' "Future of the Car Summit" in London, where I presented my perspective on the future of mobility. I talked about how rapid changes—already in progress—will dramatically impact the existing car industry, bringing both risks and opportunities.

The future of the car is the future of mobility. We can enjoy traveling on trains in big cities or flying to our favorite destinations, but the last mile is always the challenge. Cars, assuming they become autonomous and clean, could be one of the best future transportation systems.

But of course "cars" could be anything that takes you from A to B in the future. How do we design these vehicles of tomorrow?

As innovation takes place in transportation and mobility, traditional industry silos are disappearing. There is an immense wave of creativity happening today, and you will get a glimpse of it in this edition of SIMULIA Community News magazine. Dassault Systèmes has been striving for many years to provide the right platform to our customers, enabling them to break down these silos and deliver experiences that can transform their industries. As David Holman, VP of SIMULIA R&D, notes in the Future Outlook article (page 4), companies no longer need to organize themselves in a traditional fashion to innovate; instead, they are developing all kinds of innovative vehicles or even drones, flying cars and crazy transportation pods.

The acceleration of research and the rapid pace of the development of new technology make the future look closer to tomorrow than two to five years or even ten years out. According to recent articles, solid state batteries, promising range and charging times similar to those of gasoline engines, may not be available until 2022—but what is 5 years compared to 100 years of status quo? Meanwhile, tremendous research and work is being done on the more established lithium-ion technology to keep improving its safety and performance. Our cover story on Romeo Power (page 7) demonstrates how simulation technologies are helping this leap forward. Other research is focusing on the unique noise and vibration challenges of electric machines: just take a look (page 20) at the sophisticated NVH analyses that RWTH Aachen University is doing with SIMULIA solutions.

The speed of car development remains a major constraint on innovation, of course, taking five to seven years to engineer from scratch because cars require an extreme level of sophistication. The way we design, validate and build cars is being reinvented. And in the case of autonomous cars, billions of miles need to be simulated before they can be considered safe. Crash, aerodynamics, vibration, acoustics, electromagnetics—here is where Virtual Prototyping is changing the world. From aerodynamic engineering to the prediction of behavior of new materials in battery cells, simulation capabilities are dramatically reducing the production cycle and development costs, allowing millions of alternatives to be tested in the concept phase. There is no doubt that this approach and others such as additive manufacturing (3D printing), will soon generate a complete disruption in the automotive value chain.

Does this all sound like science fiction? It's not. The future of the car industry is Electric, Connected and Autonomous, and it starts today. I hope you enjoy this edition of SIMULIA Community News magazine!

OLIVIER SAPPIN,
Vice President Transportation & Mobility Industry

EMPOWERING THE ELECTRIC VEHICLE REVOLUTION

As this issue of SIMULIA Community News aptly demonstrates, the electric vehicle (EV) is evolving toward an increasingly greater role in human mobility. While the internal combustion engine (ICE) is not going to disappear any time soon, awareness of its impact on the environment—particularly as populations rise and cities expand—is now global.

In response, the EV market is rapidly growing. Both startups and existing OEMs are actively exploring the potential of electrification to dramatically change how people can get from one place to another with the least impact on human and environmental health and safety.

If you and your company are interested in, or already involved with, riding the EV trend to commercial success, you may be wondering how to achieve the most optimum vehicle designs in the most efficient manner. Dassault Systèmes is already tackling this very challenge with solutions to provide mobility-related industry customers with a powerful combination of information management and software capabilities that will best support your needs.

It will likely not come as a surprise to you that the first pillar in this strategy is the **3D**EXPERIENCE platform. The ability to connect teams together, manage information, and promote collaboration has become a fundamental requirement for companies of all sizes these days—and Dassault Systèmes' position in this area is widely acknowledged to be one of expertise and leadership.

The second pillar in our EV strategy is Model-Based Systems Engineering, which is critical when addressing the extreme complexity of an electric vehicle. And now one of our latest acquisitions, NoMagic, brings model-based systems engineering based on the powerful SysML standard—largely found in the aerospace and defense industries, but increasingly being adopted in automotive these days. This helps model the links between systems and back to requirements at a full-vehicle level.

The third and final pillar is at the core of what the Dassault Systèmes family of brands provides: key technologies and capabilities for designing, evaluating and optimizing your EV system. All are strategic additions to our existing portfolio of structural mechanics technologies that offers our users a true multi-discipline and multiscale set of solutions.

It's this kind of deep product-simulation knowledge, running beneath an enterprise-wide information-sharing business platform, that allows organizations to create models of their entire business structure, their supply chains, their competition, and so on. By capturing key performance indicators (KPIs) of how your business is doing, you can identify and optimize bottlenecks and improve how your organization functions overall. Connecting simulation with KPIs gives managers a full picture, and single source of truth, that enhances and informs the decision-making process.

The sum of the three strategies discussed above, and the true value of our offerings to you, is a future where it's all linked together seamlessly to help you achieve your product-

development goals. Bridging the different disciplines while supporting every technology you are asking us for is a vision we all share.

Let's take a look at some examples of current Electric and Autonomous Vehicle engineering challenges and how the **3D**EXPERIENCE platform connects all disciplines together and serves as the backbone that allows all the technologies we offer to work in tandem.

- As the work by Romeo Power (see the cover story on page 7) demonstrates, the **battery** of an EV is a highly complex system involving a wide array of problems combining multiple physics. CATIA, BIOVIA and SIMULIA are working together to bring a solution that truly connects mechanical and system design, materials and chemistry modeling, and performance assessment of battery cells, modules and packs.

- The **electric drive** is a much more complex system to design than it might appear to be. To meet design requirements, teams need an environment which will allow them to optimize designs by simultaneously taking into account noise and vibrations (see the Aachen case study on page 20), thermal management of the heat dissipated by high rotation speeds and electromagnetics losses, proper lubrication of the integrated gearbox, etc. Dassault Systèmes has invested in key technologies which can address all of these challenges and is bringing them together on the **3D**EXPERIENCE platform to allow for multi-disciplinary optimization of the system.

- **Radar and sensors**, already in use in traditional vehicles, will be even more important in EVs that are being designed to be autonomous, independent of driver control. It turns out that the cleanliness of those sensors—how much dirt it takes to block their function—is critical, something our PowerFLOW technology addresses with soiling analysis. This can then be combined with the analysis of the electromagnetic performance of the sensors with SIMULIA Electromagnetics solutions to ensure their proper operation.

- **Electromagnetic Interference and Compliance** (EMI/EMC) are critical factors in EV, which is packed with significantly more high-voltage cables than an ICE and has a higher potential to experience interference. SIMULIA Electromagnetics solutions help you assess the interference and compliance of electrical systems.
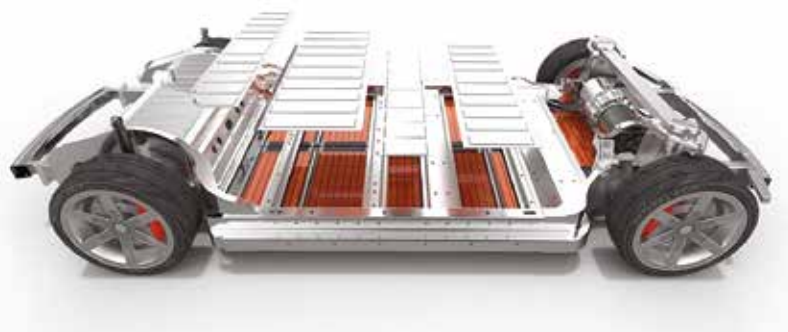
Furthermore, democratizing the access to simulation, especially in an EV space where startup companies have to operate in a very lean environment, including from a human resource perspective, is an integral part of our vision. We want to deliver solutions that are addressing full industry processes, and can be deployed to teams without the need to be entirely proficient in the simulation language. And we believe we can achieve this through seamless integration of how the technologies we mentioned work together, combined with an accessible user interface.

To understand how much further ahead SIMULIA is thinking, David Holman, Vice-President, SIMULIA R&D, shares his thoughts:

"Information should flow seamlessly in an organization and machine learning should allow algorithms and reduced-order models to be refined. Adding an increased level of automation for processes that are currently manual will move users and teams away from low-value assistance to machines or algorithms and towards higher-value decision making. This will give companies the ability to move from exploring technical KPIs to exploring business KPIs. In the end it will be about what distinguishes our customers' brand from their competitors, which is going to be key for the numerous emerging EV startups looking to promote their differentiated value proposition.

Of course, cloud will be key and is fully part of the vision. There are hundreds of new players starting from scratch without the constraints of legacy environments who are ready to disrupt the market almost instantly. These companies won't organize themselves as traditional OEMS. Engineering teams won't have separate departments for simulation, design engineering, etc. Simulation results, performance metrics, and other key information will be seamlessly connected. They will need a flexible environment which adapts to their rapid pace of development, growth and evolving technologies addressing the EV space. That is where the future lies."

The **3D**EXPERIENCE platform, available on the cloud, provides such an environment and is already used by many market disrupters. It is and will remain the true backbone to the industry solutions we are offering.

It's an exciting time in the EV world, with demand rising for new types of transportation previously unheard of. SIMULIA's long-range strategy of building out a complete multi-discipline and multiscale portfolio of technologies is now paying off beautifully for our customers in the EV space, who can take advantage of our portfolio on the platform to investigate the many opportunities opening up for them. Imagination, powered by solutions that enable design exploration and optimization, is a key trait that we know we all share as we work together to meet the expectations of a future world we are only beginning to envision.

For More Information
go.3ds.com/trustthedrive

DASSAULT SYSTEMES ACQUIRES OPERA SIMULATION SOFTWARE

### Enhancing the SIMULIA Electromagnetic Simulation Portfolio

With the acquisition of CST—Computer Simulation Technology—Dassault Systèmes forged ahead into the electromagnetic (EM) simulation space, underlining its commitment to provide customers with multiphysics / multiscale simulation technology to solve a broad range of industry challenges.

There are many industries that require electromagnetic simulation tools, dedicated to very specialized needs, comprising specific know-how and knowledge to support product innovations. Within the expanding SIMULIA EM portfolio, CST STUDIO SUITE and related EM products provide accurate results in high frequency applications within the automotive, aerospace,communication, defense, electronics, energy and healthcare industries.

New to the SIMULIA EM portfolio, is Opera Simulation Software, which complements our existing electromagnetic simulation suite with its strength in low frequency simulation, which is extremely useful for design of magnets, electric motors and other electrical machines.

The foundations of Opera were laid in the late 1970s when the Rutherford Appleton (Particle Accelerator) Laboratory needed simulation capabilities to design the latest generation of high-field magnets, for steering and focusing charged particle beams. The software was commercialized in the early 1980s as demand grew among the accelerator community for the accuracy that the design process demanded—and Opera could deliver. In common with particle accelerators, Magnetic Resonance Imaging (MRI) scanners require high magnetic fields, and parts per million homogeneity. Therefore, it was a natural progression to this field for Opera. The high field required for an MRI (10,000 times as strong as the earth's magnetic field) is typically produced by superconducting magnets. To address this problem, Opera provides specialist tools to assist the design engineer in analyzing a superconducting quench (the sudden loss of superconductivity) and designing the necessary protection circuits. Transient events such as these require accurate modeling of eddy currents and, due to Opera's ability to solve eddy current problems, it was a natural progression into the field of electrical machine design.

Accurate design of rotating electrical machines (motors and generators) initiated the development of a unique capability in Opera: re-meshing of the air-gap between the rotor and stator during solution. This innovative capability led to Opera's adoption by world-leading industrial automation and power generation companies. Today, this electrical machine design capability is being applied in the field of transportation & mobility. Development, production and market-share is increasing for electric vehicles and many countries have
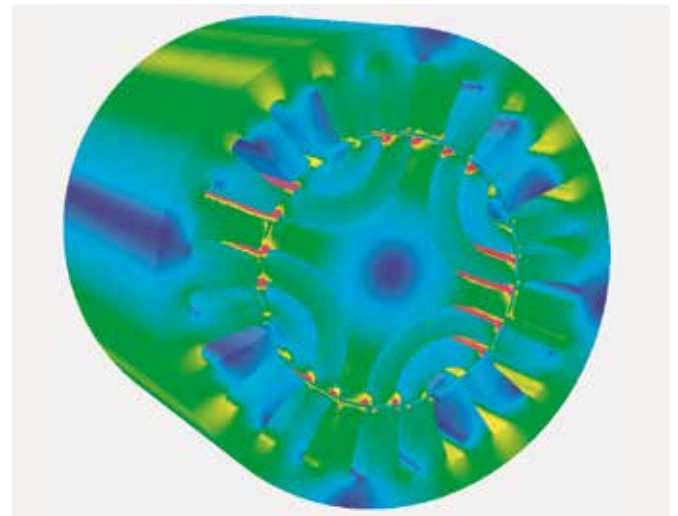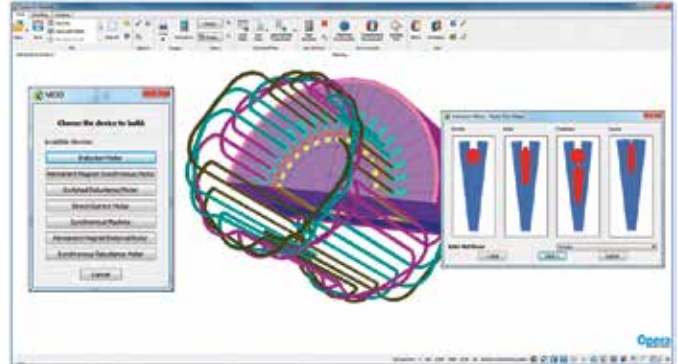
announced deadlines for the phasing out of sales of internal combustion engine-powered vehicles. Different manufacturers will demand different capabilities from their drives; from peak torque, say, to peak efficiency, to power density, while limiting parameters such as operating temperature or noise produced. Or, more likely, a combination of these. This means that the electromagnetic performance has to be combined with mechanical and electronic design, creating truly a multiscale and multiphysics problem.

For More Information on Opera's capabilities and its typical applications:
www.3ds.com/products-services/simulia/products/opera-simulation-software/

ROMEO POWER TECHNOLOGY: BUILDING BETTER BATTERIES
Simulation plays a vital role in the quest to end energy poverty

Large-scale battery systems like the one shown above can provide electricity during brown-out or black-out conditions, store the energy generated by solar or wind farms, and allow consumers to "game the grid" by collecting power during non-peak hours.

Switching on a light when it's dark. Cooling down the room when it's hot. These are just a few of the modern conveniences we take for granted. But according to a 2017 report from the International Energy Agency, safe, dependable power is a precious commodity in many parts of the world. Roughly 14% of our fellow human beings have no access to electric power, and 38% of them—nearly three billion people—rely on "dirty" fuels such as wood or coal to cook their meals.

Romeo Power Technology is on a mission to change this situation. The California-based company says they aim to end global energy poverty by 2023 through the development of cost-effective, sustainable energy storage solutions that can be used virtually anywhere on the planet. It's an ambitious goal, to be sure, but with a little help from SIMULIA the company is well on its way to meeting those objectives.

POWERING THROUGH CHALLENGES

Aside from plugging them in periodically, chances are you haven't given much thought to the rechargeable batteries sitting inside your cell phone or cordless power tool. Despite their ubiquitous nature and seemingly simple construction, however, batteries are actually complex devices, able to survive thousands of charging cycles with little drop in performance. They're also demanding to design and manufacture—especially those large enough to power a motor vehicle, suburban home, or even an entire office building. This latter kind of battery is often based on lithium-ion technology, which is Romeo Power's strength—and deliverable.

"There are multiple challenges in the battery industry right now, and as a structural engineer, I need to focus on all of them," says Saeid Emami, technical specialist at Romeo Power. "One of these is to reduce battery weight wherever possible, not only for vehicular use but to keep transportation costs down. Safety is another big concern. Batteries may short out when subjected to severe vibration, shock, or other abuses. For example a vehicle collision can lead to catastrophic failure, potentially harming the occupants or those nearby. And, of course, everyone wants the lowest cost possible, particularly in the automotive space. It's for these reasons that SIMULIA's Abaqus software has become an invaluable tool for simulating and optimizing our battery designs, allowing us to effectively address each of these needs."

> "SIMULIA and especially Abaqus are helping us to model these and other failure modes, predicting what will happen if there's penetration during a crash, for example, or the effect that vibration can have on cell positions within the pack. It's a very important part of our work."
>
> —Saeid Emami, technical specialist, Romeo Power
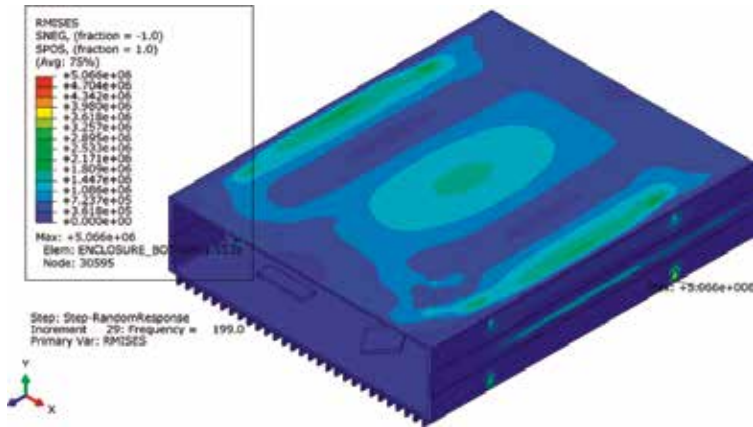
Simulated random vibration is applied to a battery module, just one of many such analyses used by Romeo Power to determine design effectiveness.

GAMING THE GRID

Founded in 2015 by tech entrepreneur Mike Patterson and hardware engineer Porter Harris, Romeo Power today employees more than 200 people, many of them engineers and designers like Emami. The main facility in Vernon, California, boasts 113,000 square feet of manufacturing space, much of it automated, giving Romeo Power the ability to produce four GWh (gigawatt hours) of storage capacity per shift. That's enough power to keep the lights burning in several million homes long enough to eat dinner with the family or watch a favorite show (and maybe even enough to send a 1982 DeLorean time machine hurtling back to the future).

With an "intelligent battery management system" and safety standards comparable to those used on spacecraft (Harris once worked for SpaceX), Romeo's electric vehicle (EV) battery packs are found in everything from motorcycles and automobiles to forklifts and four-wheel drive utility vehicles. Similarly, the Saber brand of portable energy systems can be used to charge laptops, cell phones, cameras, and drones with up to 90 watts of waterproof, shockproof, standby power for those on the go. And while the application is distinctly different, the company's stationary storage solutions are designed to collect and store power in much the same way—although in this case on a much larger scale from existing electrical grids—supplying energy to buildings and homes in the case of blackouts or reducing utility costs during times of peak demand.

Accomplishing all this hasn't been easy. As discussed earlier, batteries are far more intricate than is suggested by their unpretentious shapes. Emami describes a building block-like structure of cells, modules, and packs, each of which must be modeled for complete understanding of their behaviors, both individually and collectively. Shock, vibration, damage, fatigue—these are a few of the many conditions that he and the Romeo Power design team rely on Abaqus to simulate.

Says Emami, "SIMULIA and especially Abaqus are helping us to model these and other failure modes, predicting what will happen if there's penetration during a crash, for example, or

the effect that vibration can have on cell positions within the pack. It's a very important part of our work."

PACKING IT IN

A lithium-ion battery pack may contain hundreds or even thousands of such cells, each one about the size of a single conventional battery in your remote control. Depending on their location within the pack, voltage levels may vary from cell to cell, causing performance issues. Internal conditions such as temperature and humidity also play a factor, and as packs get bigger, stress due to loading becomes an even greater concern, potentially leading to short circuits, fire, or mechanical failure. Each of these conditions is modeled, the results analyzed, and individual cell and pack designs modified based on the results.
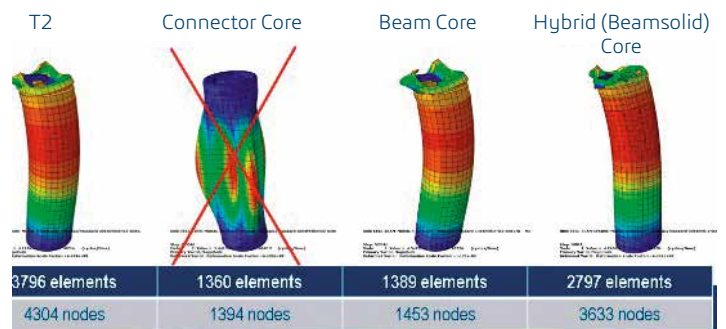
As with many engineering feats, a delicate balance between weight, cost, and capability must be achieved if the design is to be successful. "One of the major challenges is the conflict between the structural integrity, of course, and the overall weight of the battery modules," Emami says. "At the same time, we must be very cognizant of safety, a consideration that overrides all others. We develop different strategies to tackle each of these problems, and then use Abaqus to validate the results wherever possible."

UNRAVELING JELLY ROLLS

One example of this is predicting internal short circuits. The Romeo Power engineering team has constructed a "jelly roll" model to represent individual battery cells, and uses it to characterize their behavior during overcharge or crush situations, nail penetration testing (a standard in the battery industry), and thermal extremes.

In cases where suitable material models are unavailable, the team mimics reality by modeling battery cells as crushable foam with elastic enclosure, building them up to the module or pack level as needed to meet simulation requirements.

Abaqus is also used to demonstrate the effects of explicit events, such as dropping the battery pack, and implicit testing

T2	Connector Core	Beam Core	Hybrid (Beamsolid) Core
3796 elements	1360 elements	1389 elements	2797 elements
4304 nodes	1394 nodes	1453 nodes	3633 nodes

These Abaqus simulations illustrate the effectiveness of using different core materials for battery cell construction—here, the results of a modal study showing the first mode of vibration for different meshing strategies. For instance, the crossed out "Connector Core" model does not constrain the casing well and as such, its first mode of vibration introduces an unrealistic vibration, i.e. at a very low frequency, clearly visible in the casing of the cylindrical battery cell.

From left to right are the three basic components found in any lithium-ion-based power storage system—cell, module, and pack. Each must be modeled and any possible failures simulated to assure safe, reliable operation.
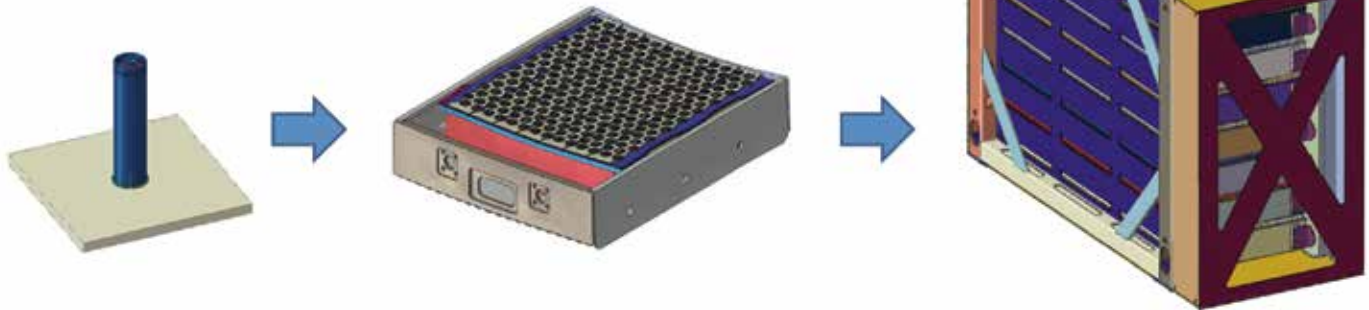
of steady-state electrical conditions. Further, Emami and his colleagues are currently working with support engineers at Dassault Systèmes to develop a 'co-simulation" electrical-structural model combining explicit and implicit events like these.

"There are just so many potential problems with battery modules and structures that need to be tackled in order to meet our design goals of lighter, safer, and less expensive," Emami says. "Rather than wait for failures to occur, we started using Abaqus early in the company's history, analyzing structural integrity as well as the behavior of the different electrical and mechanical components under various types of loading. We knew that if Abaqus predicted a problem of any kind, it was a sure sign that the battery could fail."

A BRIGHT FUTURE

What does any of this have to do with helping those in the world without access to batteries or other forms of electrical power? Interestingly enough, that's exactly what prompted Romeo Power Technology founders Mike Patterson and Porter Harris to begin the company in the first place.

Both had spent time in Haiti and India, and were determined to make life better for the people in these and other energy-poor countries. Their initial attempt to do so failed, however—after building a prototype solar-powered storage unit, they

soon discovered that it was too expensive for their intended customer base, despite the fact that the storage unit was constructed of relatively low-cost components.

Not long after this disappointing start, the two were approached by a number of companies looking for alternative sources of EV batteries. Realizing that a profitable business was probably the best way to fund further development of off-the-grid power sources, Patterson and Harris launched Romeo Power, never forgetting their vision of ending energy poverty once and for all.

As for Emami, he's quite happy to be part of the Romeo Power team. "We have a group of very bright, committed people who, working together, have developed the most efficient batteries for their size available on the market today," he says. "Despite this early success, we're constantly looking at novel ways to improve battery efficiency. These include the potential of using composites and other materials in order to reduce battery weight, for instance, and finding ways to increase cell density. Whatever path we take, I'm sure that Abaqus and the other parts of the SIMULIA software suite will help us with whatever design challenges come our way."

For More Information
https://romeopower.com
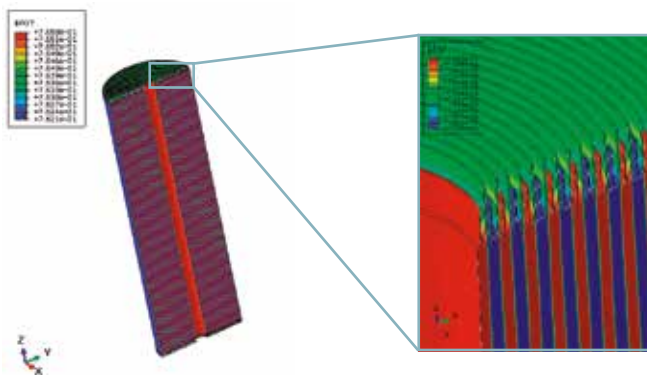
Batteries we take for granted are actually complex assemblies, prone to a host of potential failures that could lead to short-circuiting, shortened product life, and runaway thermal events.

Model Correlation
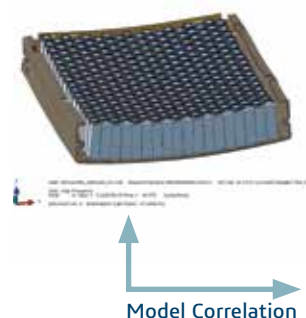
Like any good engineering company, Romeo Power routinely validates simulation results through real-world testing methods.

IS YOUR BATTERY FIT?

A guide to fast and flexible engineering
decisions to win the e-mobility championship

THE BATTERY GRAND CHALLENGE

15X

Sales of electric vehicles
are expected to increase
15 times by 2030! [1,2]

50%

The battery represents up
to 50% of the total electric
vehicle cost today[3]

1 **NEW VEHICLES**
The race is on globally to introduce new vehicle types—shared, connected,
autonomous, and purpose-tailored vehicles on the ground, air and sea.

2 **COST AND PERFORMANCE**
Manufacturers are looking to reduce the high upfront battery costs, without
compromising performance and safety. They must find ways to leverage
technology innovations such as evolving Li-ion solutions, solid-state, and
those to scale production and the supply chain.

3 **KNOW-HOW**
Decentralized know-how across organizations is preventing the agile
engineering of the right-for-each-vehicle batteries and their timely delivery.
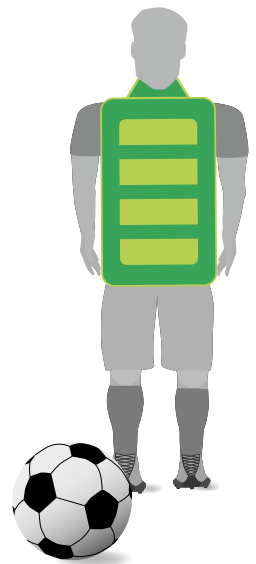
WHAT MAKES A WINNING BATTERY?

SAFETY   **10+** **LIFESPAN**   **$ COST**   **RANGE**   **CHARGE RATE**

VIRTUAL FIELD FOR BATTERY DEVELOPMENT

The **3D**EXPERIENCE® platform offers a collaborative and connected environment of digitally united best-in-class solutions
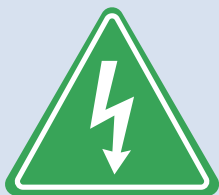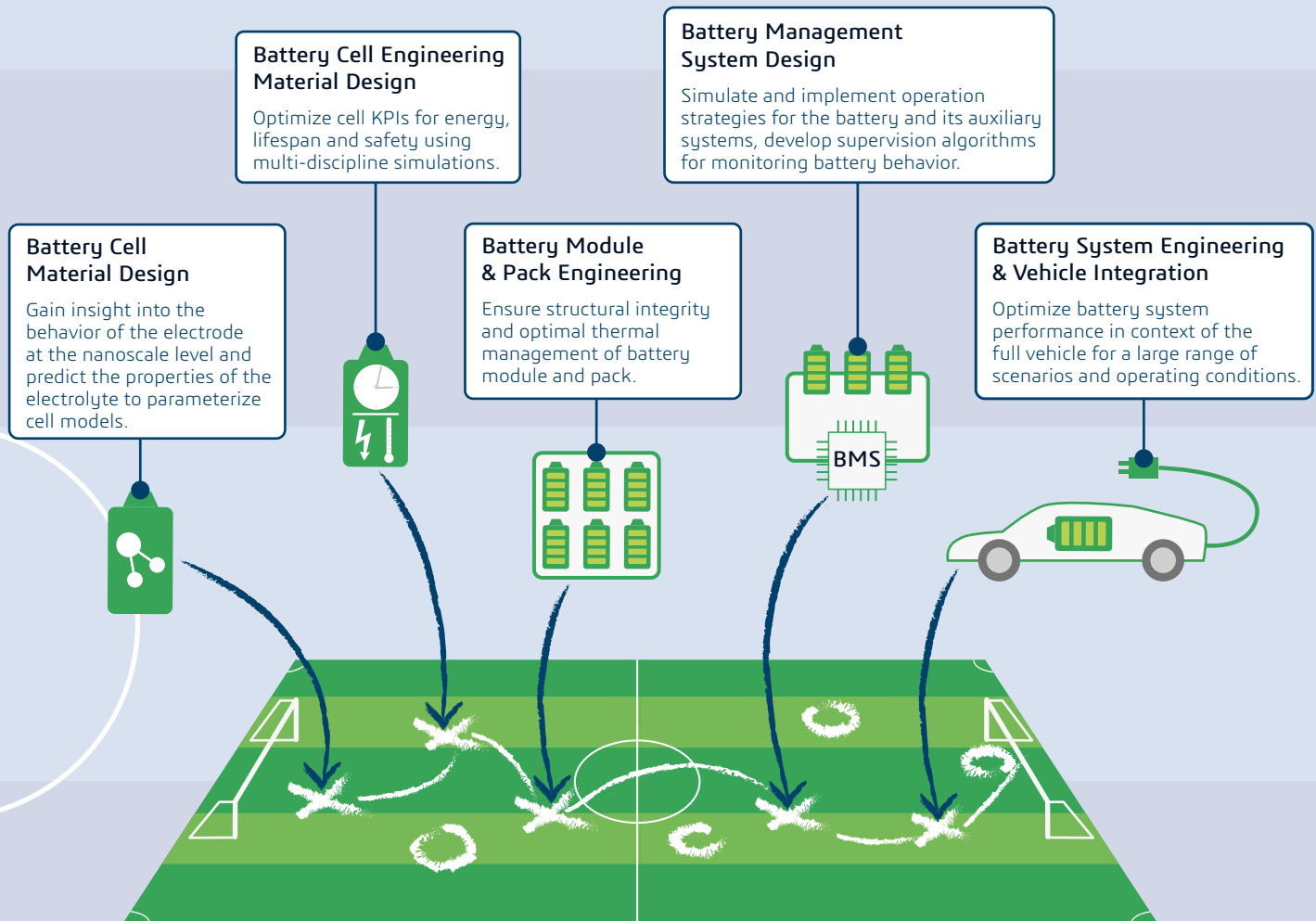
Battery Cell Engineering Material Design

Optimize cell KPIs for energy, lifespan and safety using multi-discipline simulations.

Battery Management System Design

Simulate and implement operation strategies for the battery and its auxiliary systems, develop supervision algorithms for monitoring battery behavior.

Battery Cell Material Design

Gain insight into the behavior of the electrode at the nanoscale level and predict the properties of the electrolyte to parameterize cell models.

Battery Module & Pack Engineering

Ensure structural integrity and optimal thermal management of battery module and pack.

Battery System Engineering & Vehicle Integration

Optimize battery system performance in context of the full vehicle for a large range of scenarios and operating conditions.

All Physics, All Scales   **Data Driven**   **On Premise, On Cloud**

Are you ready to take on the challenge? Let us help you!

To learn more, visit **go.3ds.com/TrustTheDrive**

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Partner Highlight

CAELYNX

As a design and simulation consulting company based in Ann Arbor, MI, Caelynx stands at an interesting vantage point from which to observe the ever-changing landscape of the ground-transportation industry. This perspective is informed by requests from OEM and tier-one suppliers who ask Caelynx to work on specific needs related to their innovation initiatives, particularly in electric vehicles. This often leads to methodology development projects for new technologies for which standard analysis techniques are insufficient or inapplicable.

Thirteen years ago, when Caelynx was established, we received two large consulting projects. A brief description of these projects will give a sense of what it's like to be a finite element analysis consultant and, as we compare the two, it will be clear that change is on the way and that design innovation will extend into simulation technology and even how we approach the simulation process.

FE model of electric motor.

The first project was for a new high-horsepower internal combustion engine design. The design included numerous fine-tuning concepts to improve efficiency, torque, and power. One of Caelynx's tasks was to simulate the thermal and pressure cycling of the cylinder head and exhaust manifold. Although the design was fabulously unique, traditional simulation methodology, thirty years in evolution and practice, would be the ticket to success—CFD results mapped onto structural mesh, thermal expansion, structural assembly loading, time-dependent creep and low-cycle fatigue, and some topology analysis for the cherry on top. Yes, still quite complex from an FEA point-of-view, but nothing to give us the feeling that disruptive industry changes were on the way.

The second project was a direct request from a large OEM's transmission group regarding one of their first hybrid vehicles. They needed help understanding the noise content of the electric motor, a whole new concern in their transmission assembly. Neither Caelynx nor the OEM had direct experience simulating this phenomenon, and even physical testing was still a work in progress. Over the next nine months, we developed a simulation method that correlated to physical testing and was robust enough to be used in standard simulation processes for new production vehicles.

Although common FEA techniques—like assembly preloading for linear dynamics—were foundational, technological innovation brought novel challenges that allowed us to flex our simulation muscle: What was the best way to model the motor's elaborate copper windings and their epoxy coatings? How could we include the stator, comprised of hundreds of thin plates? But most interestingly, how could we really push the simulation to the next level with multiphysics? Electromagnetics would provide vibrational loading for structural, structural would provide velocity excitation for acoustics, and so on. The project gave us a feeling that we were working on technology that could change the world – and for the better.

Today, Caelynx projects are dominated by new technologies, and that often means looking for ways to integrate simulation into new design processes. A typical day in the life of Caelynx includes a large variety of simulation methods for electric vehicles. Just like motor development, battery development also needs simulation, including CFD for thermal management, impact and crush testing, as well as random vibration and fatigue. With the rise of autonomous vehicles, we have also seen an increasing need for interior cabin design, which introduces concerns like cabin seating comfort, variable airflow designs, and new crashworthiness criteria, just to name a few.

The world is on the cusp of great technological change, and Caelynx brings simulation expertise to the innovators at the vanguard of this electric and autonomous revolution in transportation. In these endeavors, we are proud to be a partner of Dassault Systèmes for sales and support of SIMULIA and the **3D**EXPERIENCE platform.
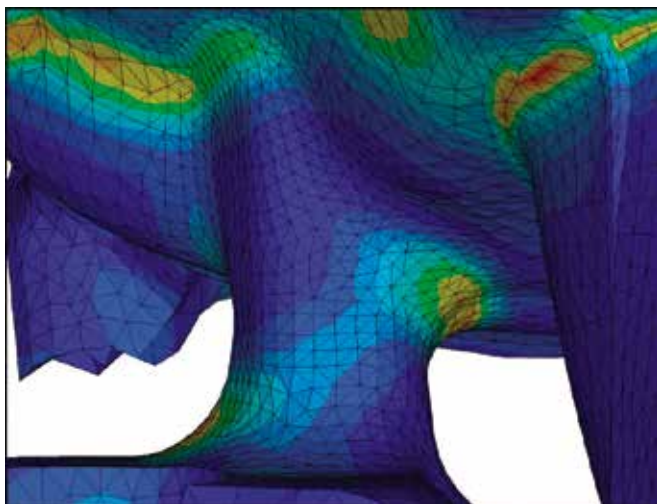
Optimization with Abaqus, Tosca and fe-safe.

For More Information
https://caelynx.com

DRIVING ELECTROMOBILITY WITH THE 3DEXPERIENCE PLATFORM

Kreisel Electric, based in Austria, develops the worlds most advanced battery technology for electric vehicles and combines them with battery management systems, transmissions and electric motors to create complete electric vehicles—including the world's first electrified Hummer H1.

The company was founded by three brothers whose passion for electric propulsion has given birth to high performing battery packs and energy storage systems for the road and home. Passion for electromobility technologies and fast cars were the driving forces behind Kreisel Electric's project to electrically-power a 1971 EVEX Porsche 910, baptized the Kreisel EVEX 910e.

Replacing this classic model's original combustion engine with its patented and award-winning long-range battery pack required careful planning, ingenious engineering and 3D technologies from Dassault Systèmes' **3D**EXPERIENCE platform.

> ## "We can integrate parameters like the heat transfer from the motor. We can set temperature limits. We can basically simulate everything."
>
> –Helmut Kastler, Head of Mechanical and Electrical Engineering, Kreisel Electric

ELECTRIC POWERTRAINS

Kreisel Electric uses sophisticated modeling and simulation software to optimize a motor's performance and balance all components of an electric powertrain, says Helmut Kastler, Kreisel Electric's head of mechanical and electrical engineering.

One challenge is verifying that transmissions can keep pace with new, more powerful electric motors. In the early days of applying electric motors to transportation applications, a transmission had to handle 5,000 to 6,000 revolutions per minute (rpm); now, electric motors can generate 15,000 to 20,000 rpm. Electric sensors on the transmissions communicate information to the vehicle's electronic control unit (ECU), which acts like a central nervous system, providing lubrication on demand to limit friction and heat.

"The software allows us to easily connect the characteristics of individual parts together and see the combined effect of the mechanical power, thermal power, electrical power, each to the other, so that we can create a whole system," says Johannes Pumsleitner, a research engineer at Kreisel Electric. "We can start simulating systems by providing any parameter, and we can also simulate driving behavior."

Noise management is another key issue. An electric motor can run almost silently. But the transmission, which has more mechanical components, generates noise if it is not properly synchronized with the motor. "We have to take care of the noise," Kastler says. "You can simulate whatever you want, but you need to know which attribute has to be optimized."

With **3D**EXPERIENCE, Kreisel Electric engineers had a single source of trusted information that promoted real-time collaboration, state-of-the-art design and simulation applications to engineer, test and manufacture all required components and systems as well as planning tools to ensure the project stayed on budget and on schedule.

CHALLENGE

To transform the legendary 1971 EVEX Porsche 910 combustion-powered car into an electrified supercar Kreisel Electric needed to design and build a battery pack, cooling system, gearbox and powertrain that would fit in the car's available space. To achieve this, the company needed a solution that was robust yet flexible enough to enable the different disciplines involved to collaborate while keeping costs and schedules in check.

SOLUTION

Kreisel Electric relied on the **3D**EXPERIENCE platform and its Electro-Mobility Accelerator's integrated applications that cover the entire development lifecycle from requirements to digital concept, design, simulation, manufacturing as well as overall project management.

BENEFITS

Project stakeholders enjoyed real-time collaboration, centralized and secure access to geometric data, company know-how and project information thereby promoting creativity and innovation while reducing costs and overall development time. Digital crash simulations reduced physical prototyping costs and the integration between engineering and production enabled early manufacture of designed parts.

For More Information
www.3ds.com/customer-stories/kreisel-electric

Industry Perspective

IS THERE A "BEYOND" TO LITHIUM ION BATTERY ELECTRIC VEHICLES?

Dr. Menahem Anderman, Founder of Total Battery Consulting

Lithium (Li) ion batteries have been the chemistry of choice for over 20 years, with an increasing number of applications. The chemistry provides the possibility for a large variety of formulations where lithium ions migrate between a solid positive electrode and a solid negative electrode through an organic liquid electrolyte and a macro-porous polyolefin separator. State-of-the-art small cylindrical '18650' cells, which were introduced in 1991 with an energy density below 250 Wh/liter today deliver 750Wh/liter. Cell prices have also dropped dramatically from over $1000/kWh in 2006 to $120-140/kWh in 2018.

Lithium-ion batteries are the technology of choice for Battery Electric Vehicles (BEVs). Their combination of high energy density, long cycle life, excellent power density and acceptable operating temperature range is compelling, and today's technology can support vehicles with a 300-mile range. BEV technologists are focused on enhancing battery value propositions by addressing three variables: (1) Reduced cost, (2) increased volumetric energy-density, and (3) improved charge acceptance rate. All three must be achieved without sacrificing life, manufacturability and, above all, safety.

One way to improve energy density and potentially safety is to replace the organic liquid electrolyte and the polymeric separator with a solid, non-combustible electrolyte. If this is done inside the lithium ion umbrella energy density will suffer and cost will rise. Some longer term attempts are to combine solid electrolytes with a cell based on a metallic lithium anode. Compared to Lithium ion batteries, such cells could theoretically offer a 40-70 percent improvement in energy density.

Rechargeable batteries based on metallic lithium have been under development for about 40 years—prior to the lithium-ion period. All commercial attempts to date have failed, due to the formation of powdery dendritic lithium during plating, (charging) where life limiting shorts with safety concerns occur. The new push is to replace organic liquid electrolyte with a solid electrolyte and hopefully avoid the problem of dendrite formation. Some approaches under development include: (1) polycrystalline metal oxide, (2) polycrystalline metal sulfides, (3) glass based metal oxides or metal sulfides, (4) polymer electrolyte, (5) gel electrolyte, and (6) a combination of two or more of the above options. Discrete material modeling and simulation may be helpful in uncovering new material options and reducing the time and cost of physical prototyping

In addition to blocking dendrites on charge, the electrolyte must provide sufficient ionic conductivity at the required operating temperature, be chemically stable to the battery environment, and be economical to make and use in batteries.

Notwithstanding is the tremendous development of realizing sufficient room temperature ionic conductivity to several sulfide-based electrolytes. This technology is still in the research rather than development stage relative to cycle life, manufacturability, cost, and charge rate. To accelerate time-to-market, which is expected to be more than 10 years, it is necessary to evaluate all options including operating the battery above room temperature. At 60 to 90 degrees centigrade, more ionically conducting materials are available and the softness of the lithium deposition makes dendritic shorts less likely. It is prudent that cell battery system and vehicle simulation be applied to evaluate the most promising route to promote post lithium-ion battery technology and overcome its very large challenges.

Dr. Anderman inspects a battery module.

Dr. Menahem Anderman is the founder of Total Battery Consulting. He earned a Ph.D. in Physical Chemistry from the University of California. His corporate experience encompasses materials research, cell design, and battery engineering, as well as market and business development and general management.

He also founded Advanced Automotive Batteries (AAB) to provide information on the rapidly growing field of energy storage for advanced automotive applications.

tbc total battery consulting

For More Information
https://totalbatteryconsulting.com

BIOVIA: MODELING MATERIALS FOR BETTER, SAFER BATTERIES

Dassault Systèmes' BIOVIA brand offers a wide range of tools from lab automation to materials modeling. BIOVIA Materials Studio is a suite of integrated tools for understanding material properties and material behavior from nanoscale to just below microscale. It includes a range of solvers based on theory such as quantum mechanics and classical simulations.

Batteries are complex systems of materials. For example, in a lithium-ion battery the electrodes contain an active material such as graphite or a mixed metal oxide combined with a polymer binder, while the electrolyte is a complex formulation of organic and organometallic materials. As the battery charges and discharges, many chemical reactions occur, causing the underlying chemistry of the battery to change. This leads to formation of the solid-electrolyte interphase (SEI) which protects the anode but also contributes to capacity fade and can lead to battery failure.

BEHAVIOR OF BATTERY MATERIALS

Different solvers in BIOVIA Materials Studio can be used to gain insight into the behavior of the battery materials and calculate properties that are relevant to battery material engineers.

For example, special additives are included to modify the properties of the electrolyte and control the formation of the SEI. However, the additives must not inhibit the flow of lithium ions across the electrolyte. Using classical simulations, molecular dynamics can be applied to model the diffusion of lithium ions in different formulations and this can be linked directly to the conductivity of the electrolyte. Such properties can be used to screen for new additives and also to connect to larger scale models like the Newman models provided by CATIA.

Besides allowing screening of materials, the electrolyte simulations also provide insight into why the conductivity changes in different formulations. Examining the precise movement of the lithium ions reveals the effect of the local environment on diffusivity, facilitating new design rules for the development of the next generation of additives.

A major challenge in the development and integration of electrode materials is the lithium-induced expansion and compression during charging and discharging. If the volume change is too large, the electrode will likely suffer from fracturing, electrical disconnection and eventual failure. Accurate simulations of the effect of intercalation of lithium ions on the electrode volume can be performed using the solvers based on electronic models in BIOVIA Materials Studio. This information could be used to provide input parameters for Abaqus calculations and understand the macro-structure implications of an expanding electrode on battery cell performance. Besides calculating the volume change and lattice expansion as a function of lithium intercalation, the simulations also provide information about the change in bonding between the layers. This can be used to estimate the level of intercalation within a layer that can lead to exfoliation and failure of the electrode.

The discrete modeling tools provided in BIOVIA Materials Studio enable battery-materials engineers to screen new candidate materials, explore the wide materials space and understand material behaviour. The use of discrete modeling tools accelerates the development of the next generation of battery materials required to support future electric vehicles.

For More Information
http://3dsbiovia.com/products/collaborative-science/biovia-materials-studio/
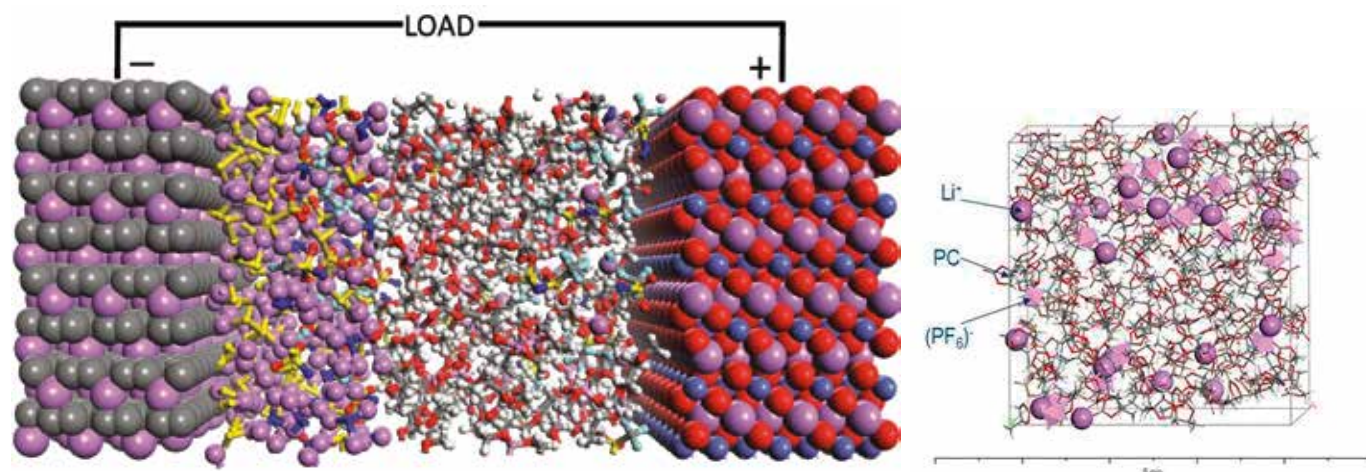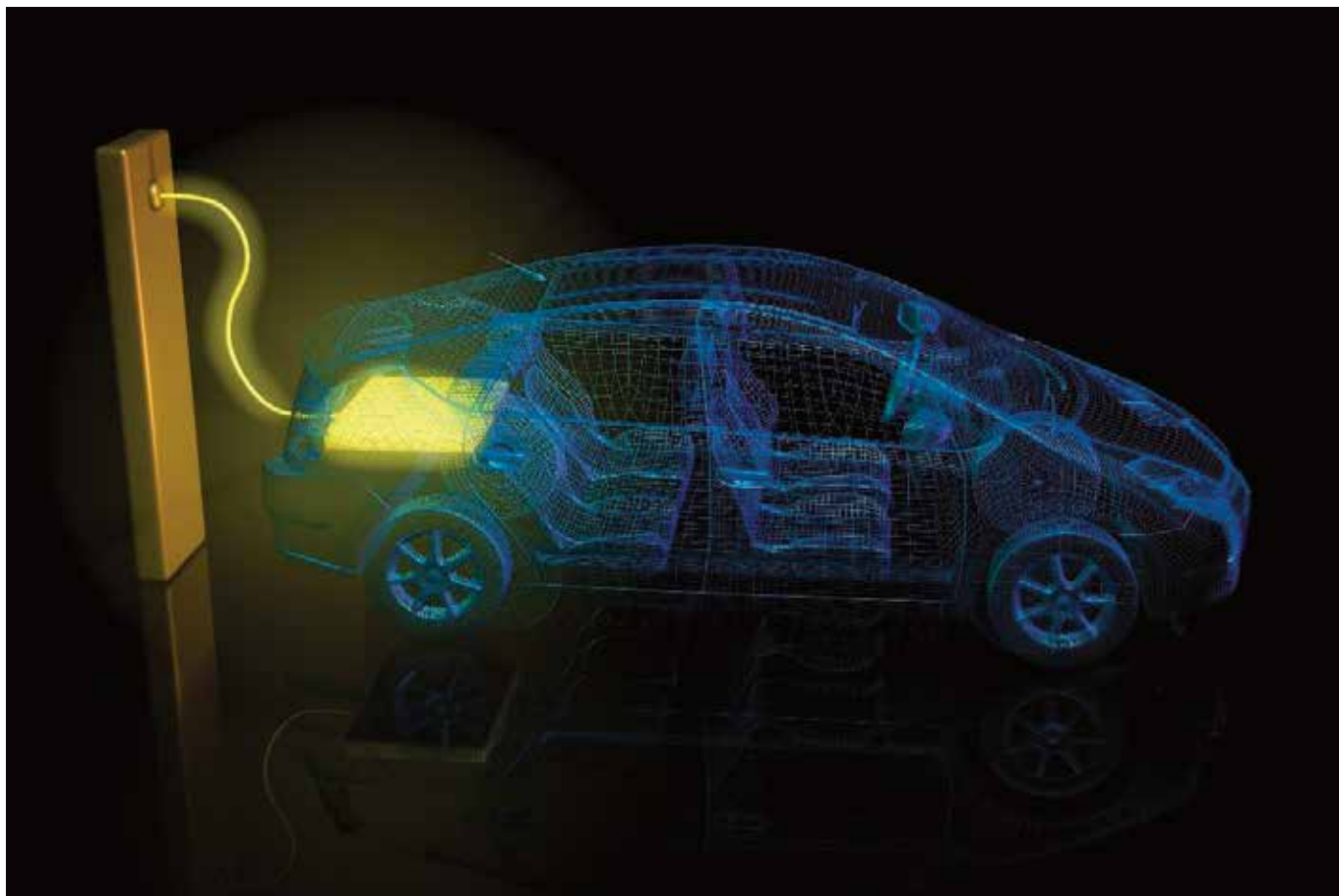
DESIGNING THE BATTERIES OF THE FUTURE

EDEM and SIMULIA collaborate to advance the use
of simulation for Electric Vehicle battery design and performance

The Electric Vehicle (EV) market is growing quickly (45% increase in sales globally in 2017[1]), and an increasing number of automotive manufacturers are announcing plans to move to electric and hybrid-focused product lines. This growth is putting increasing demand on the battery manufacturing sector as EV suppliers demand batteries that deliver longer driving ranges and shorter recharge times, all while being smaller and lighter in size. With the EV sector expected to account for 90% of lithium-ion battery usage by 2025[2], battery producers are under pressure in the coming years to design and deliver these batteries of the future.

BUILDING A BATTERY

A typical battery consists of three parts—electrodes (anode and cathode), separator, and electrolyte. The production of electrodes is a complex, multi-stage process that begins

with powdered materials such as graphite, binding agents, and active materials (e.g. lithium oxide). These materials go through a series of mixing, coating, calendaring, cutting and folding processes until wafer-thin cathodes and anodes are produced that can be layered together to produce the battery.
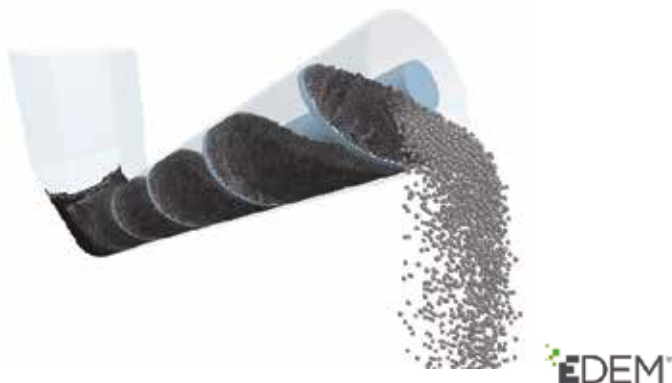
The decisions made at each manufacturing stage during electrode production will influence the set-up of subsequent processes and, ultimately, the overall battery performance. Engineers must carefully choose what combination of parameters should be used at each stage to deliver an optimal battery design. However, the volume of possible process parameters, as well as their interdependency, poses a significant challenge to battery manufacturers.

SIMULATING BATTERY DESIGN AND PERFORMANCE

Simulation offers battery manufacturers a predictive environment, where choices of battery production parameters can be linked to battery performance analysis. Dassault Systèmes software tools—such as Materials Studio and Abaqus—provide engineers with the opportunity to

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1 https://innovateuk.blog.gov.uk/2017/12/11/the-challenge-of-creating-a-uk-vehicle-battery-industry/

2 https://www.weforum.org/agenda/2017/11/battery-batteries-electric-cars-carbon-sustainable-power-energy/

explore the design of electrode materials at the atomic level and to understand the macro-scale performance of entire cell.

EDEM, a SIMULIA Alliance Partner, is the market leader in bulk material simulation. EDEM software accurately reproduces the complex and dynamic behaviors of bulk and granular materials such as dirt, soil and powders during handling and processing operations. EDEM is used in a wide range of industry sectors including construction, pharmaceutical, mining and agriculture sectors.

In the case of battery manufacture, EDEM has applications in the electrode manufacturing process and battery performance analysis, providing engineers with an understanding of powder and micro-structure behaviors as electrodes are analysis, providing engineers with an understanding of powder and micro-structure behaviors as electrodes are formed and operated.

SIMULATING THE BATTERIES OF THE FUTURE

In 2016 EDEM launched the EDEM-Abaqus coupling. This innovation addressed a need that was seen in many industries to bring detailed data describing forces and pressures caused by the interaction of bulk materials on equipment and product structures. Engineers can now export realistic bulk material force data from EDEM into Abaqus FE simulations—leading to improved design accuracy and reduction of prototyping costs.

While this capability is most regularly used in 'Heavy Equipment' applications, following the Science in the Age of Experience Conference, EDEM and SIMULIA teams identified that the insight EDEM brings to battery simulation complements the solutions offered by SIMULIA. Both teams have now embarked on an R&D collaboration to understand how the EDEM-Abaqus coupling can be advanced to enhance predictions of battery performance.

The targeted EDEM-Abaqus solution is being developed jointly and will strengthen the link between production process parameters, materials selection, and the final performance of the battery. For battery manufacturers, this means even more investigations can be performed in the virtual environment, a reduction in the dependency on physical testing, and ultimately help them deliver the battery technologies of the future.

If you are interested in knowing more about EDEM simulation in the battery sector and this R&D initiative, please contact david.curry@edemsimulation.com

For More Information
www.edemsimulation.com
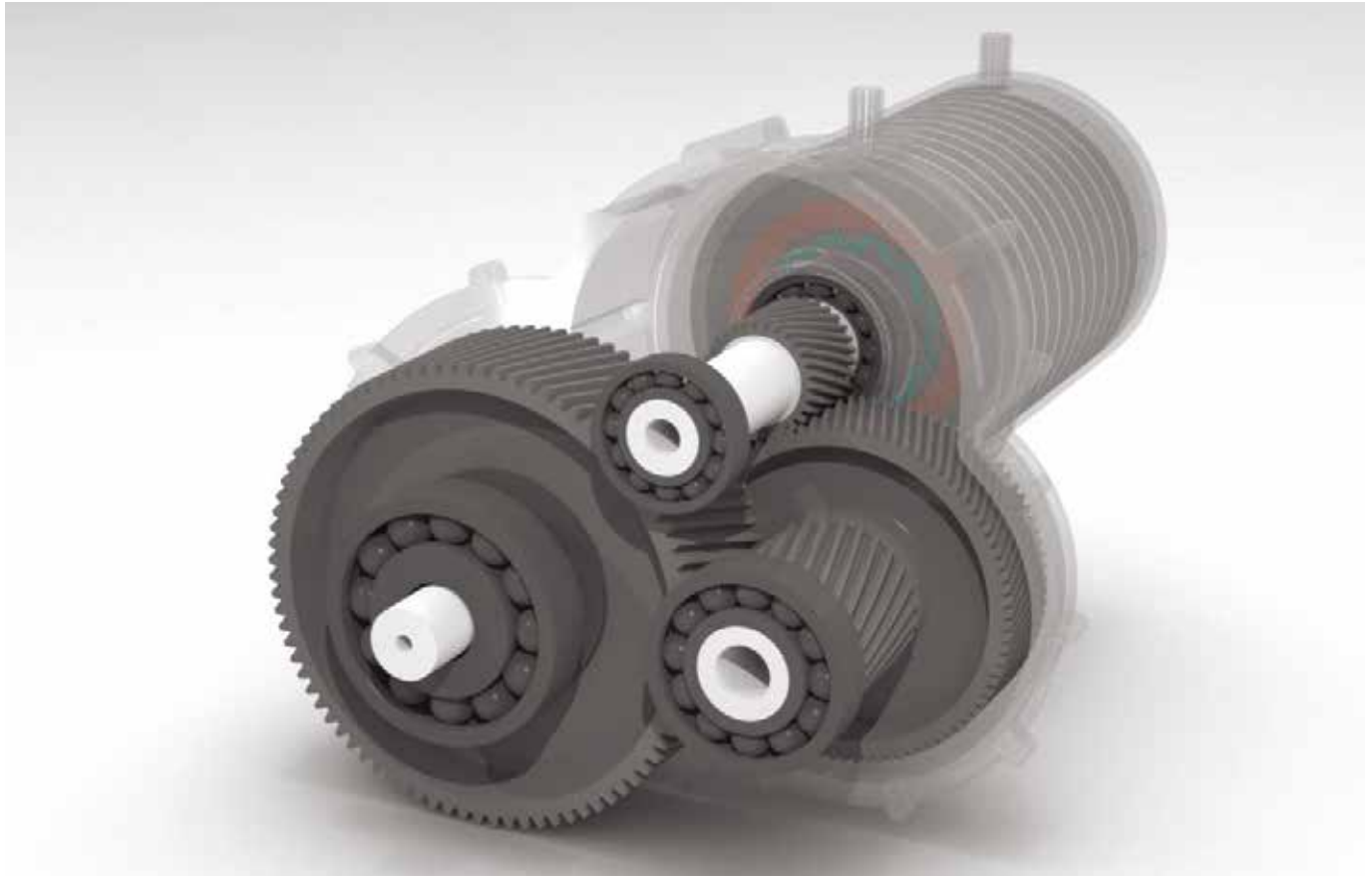
THE CHALLENGES OF SIMULATING ACOUSTIC COMFORT IN ELECTRIC VEHICLES

The automotive industry is experiencing disruptive changes with electric, autonomous and connected mobility. Automakers (OEMs) and suppliers are entering a new phase in powertrain systems—ramping down internal combustion engine design and production and ramping up design and production of electric vehicles. Electric drive systems, comprised of the electric machine and a gearbox, are complex and their performance in different domains needs to be evaluated to improve and optimize their design.

HOW DOES THAT CHALLENGE AFFECT THE VEHICLE OR PRODUCTION OF THE VEHICLE?

One of the challenges in electric drive engineering is to ensure acoustic passenger comfort. Electric machines and gearboxes can produce tonal noises that are perceived as unpleasant. The internal combustion engine in traditional vehicles helped to mask some of these noises. Now with the general reduced noise level in electric vehicles, in particular at low and medium speeds, there needs to be a special focus on the noise and vibration behavior of these components.

OUR SOLUTION

To analyze the noise and vibration behavior of electric drive systems, a multi-discipline approach is required.

Electromagnetic simulations are essential to obtain the forces originating from the electric machine, which causes structural excitations. These forces are incorporated in a flexible multibody model to be able to get the coupled system response of machine and gearbox.

HOW IT WORKS

The basis for the noise and vibration analysis is an elastic structural model of the electric drive system. A finite element model of the stator in an interior permanent magnet synchronous machine (IPMSM) as well as the overall gearbox housing is used to characterize the dynamics of the structure. A reduced-order model is obtained using the dynamic substructuring technique. This model representation is important to describe the dynamic behavior of the structure with relatively few degrees of freedom thereby achieving much faster computations with negligible loss in accuracy for the desired use in the noise and vibration analysis.
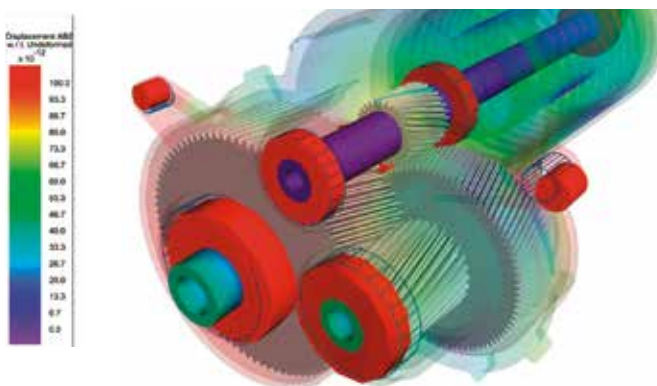
Dynamic electromagnetic forces acting on the stator and rotor of the electric machine lead to structural vibrations. Therefore, electromagnetic simulation needs to be carried out to determine forces and torques for the desired speed range of the machine.
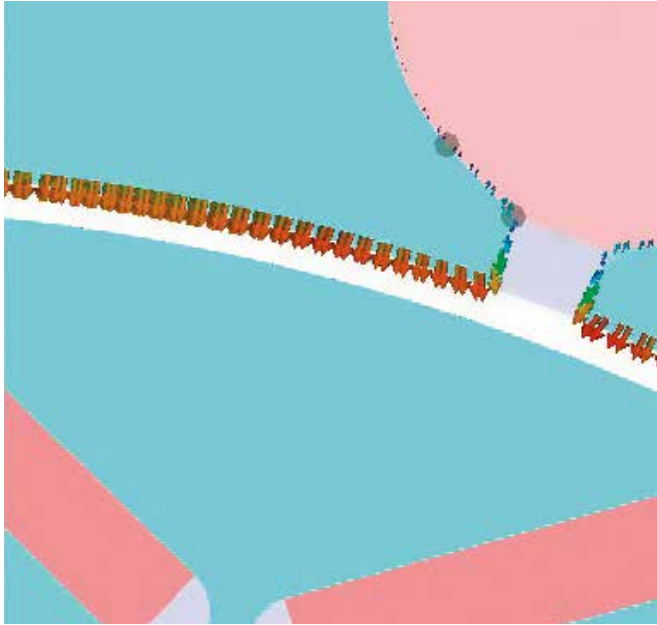
Force density on stator teeth generated with CST Studio Suite.
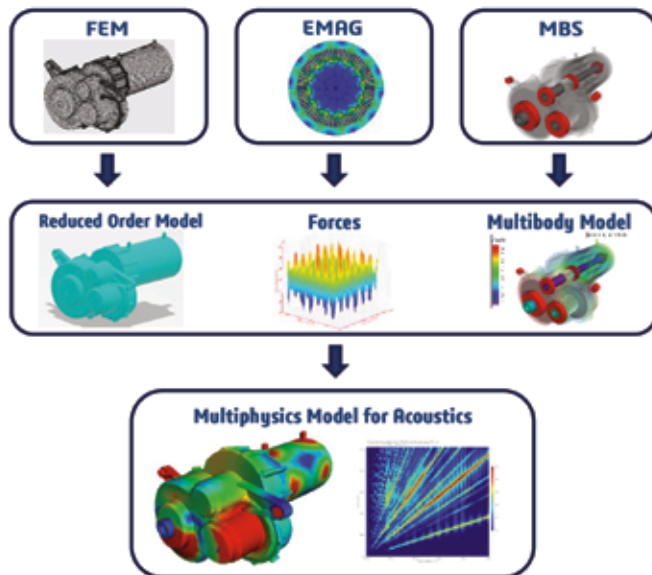
Flow chart for the multiphysics model.

Operating Deflection Shape (ODS) created with Simpack.

Multibody simulation is the ideal tool to study noise and vibration phenomena of complex drive systems because of the higher abstraction level used for the models. In contrast to full-scale finite element models with generic 3D contact formulations, SIMULIA Simpack Multibody Simulation offers a large catalogue of application-specific elements. Those elements are mostly based on analytical formulas, with the aim of modeling a part of the system with exactly the required level of detail for reducing unnecessary complexity and simulation effort while sustaining the highest level of accuracy for the desired application.

Apart from the electromagnetic forces from the preceding electromagnetic simulation, dynamic gear forces due to varying contact stiffness are the other main excitation source in the electric drive. Simpack multibody simulation has an advanced non-linear analytical model for gear contact. Furthermore, it is important to model the shafts as flexible, which can be either done by using a beam model or using dynamic substructures like that of the housing. The rolling bearings, which support the shafts relative to the housing, are also modeled using effective analytical methods that represent the bearing in the form of non-linear coupled stiffness functions for all six degrees of freedom. The bearing model also includes backlash, which enables the multibody model to be used for rattling analysis.

Multibody simulation brings together the mechanical properties of the flexible components with typical non-linear excitation mechanisms, allowing for the efficient study of noise and vibration phenomena in electric drive systems.

When engineers are looking at the results of the simulations, they typically study forces, velocities and accelerations at different locations in the model using plots and operating deflection shape (ODS) animations. Furthermore, the surface vibrations of the housing structure can be used in a subsequent vibro-acoustics analysis with the software wave6 to obtain the airborne sound.

OUTCOMES

Dassault Systèmes provides an end-to-end suite of multiphysics solutions for every aspect of the electric drive design and engineering process. The application for noise and vibration analyses enables engineers to study various design alternatives and optimize the product in an easy and seamless way leading to better acoustics comfort and a reduction in the overall engineering process time.

For More Information
www.3ds.com/products-services/simulia/products/simpack

Academic Case Study

Electric car

ELECTRIC VEHICLES ARE NOT ALWAYS AS QUIET AS YOU THINK!

RWTH Aachen University team employs SIMULIA solutions to develop drivetrain simulations that assess noise and vibration

You've likely been caught by surprise when you're out walking and an electric car drives up behind you. A light hum, and perhaps the soft crunch of tire on pavement, is all you hear. There's certainly a lot less external noise than an internal-combustion vehicle would make.

But the irony of the electric vehicle (EV) is that the quietness of its machine allows the driver and passengers to hear more of other noises happening inside the car. Rattle, squeak and vibration, which the sounds from an internal combustion engine (ICE) might mask, become more apparent in an electric car. What's more, that distinctive EV hum can become amplified throughout the car at certain speeds—to noticeably annoying levels.

So what's an automotive engineer to do? For one group of researchers at Germany's RWTH Aachen University, the answer is to use simulation and systems engineering to uncover hidden sources of EV noise and explore ways to mitigate them.

HUNTING DOWN THE CAUSES OF EV NOISE

RWTH Aachen Ph.D.-candidate Pascal Drichel presented the latest findings of his engineering team (Mark Mueller-Giebeler, Markus Jager, Joerg Berroth, Matthias Wegerhoff, Johannes Klein, Sebastian Rick, Georg Jacobs, Kay Hamayer

and Michael Vorlander) at the Simpack 4th Wind & Drivetrain Conference in Hamburg, Germany earlier this year. The group is focusing on developing methods and models for the analysis, optimization and assessment of the noise and vibration (aka NVH) behavior of vehicles. SIMULIA solutions are key tools for them as they perform FEA and multi-body simulations; they also carry out on-site measurements for parameterization as well as validation of their component, assembly and system-level models.

Drichel is team leader of the NVH group of the drive technology department/division at the Institute for Machine Elements and Systems Engineering (MSE) in the University's department of mechanical engineering. When he came to the Institute

> "From the research point of view, we like the combination of state-of-the-art nonlinear solvers, well-proven modeling element libraries that are continuously getting better and wider, and the user-routine capability...."
>
> — Pascal Drichel, Ph.D.-candidate, RWTH Aachen

almost six years ago, he already had a good bit of simulation expertise under his belt. "I started working with both Abaqus and Simpack more than ten years ago," he remembers. "When I began my studies in 2007 I used the software as a student worker in the Institute, doing dynamic simulations, and was also an intern at one of the big german automotive OEMs working on whole-vehicle simulations for electrical drives."

This kind of intern/OEM relationship is available to motivated students at RWTH Aachen. The University has a philosophy of close collaboration with a variety of key industries and, in the case of the MSE Institute, liaises with wind turbine manufacturers (who are understandably also interested in drivetrain technology) as well as automotive ones. The benefits go both ways: In Drichel's team's current study, partnership with the leading german drive technology companies, bundled in the research association for Power Transmission Engineering (FVA) provides real-world data to compare with the engineers' models.

It's a work in progress, notes Drichel. "Increasing electrification in all vehicle classes, such as the e.Go, the VW E-Golf and the Tesla Model 3, keeps bringing to light new challenges regarding NVH behavior," he says. "Virtual product-development methods are becoming very helpful in addressing these, and we are working to further refine tools for the assessment and optimization of different drivetrain variants."
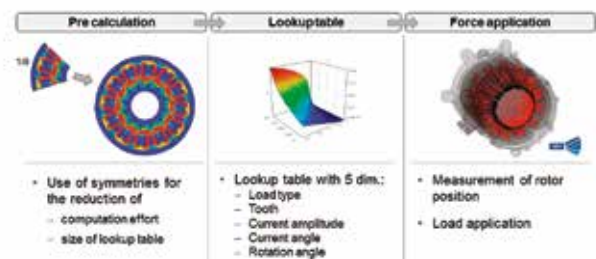
THE DRIVETRAIN DID IT

Why is the drivetrain, which is the group of components that deliver power to the driving wheels , the main focus of the Aachen team's work? Because it's critical to sound control: No matter how quiet the electric machine itself is, the transfer of tonal excitations from it through the transmission, differential, shafts, axels and so on to the car interior results in vibration and other noise-producing conditions that may need to be mitigated in an EV.

"Dealing with drivetrain-related NVH phenomena is a challenging engineering task," says Drichel." You're working within a highly complex system that usually involves different multiphysics domains." To understand the full scope of

potential noise-generators in the drivetrain, Drichel's group is using an multi-domain hybrid approach consisting of simulation and measurement components that looks at electrics, structural dynamics and acoustics, where a central part is the multi-body-dynamics model of the drivetrain.

Electromagnetics: The group is developing models that describe exciting forces in an inverter-fed electrical machine. This involves both analytical and numerical modelling approaches for computationally efficient force calculation. Analytical modelling is supported with data from excitation tables and conformal mapping, while numerical modeling uses the Finite Element Method. The force-excitation spectra are analyzed to determine which effects are most dominant and should be focused on for efficient further processing.

Electromagnetics analysis.

Structural Dynamics: The team has created their own user routine for applying the previously determined electromagnetic forces to the drivetrain. Their Abaqus FEA models of drivetrain subassemblies include full flexible housings and shafts. The submodels are brought together inside a Simpack multibody simulation, which permits a significant reduction in the
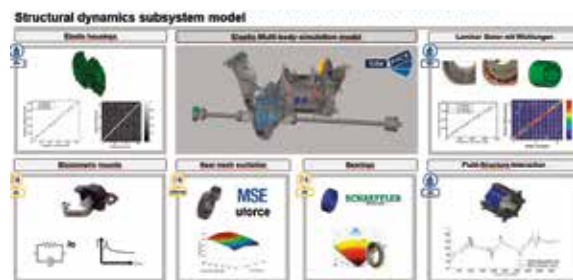
Structural dynamics analysis.

The machine and drivetrain of an electric vehicle can be the source of unique acoustics challenges.

number of degrees of freedom. This results in a highly efficient model in which many different load cases can be run quickly. Subjects of study include the transversal isotropic behavior of the stator, fluid-structure-interaction of both stator housing and machine coolant, and nonlinear bearing stiffness.

Acoustics: A complete acoustics picture of an EV must capture both airborne and structure-borne noise. Once a drivetrain simulation is set up, radiated airborne sound from the entire powertrain can be computed using an in-house acoustics tool. This is extrapolated to auralization of the car cabin noise using transfer-path synthesis. Resonance effects within the system can be studied at different machine speeds and adjustments made in the mechanisms that cause excitation and excess sound. Objective as well as subjective evaluation of the resulting "ear signals" can be carried out to evaluate how changes to drivetrain geometry affect overall noise levels in a particular EV car design.
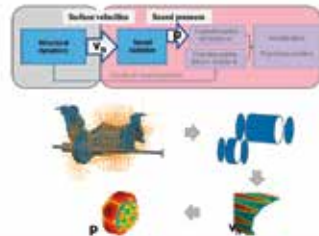
Acoustics analysis.

SIMULIA SOLUTIONS ARE KEY TO THE SEARCH

"In much of this work, Abaqus and Simpack are common tools for us," says Drichel. "From the research point of view, we like the combination of state-of-the-art nonlinear solvers, well-proven modeling element libraries that are continuously getting better and wider, and the user-routine capability—which is a very strong feature as it allows us to incorporate our own ideas for sub-analyses into the software."

Most recently the team began using Isight for process automation and optimization as well. "In the first phase of this three-year project we didn't use Isight and it was a real pain bringing everything together manually," says Drichel. "In the second phase we decided to make everything more automatic with Isight. Now we can bring different software workflows together, which is especially important here in our environment because we have so many domains to analyze."

Multi-body, multi-scale simulation and process automation give product developers the ability to quickly gain greater insight into a system while in the process of designing it, Drichel points out. "Modern methods allow a holistic approach to system simulation of EV powertrain design that allows the identification, understanding and development of solutions for specific engineering problems that are characterized by the interactions of components and subsystems.

"It's an interesting challenge to deliver tools and models that put the sound engineers in the position of shaping the drivetrain-noise-DNA of electric vehicles," he says. "This kind of capability is very important for the automotive industry—they can spend more time working on developing their cars instead of putting workflows together!"

ANSWERS AID AUTOMOTIVE ADVANCES

OEM partners are certainly interested in these kinds of results. "With the 'hybrid multi-domain toolchain' we've developed, the automotive industry will be able to do "hot spot" analysis that lets them identify resonance effects at particular speeds," says Drichel. "This in turn helps them optimize vehicle interior sound that's caused by the electric drivetrain, making EVs more pleasant and more attractive to potential buyers."

Psychoacoustics.

The Institute team's next research goals are twofold: first, to increase model fidelity in all domains to achieve even better correlation between measured and predicted quantities. And second, to balance result quality and computational time to analyze different model fidelity levels using "psychoacoustic" metrics, attuned to the human user's perceptions of sound. Subjective assessment of sound is a complex challenge, because it is dependent on loudness, sharpness and tonality, inter alia—all of which vary according to where within a vehicle the sound is coming from.

Drichel clearly enjoys the complexities of his team's project—but does he have an electric vehicle of his own? "I'd love to have an EV, but it's a bit too expensive for me right now," he says. In the meantime, as a self-described "passionate driver," he rides to work in a vintage BMW M3 series E46. "It's a nice car," he notes with pride. It certainly sounds like the research Drichel and his colleagues are conducting at RWTH Aachen will help make the EVs of the future quieter and more affordable for everyone.

From left to right: Mark Müller-Giebeler (ITA), Pascal Drichel (IMSE), Markus Jaeger (IEM).

For More Information
www.rwth-aachen.de

A CONTINUOUS WORKFLOW FROM CELL TO PACK LEVEL IN BATTERY-SYSTEMS SIMULATION

THE CATIA BATTERY LIBRARY

The Battery library is a Modelica-based library for the modeling of cells and battery packs in a wide range of applications, including auto- motive, aerospace, industrial equipment and process industry. It provides

- Cell models structured into thermal, electrical and aging domains
- Battery pack models of different levels of detail (scaled/ discretized)
- Interfaces and templates for easy customization and extension
- Complete insight into the Modelica code

Here we present a continuous workflow from an electro-chemical (P2DM) to an equivalent circuit cell model (ECM) that enables the investigation of a battery system on multiple levels.

EXPLORING CELL BEHAVIOR WITH ELECTROCHEMICAL CELL MODELS

The electrochemical model is a pseudo-2D-model based on the porous electrode and concentrated solution theory. The model predicts the spatially distributed behavior of the essential quantities of the battery, such as concentration of lithium ions and potentials in the electrolyte and the active solid electrode material. Knowledge of these quantities helps to determine the state of the battery as well as its ability to provide energy.

In combination with the Modelica Standard Library (MSL) and other commercial libraries, the user can build test benches of various complexity to investigate the cell in different scenarios and gain knowledge of its capabilities and restrictions.
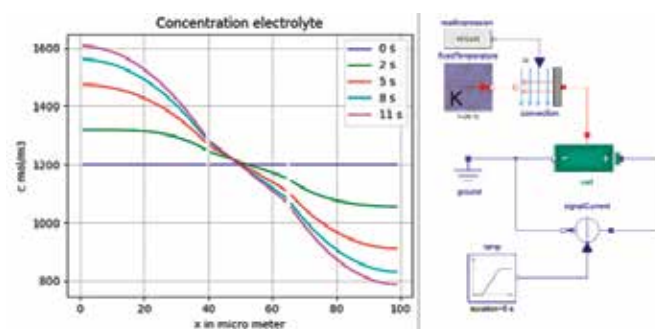
FROM ELECTROCHEMICAL TO CIRCUIT MODELS

The computational effort for the electrochemical model is usually too high to use it for battery pack simulations and/ or an integration into a complex system, like a powertrain or an entire vehicle. For this purpose, a faster computing representation of the cell is required. A proven solution for this is an electrical equivalent circuit model (ECM).

The Battery Library offers a Python-based workflow for the generation of lookup tables for an ECM from a P2DM. With these lookup tables, optimized on current pulses performed on the P2DM, the ECM gives a good approximation of the electrical behavior of the cell.
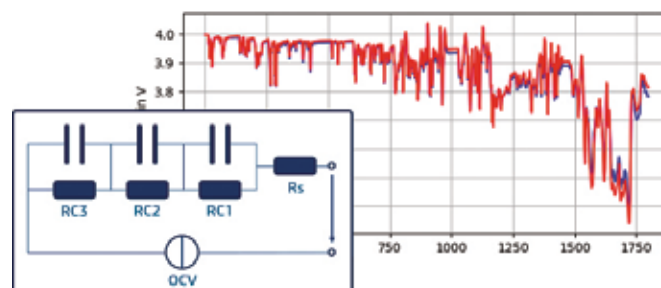
EXPLORING THE BATTERY PACK

The battery pack models enable the simulation of the thermal and electrical interaction of multiple cell models. A cell model includes an ECM using the generated tables, a thermal model and an aging model. The thermal model is a network of thermal conductors and capacitors computing the temperatures inside the cell and the heat exchange with the environment. The aging model is usually an empirical model with superimposition of calendar and cyclic aging effects.

With the pack models, all kinds of investigations are possible:

- How do differences in cell characteristics (e.g. capacity, state of charge) affect performance?
- How do different cooling strategies behave?
- How is the performance of the pack integrated into the system?

BRIDGING SCALES

3DEXPERIENCE and the Multiscale Systems Specialist Role make it possible to link Modelica-based behavior models (or any FMI compliant model) with 3D Finite Element models in a co-simulation fashion. This allows, for example, conducting a thermal analysis on a battery module in which the heat generated by the battery cells is modeled at the 0D scale while the cooling of the battery module can be modeled in the 3D domain with Computational Fluid Dynamics (CFD). This is done in order to pass the current cell temperatures back to the Modelica-based behavior models for loss recalculation as the properties used to calculate these losses are temperature dependent.

For More Information
www.3ds.com/products-services/catia/disciplines/ systems-engineering/

SOLVING ELECTRIC & AUTONOMOUS VEHICLE CHALLENGES

CHALLENGES FOR ENGINEERS

REDUCE AERODYNAMIC DRAG
At 130 kph, EVs use 80% of their power to beat aerodynamic resistance, depleting battery life and limiting range more than any other factor.

BOOST BATTERY LIFE AND RANGE
Improving drag 5% increases range 4%, saving battery life, increasing range, and improving the customer's experience.
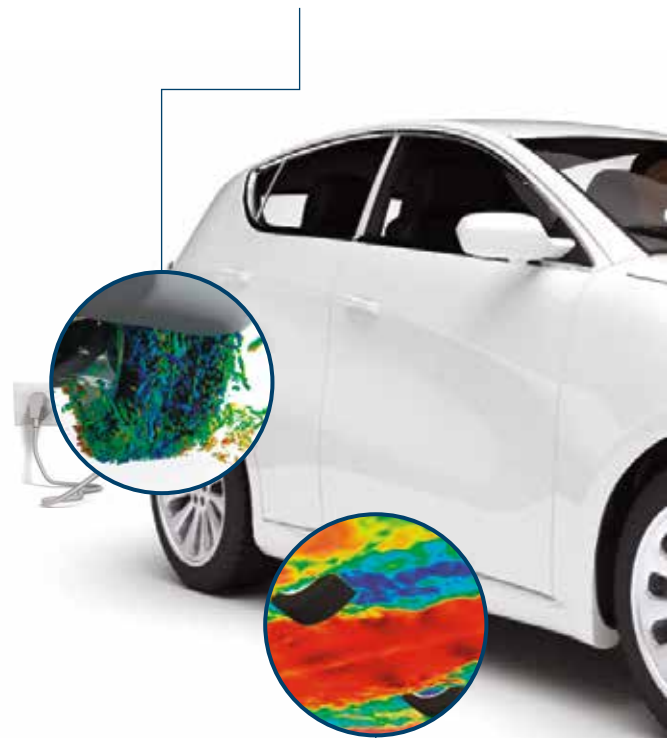
SUPPORT AUTONOMOUS SYSTEMS
Reducing aerodynamic drag can actually increase vehicle soiling and obstruct cameras and sensors vital to autonomous systems.

COMPARE DRAG SOURCES IN ELECTRIC VEHICLES

Tires & Wheel Arches

35% / **30%**

Underbody & Suspension

10% / **20%**

THE EV-AV CONNECTION

The increased electronics onboard EVs offer more capacity to support AV technology, while AV smarts can better manage energy usage than people can, extending battery life and vehicle range.

TO THOSE OF TRADITIONAL GAS VEHICLES

Shape

50% / **40%**

Air Inlets

5% / **10%**

THE BENEFITS OF SIMULATION

SOLVE DESIGN CHALLENGES

With PowerFLOW, evaluate new aerodynamic design solutions including vehicle shape changes, front fascia and underbody design, and air inlets, tires, and wheels to reduce drag, collectively, up to 0.060 or better.

DISCOVER NEW SOLUTIONS

Reducing aerodynamic drag is just one way to preserve battery life and range: PowerFLOW solutions for battery thermal management and cabin comfort help ensure efficient battery design and balance cabin comfort with vehicle range.

EXPERIENCE NEW RESULTS

New vehicle designs can increase or reduce soiling: PowerFLOW solutions simulate dirt and water deposition to assist in sensor placement and to ensure autonomous systems will work as expected.

LEARN MORE

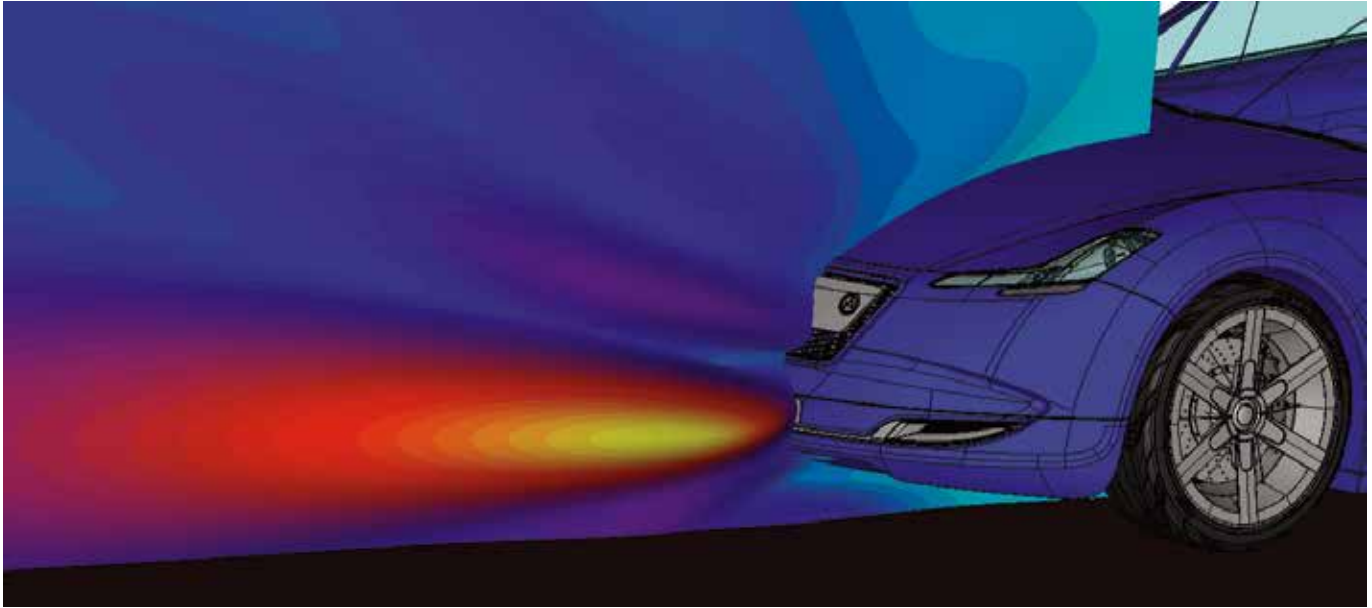*www.3ds.com/products-services/simulia/products/powerFLOW*

Figure 1. Electric field from a radar sensor on the front of a car.

SIMULATING AUTONOMOUS AND CONNECTED MOBILITY

Innovation has always been key to success in the automotive industry. Every aspect of vehicle design is being constantly optimized and new technologies regularly emerge that revolutionize what a car can do.

Right now, many of the trends in vehicle design are converging towards intelligent electronic systems. These include increasingly integrated onboard computers, advanced driver-assistance systems (ADAS), vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) systems for monitoring and negotiating with the environment, autonomous driving and electric drive.

Integrating these technologies into a vehicle affects every area of the design and requires multiphysics simulation. Replacing the engine, usually mounted at the front, with batteries and motors slung under the body changes the vehicle's center of gravity, affecting the performance of the chassis and suspension, and the removal of the front radiator grille changes the aerodynamics and affects heating, ventilation and air conditioning (HVAC) of the passenger cabin.

To fully model an electric car, the engineer needs multibody, mechanical, vibro-acoustic, fluid dynamics and electromagnetic (EM) simulation tools, all of which can be found on the **3D**EXPERIENCE platform. This article focuses on the latter, and highlights some of the areas of modern vehicle design where EM simulation with CST STUDIO SUITE can reduce design time, optimize performance, and identify and mitigate concerns about health, safety and interference regulations.

CONNECTED VEHICLE DESIGN AND ADAS

One of the most important lessons taught to any learner driver is to always be aware of your surroundings. Communication, navigation and ADAS systems supplement what the human eye can see and help keep drivers informed about where they are, what the road ahead is like, and what other drivers are doing around them. Antennas are the eyes and ears of these systems, transmitting and receiving signals such as radio, mobile telephony, GPS and radar.

The performance of an antenna is affected by where it is placed on the vehicle, as the metal body reflects, blocks or conducts signals in ways that are hard to predict without simulation. Avoiding blind spots in a radar, for instance, is safety-critical (Figure 1). Where there are multiple antenna systems close together, there is also a risk of co-site interference between them. To model this risk, CST STUDIO SUITE offers a Co-Site Interference workflow that takes the properties of all the different transmitter systems into account to calculate the interference risk.

ELECTRONIC EQUIPMENT DESIGN

Automotive electronics encompasses the chips themselves, the packaging, printed circuit boards (PCBs) and connectors that carry signals. Electromagnetic compatibility (EMC) between electronic systems and signal and power integrity (SI/PI) within systems are all crucial here. EMC relates to how much interference, in the form of radiated and conducted emissions, a device produces. SI concerns how well an electronic channel conducts signals without degradation, and PI is about ensuring that the power supplied to a component is clean, without voltage spikes or drops that might affect performance.

Not only are there legal regulations on the interference a device may produce, OEMs specify strict limits to their suppliers in order to ensure the reliability and integrity of the car as a whole. This means that EMC and SI/PI compliance is crucial at all points in the automotive supply chain. CST STUDIO SUITE

includes a range of specialized tools for identifying potential EMC and SI/PI issues from the earliest stages of design.

Thermal management is another important factor in automotive electronics, particularly in the high current parts of electric vehicles. Airflow significantly affects how hot a device becomes in use, and so a multiphysics simulation approach—combining EM, thermal and fluid dynamics technology—is the only way to accurately model the cooling systems.

3D WIRE HARNESS ENGINEERING

An extra topic of electronics, which is especially important to vehicles, is the wiring. Cars need a complex tree of cables linking all their components, and these are bundled together into harnesses to save space. The close proximity of wires in a cable harness can cause interference, but adding shielding to every cable would add significant weight and bulk to the vehicle. Hybrid simulation allows even very complicated cable harnesses to be simulated in a realistic environment in order to analyze performance and find the right balance between weight and shielding.
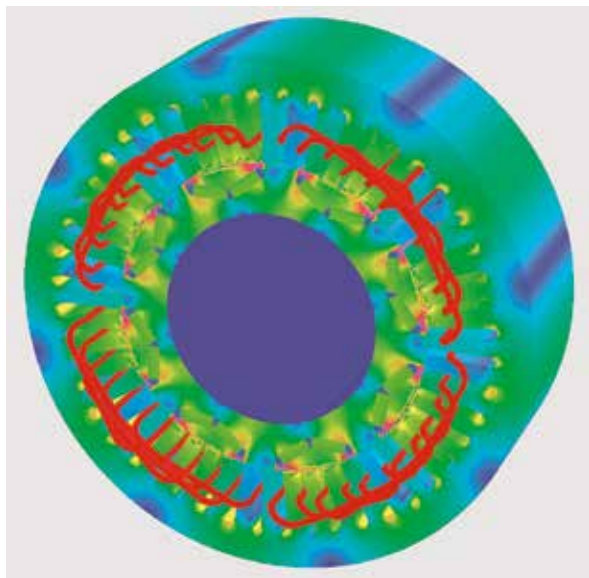
ELECTRICAL DRIVETRAIN ENGINEERING

Figure 2: Cross-section of a motor, showing the electric field within.

Electric mobility poses a range of new questions to automotive engineers. How much space is required for the batteries and motor? Are the high-voltage, high-current systems safe? Is the motor design efficient enough? These questions can be answered with simulation.

Automatically optimizing motor geometry (Figure 2) through simulation can quickly improve the performance and power consumption. Equally important is understanding how the efficiency of the motor changes at different speeds. CST STUDIO SUITE can automatically calculate the efficiency map—a plot of efficiency for all torques and speeds—which can be used to find the optimal configuration.

Wireless charging systems are another application. Similar to the charging mat technology used with some phones, but on a much larger scale, wireless charging is expected to make electric vehicles more convenient by allowing them to recharge their batteries in car parks, bus stops and warehouses. The technology is based on transmitting power between two coils, a primary one buried in the road and a secondary one in the vehicle, which need to be placed as centric as possible to each other. Engineers need to know how many wires are needed in the coils, which materials the coils should be made from, what the best design and coil configuration for perfect power transfer is, and how much shielding is needed to meet safety regulations while also limiting weight.

ELECTROMAGNETIC COMPATIBILITY

One thing that all the systems listed above have in common is the risk of interference. EMC is a legal requirement and indispensable if individual systems are combined into a vehicle. Components ranging from the power electronics that control the motors to the passenger's phone can all produce interference, and cables, vents and seams can leak and allow EM fields to couple to unexpected parts of the vehicle. Full system simulation, using multiple 3D and circuit simulation techniques, is crucial to analyzing the EMC performance of the vehicle before committing to constructing a full prototype, and the ability to visualize EM fields in 3D allows designers to easily find and deal with the causes of interference.

In addition, high-power electric fields—particularly from wireless charging—are limited by health and safety regulations. The exposure of the human body to transmitted EM energy is measured in terms of specific absorption rate (SAR). CST STUDIO SUITE includes realistic human body models, and calculates both the SAR and the actual heating caused by EM field exposure.
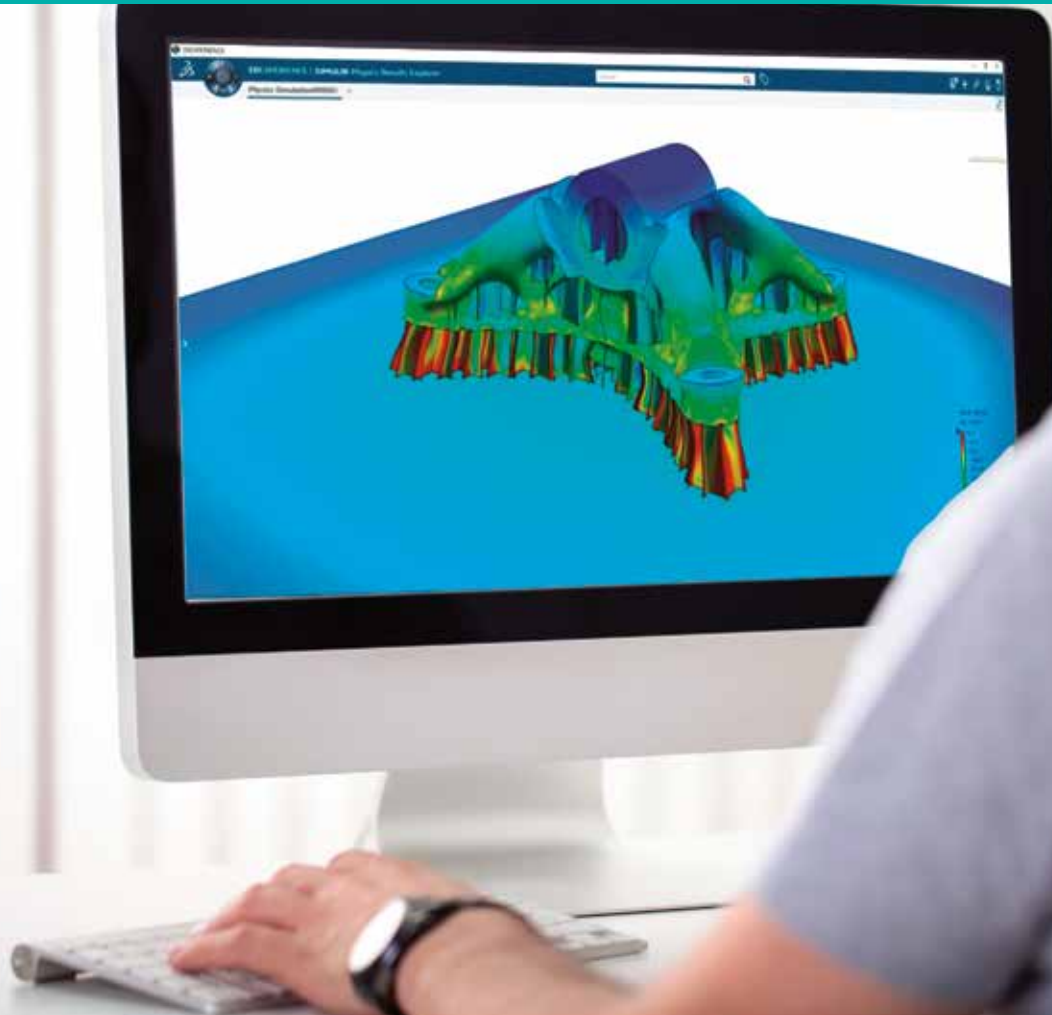
SUMMARY

Electronics is transforming the automotive industry. Due to the high complexity and sheer number of electronic systems, electromagnetic simulation is key in the entire development process. Virtual prototyping and simulation of all product variants is essential in the ever shorter development process and will be the next big step in the automotive industry. The success of vehicle design relies on the mastery of many areas of physics, and the addition of EM to the range of simulation tools available on the **3D**EXPERIENCE platform makes SIMULIA's portfolio for automotive simulation even more comprehensive.

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