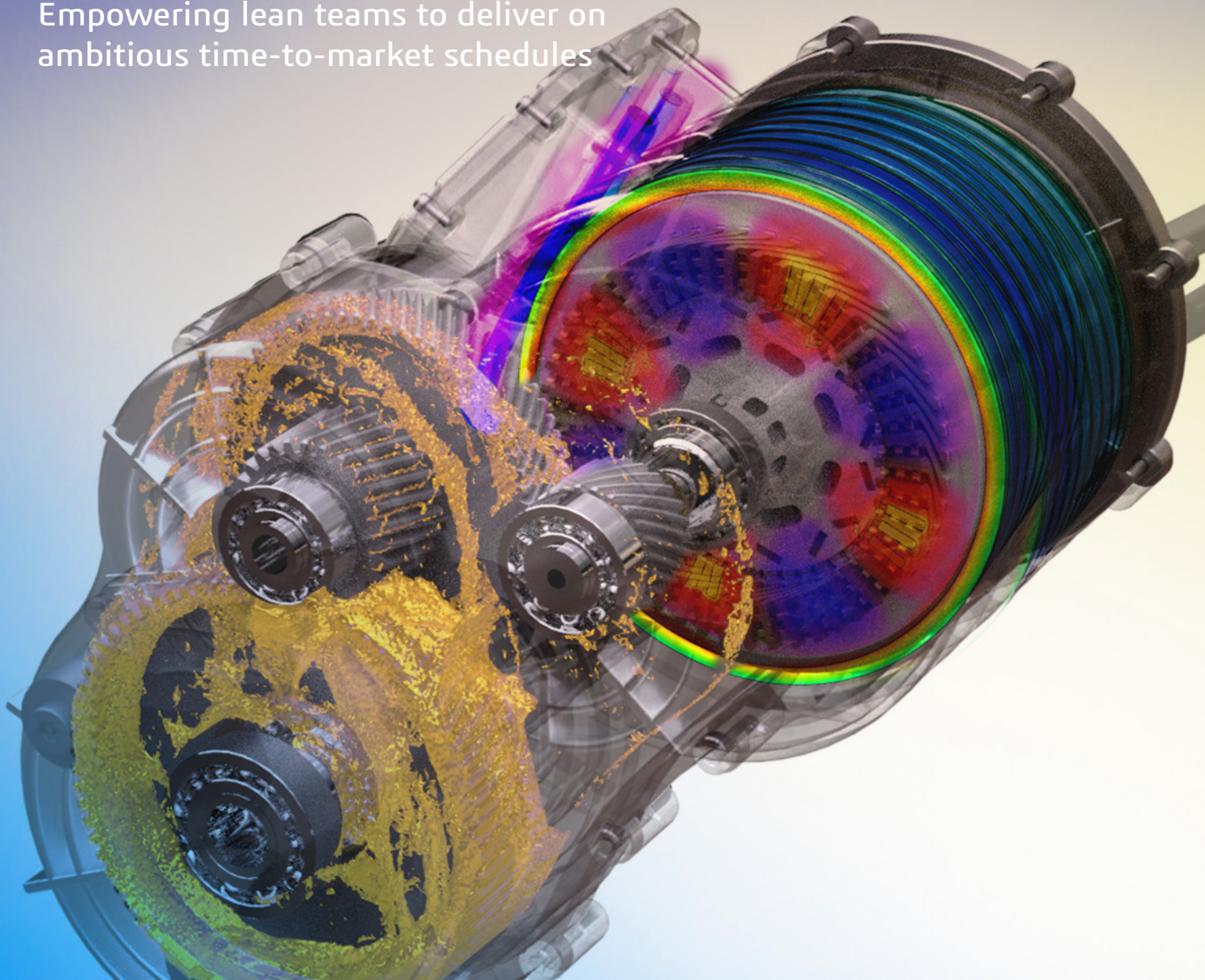


ACCELERATED ELECTRIC-DRIVE INNOVATION

Empowering lean teams to deliver on ambitious time-to-market schedules



POWERING VEHICLE ELECTRIFICATION

Competition is intensifying in the electric vehicle (EV) market, with a 10-fold increase in production predicted between 2021 and 2028. As traditional vehicle manufacturers ramp up their EV development, they're under pressure from mature electric vehicle pioneers that are already launching lower-cost, mass-produced models. To get new designs quickly to market, manufacturers need to significantly reduce development time while overcoming the shortage of EV expertise.

At the heart of every EV, the electric drive system (e-drive) embodies the complexity of that innovation challenge. This is the propulsion system, including the motor and gear drive that power the vehicle and the structural housing that protects them. Designing & validating e-drive units involves multiple disciplines including geometric modeling, electromagnetics, thermodynamics, acoustics (for noise & vibration) as well as structural & fluid mechanics. Accurate simulation of these physics plays a crucial role in meeting key performance indicators (KPIs), from speed and acceleration to range, efficiency and driver comfort. Getting an optimum design can involve many tests and design tweaks.

UNIFYING PROCESSES TO EMPOWER LEAN TEAMS

E-drive development represents a big shift for organizations transitioning from internal combustion engine (ICE) vehicles. As the beating heart of the EV, it is important to get e-drive development right, but expertise is in short supply. In a fiercely competitive market, it is crucial to cut the time it takes to get new vehicles to market. Conventional development processes, involving repeated data exchange between various systems and multiple physical prototypes, are not quick or efficient enough to compete in the fast paced, high-pressure EV markets.

Companies can overcome these challenges by building connected engineering processes via a virtual twin that benefits from the unification of modeling and simulation on a common data model —the MODSIM approach. This empowers their engineering teams to collaborate and streamline e-drive development. Using a virtual twin as a single source of truth, they can create customized as well as automatized processes that democratize simulation and enable early insights into product performance. In doing so, manufacturers can maximize the value of their experts and empower non-experts to meet every KPI during the virtual design phase, before moving on to physical tests.

This 'unification' democratizes vehicle development so that:

- fewer people are needed to develop new vehicles, so vehicle makers can rely on lean development teams
- there is less need to build physical prototypes, reducing manufacturers' reliance on scarce materials
- development time is dramatically reduced, typically from around 60 months to 24 months

A HOLISTIC APPROACH SAVES TIME

A holistic approach is also key to gain results quicker. In fact, researchers have proven that evaluating the whole system's performance brings far greater results than doing things piecemeal. A five-year study by one leading EV maker found that optimizing all the elements of an electric drivetrain separately brought efficiency savings of between 15% and 25%. In contrast, when the company approached the e-drive as a single, integrated system, those efficiency savings reached 40%.

To achieve that holistic approach, vehicle manufacturers need a unified data model in an integrated environment that supports an always-connected process at every stage of development. The Dassault Systèmes **3DEXPERIENCE**[®] platform provides that integrated environment, creating a space where the MODELing capabilities of CATIA and SIMulation functionality of SIMULIA are brought together for true engineering driven design. This MODSIM approach to vehicle development, is enabled by unifying modeling and simulation on a common data model within a single user environment on the **3DEXPERIENCE** platform. Users can collaborate around a 3D virtual twin that replicates reality with scientific accuracy. In effect, this creates a large, multi-physics design space where teams from across the enterprise can

work together at every stage of the development cycle—from ideation through preliminary and detailed design stages to production of a prototype. There is no need to transfer and interpret data between different systems because everyone, from designers to engineers to simulation analysts, is working with the same information—offering a true holistic perspective.

This single-platform, multi-physics approach democratizes modeling and simulation processes so non-experts can use them with confidence. It also brings opportunities to automate workflows and complex tasks and make them accessible through a simple user experience. Its powerful parametric modeling capabilities allow designers and engineers to test out new ideas and understand the impact of every design tweak, knowing that each change will be reflected in the virtual model.

As a result, developers can create more right-first-time designs in the virtual world, which reduces reliance on physical prototypes, supplier dependencies and the materials needed to make them. Ultimately, this means faster, more efficient and unconstrained innovation. In fact, companies adopting this approach can typically reduce development time from around 60 months to 24 months.

WHAT CAN WE DO TO ACCELERATE EFFICIENT E-DRIVE DEVELOPMENT?— A SHOWCASE

To see exactly what can be achieved by a MODSIM approach for an e-drive, let's look at the development of two different EV models. First, the **3DEXPERIENCE** platform has been used by a manufacturer to develop an XLS Sport model of its vehicle. This model has a range of 620 kilometers, a maximum speed of 270 kilometers per hour (km/h), acceleration of 0-100 km/h in 2.2 seconds and a 25-minute charging time.

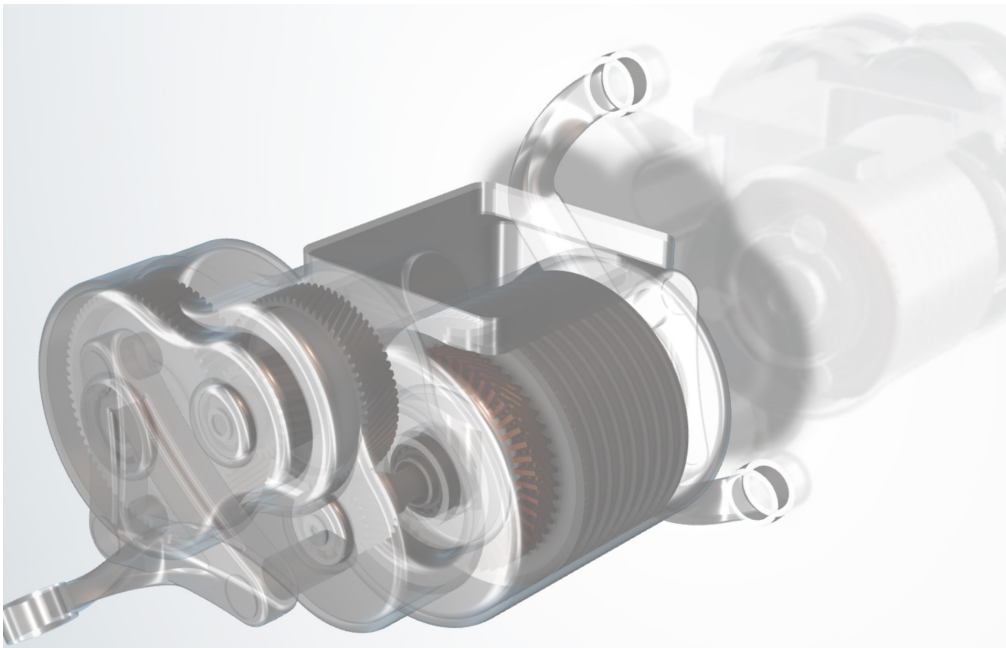


Figure 1: Concept electric drive model

Here's what its e-drive looked like during the conceptualization phase. Designers used the **3DEXPERIENCE** platform to create a topological representation of the design, including essential parameters and finite elements. It took just a few minutes for them to generate a flexible body model, which they used to create and assess the components of the mechanical system.

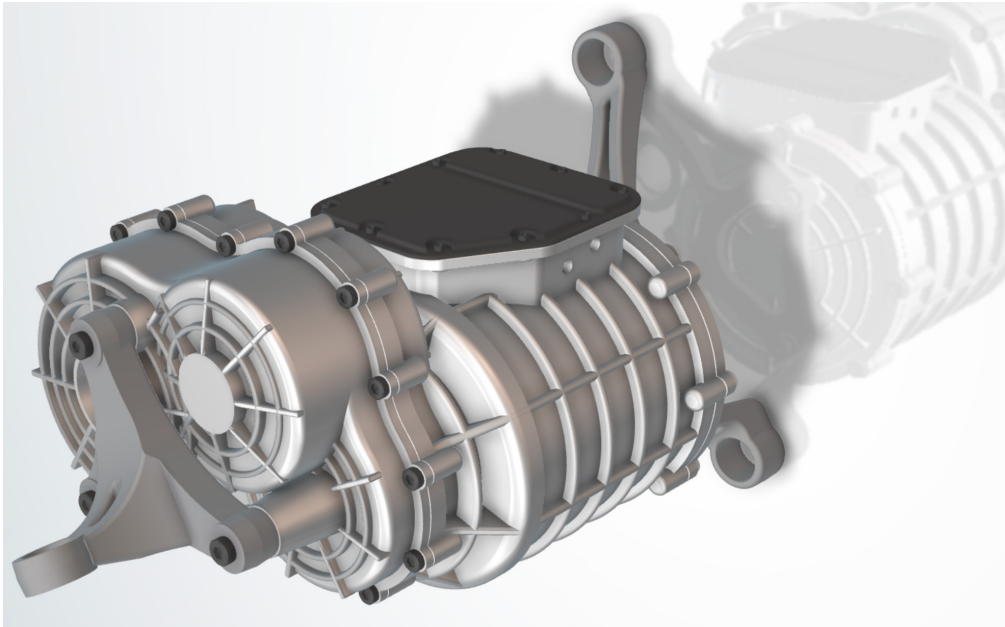


Figure 2: Detailed electric drive model

A more detailed model was then created as the design became more advanced. This one provides a realistic representation of the finished product, with more local parameterization and finite elements in place. At this level of detail, generating a flexible body model took just a few hours.

Deriving new model designs

With the XLS Sport model successfully brought to market, the manufacturer's next step is to create an SE Classic model of the same car. This time, the requirements are different: a 600 km range, a maximum speed of 200 km/h, acceleration of 0–100 km/h in 4.5 seconds and a charging time of 35 minutes.

When the XLS Sport was developed, all the components of the e-drive were parameterized and linked together on the **3DEXPERIENCE** platform. Every requirement, system, subsystem and part has been associated in the virtual twin, so engineers can see clearly which parts are involved in achieving each requirement.

This makes it possible to derive the e-drive of the SE Classic model from the one designed for the XLS Sport in a fast and efficient way. For instance, engineers can see that the reduced maximum speed can be achieved through changes to the gear ratio and the case gear clearance which affect lubrication. Meanwhile the lower requirements on acceleration point to modifications of the electric motor, the gear reduction ratio and the case design. Since the two cars are built on the same chassis, the attachment points must be kept the same, and these are included among the constraints built into the model.

Reusing a proven e-drive design to develop variants

Since the MODSIM approach has been used to develop the XLS Sport, parts and system simulations are already linked to the 3D model of the e-drive. This means that a modification to the 3D model will automatically generate the new corresponding meshing of the parts, keeping all the predefined boundary conditions and immediately yielding new simulation results.

To break the design cycle down further, let's look at some of the multi-physics simulations used to analyze and validate the different variants of the new e-drive.

Evaluating electromagnetic performance

A key challenge in e-drive design is finding the perfect balance of torque and speed that will make sure the vehicle performs as its driver expects it to. EVs rely on electromagnetics to provide driving torque – a very different design challenge from ICE vehicles where combustion (a chemical reaction) provides the driving force. By running an electromagnetic simulation, designers can evaluate the maximum torque, power and efficiency of the electric motor.

They can work within the simulation to analyze and optimize elements such as:

- torque and power
- efficiency, torque disturbances and demagnetization
- cost of magnets
- durability and reliability of the e-drive's electromagnetics

In the case below, different magnet configurations are evaluated and the performances are compared to the baseline. The EM-var1 design shows increased torque and power output for the same magnet mass. On the other hand, EM-var2 shows slightly better torque with significantly worse torque ripple and magnet mass. A trade-off analysis can be carried out to ensure optimal performance with minimal cost increase.

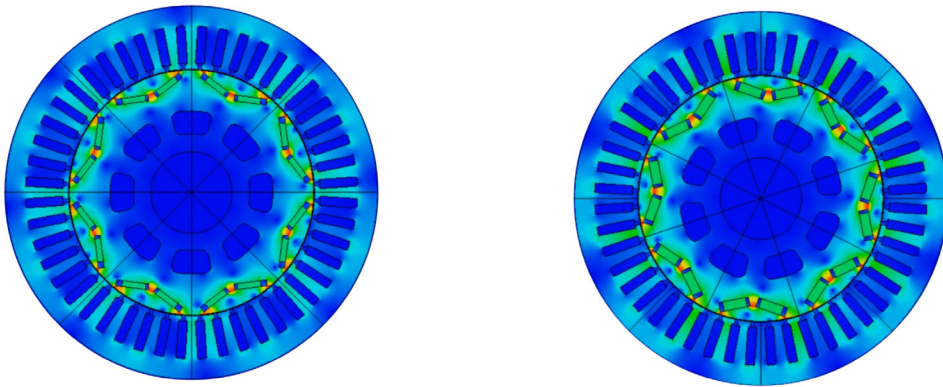


Figure 3: Electromagnetic map of Standard Vehicle, efficiency > 95% (left) and electromagnetic performance of high-performance Vehicle, efficiency > 91% (right)

Using structural simulation to assess integrity

EV motors include complex elements that must be tested to make sure they can work together without failing or deforming under pressure. Assessment of the structural integrity of laminates and hairpin windings, for example, is key to ensure the lifespan of the electric motor. Structural simulation provides designers with detailed insight into how high-speed rotation can result in failure scenarios over the life of the electric machine. In the case below, an assessment of how stator dynamics respond to increased load enables designers to identify how and why different elements might fail during the vehicle's operation.

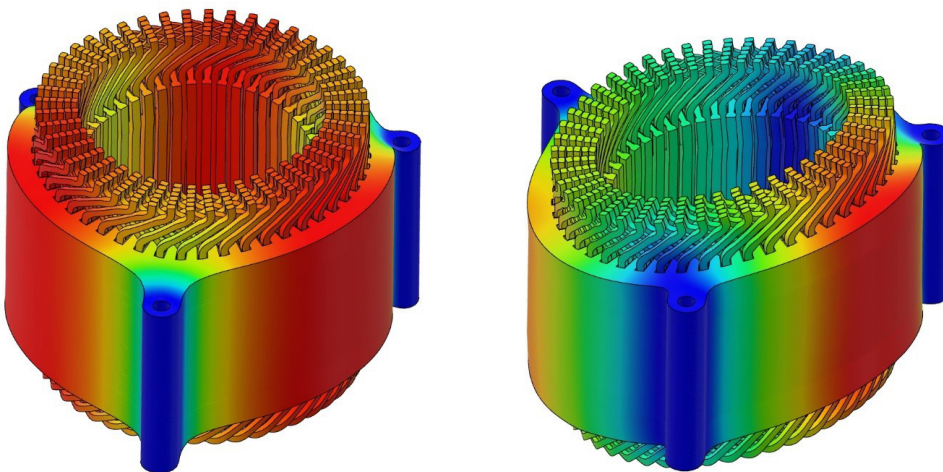


Figure 4: Assessment of stator dynamics response to the load is key to identify failure modes when the vehicle is accelerated during operation.

Thermo-fluid analysis

Heat transfer and cooling are critical for the e-drive to perform well in different conditions and to ensure its durability. By modeling and simulating thermo-fluid performance, designers can evaluate the coolant mass flow needed to maintain a good operating temperature, identify the areas that need adjusting, and see how and where their changes affect thermo-fluid performance.

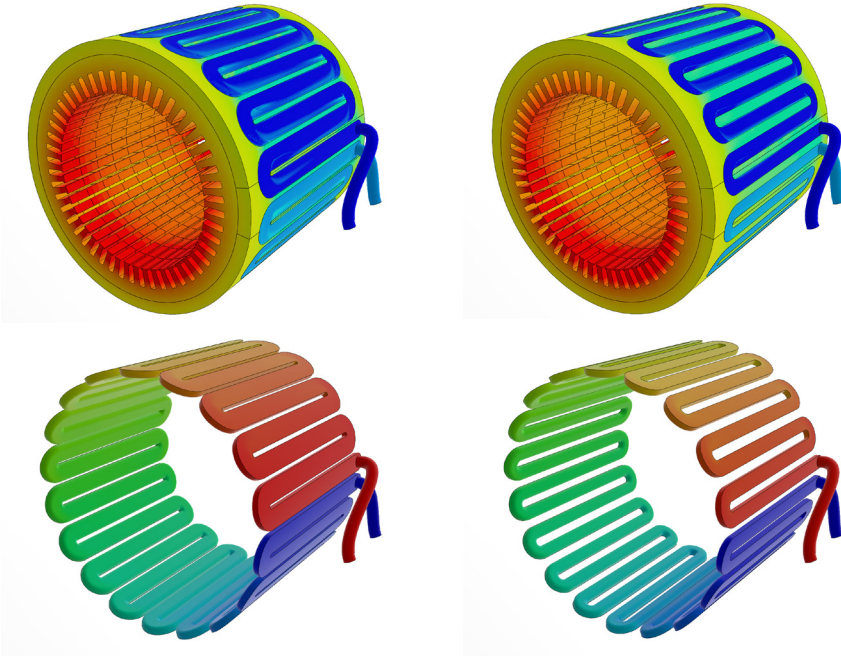


Figure 5. Temperature contour plot of design 1 (top left) and pressure plot of fluid domain (bottom left). The new design with 27% reduction of channel width (right column). The temperature distribution of new design (top right) showed similar temperature range and pressure drop (bottom right) is reduced by 6%.

Refining noise and vibration

It's essential that the e-drive can perform efficiently and quietly, even when challenging driving conditions demand extra power while other systems, such as the air conditioning, are also drawing energy from the battery. Often, with traditional design methods, cabin vibration issues in conditions like these are only discovered when the physical prototype of the e-drive goes for testing.

By running noise and vibration simulations, designers can make sure that the e-drive runs smoothly in different conditions, meeting requirements for power, performance and cabin comfort.

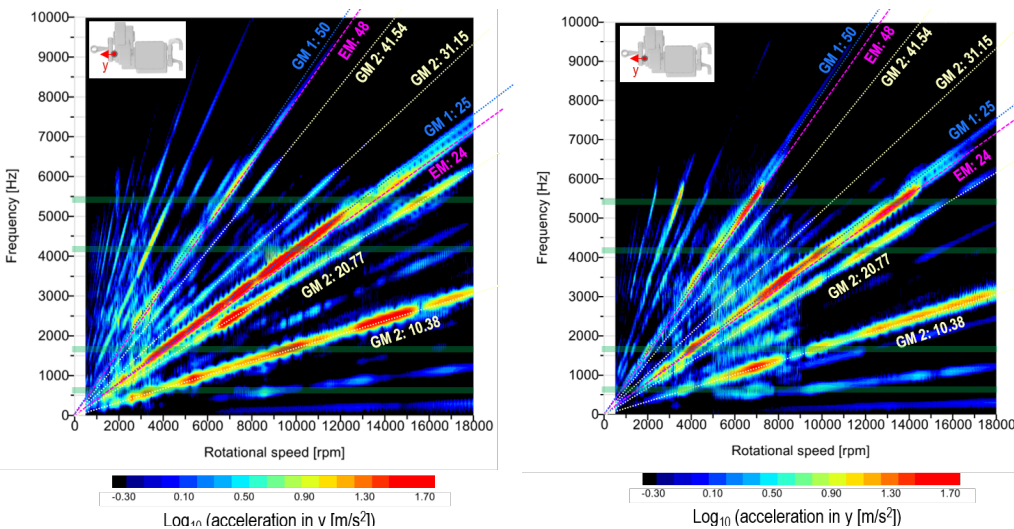


Figure 6: Campbell diagrams of the concept case where only the case is modeled as a flexible body (left) and the detailed case where all the components are modeled as flexible bodies (right) based on the axial acceleration at the end of high-speed shaft: resonance frequencies common to both are indicated in green lines (order lines for gear meshing (GM 1 and 2) and electric machine (EM) are also shown)

Optimizing gear lubrication

Gear lubrication is important to reduce friction and wear & tear, increase efficiency and improve the durability of the gear. The **3DEXPERIENCE** platform enables designers to generate a 3D, multi-phase simulation of lubrication flow with moving geometry, so they can assess the mechanical efficiency of the gear drive.

This can be coupled with thermal analysis to gauge temperature distribution in the gear in relation to the thickness and flow of the lubricant.

Designers can also analyze the interaction between gear lubrication and air, so they can adjust their designs to maximize lubrication and minimize churning losses.

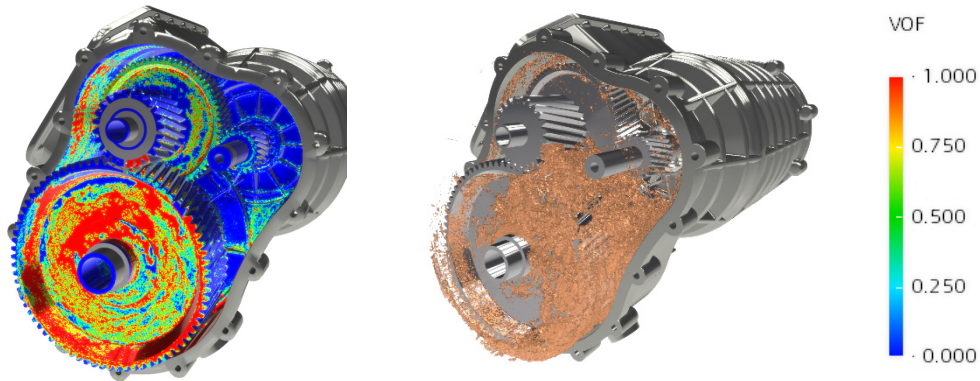


Figure 7: Gear reducer XFlow simulation results. Gear surface and casing oil coverage (left) to inspect lubricated area around the gear teeth. Gear reducer internal oil splash pattern (right) to check oil distribution of internal region.

INTEGRATION WITH OTHER SYSTEMS—POWER ELECTRONICS

Working with a virtual twin and a single source of truth also facilitates the integration with other, key systems of the electric vehicle. The power electronic system manages the transfer and conversion of electrical energy between the battery and various components of the vehicle such as the electric drive. Multiple disciplines are involved in the design of this system, so it's crucial that everyone involved is working with the latest data model.

For example, power conversion in an inverter—which controls the power delivered to the motor—is the second largest source of electric energy loss in an EV, after the motor itself. Simulation enables designers across disciplines to maximize the inverter's performance by optimizing the electrical design of interconnects and inverter switching.

Simulation allows designers to make sure the inverter controls the power delivered to the motor in a way that is robust, fast and accurate. Virtual prototyping enables them to efficiently study the sophisticated cooling mechanisms required to do that.

A MODSIM approach is also enabling EV designers to overcome a new challenge—electromagnetic compatibility (EMC)—which simply was not present in internal combustion engine design. Designers need a clear, holistic view of how the EV's electronic components will interact with electromagnetic waves, so they can make sure the vehicle's systems will still work properly when exposed to high levels of interference.

Electromagnetic simulation tools enable this holistic approach, empowering designers to create EMC compliant designs before the product is built. Using these tools, designers can assess how different parts of the vehicle will respond to electromagnetic frequencies and make any required changes in the virtual model.

MEETING MULTIPLE MILESTONES

As competition continues to intensify in EV markets across the world, vehicle manufacturers need to get new models to market fast. To do that, they're looking for rapid and robust innovation processes that empower people across the design cycle.

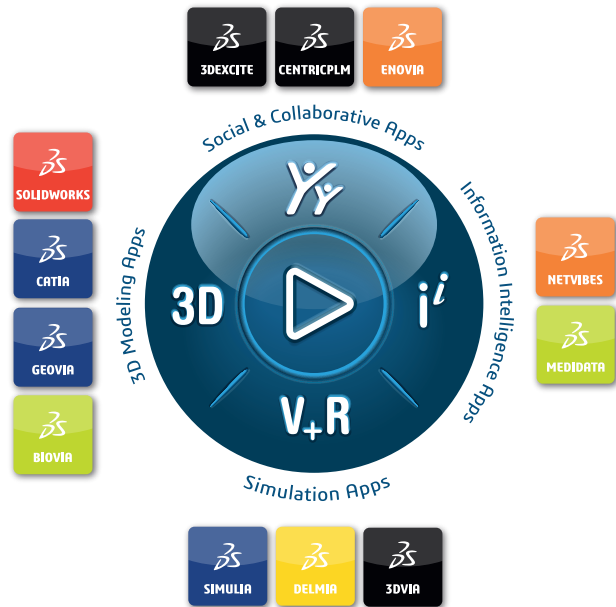
By using the MODSIM approach, unifying modeling and simulation on one common data model and integrating their data in one collaborative environment, the **3DEXPERIENCE** platform allows vehicle makers to put automated, customizable and highly flexible tools in the hands of experts and non-experts alike, at every stage, from concept to detailed design. Being able to simulate and test their designs early on, in a virtual twin that is connected to all the other models that make up the vehicle, means that designers can make sure they meet all KPIs during the virtual phase of development.

This helps vehicle manufacturers to achieve the best balance of competing performance targets, accelerate e-drive innovation and enable right-first-time designs during the virtual phase of development. As a result, they can meet their development milestones with lean teams in a highly efficient way.

Our **3DEXPERIENCE**® platform powers our brand applications, serving 12 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the **3DEXPERIENCE** Company, is a catalyst for human progress. We provide business and people with collaborative virtual environments to imagine sustainable innovations. By creating virtual twin experiences of the real world with our **3DEXPERIENCE** platform and applications, our customers can redefine the creation, production and life-cycle-management processes of their offer and thus have a meaningful impact to make the world more sustainable. The beauty of the Experience Economy is that it is a human-centered economy for the benefit of all –consumers, patients and citizens.

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