SIMULATION APPLICATIONS STREAMLINE THE DEVELOPMENT OF ELECTRIC VEHICLE MOTORS

Volkswagen Kassel accelerates the design process for electric motors by building and distributing simulation applications that evaluate the strength of rotor laminations.

By **THOMAS FORRISTER**

AS MORE CONSUMERS EXPRESS concern for the environment, electric vehicles are on track to outpace conventional internal combustion engine vehicles as the transportation mode of choice. In response to this growing demand, leading automakers are doing their part to pave the way for EVs, revving up the development of electric and hybrid motors alongside the manufacturers of combustion engines. One such automaker is Volkswagen, whose Kassel plant in Germany specializes in the development, planning, and production of electric drives. It has a production output of 150 electric and 300 hybrid drives daily.

As essential components in electric drives, rotors need to be tested for durability, since they must endure a very large number of revolutions at varying speed and torque during drive operation. However, evaluating the strength of rotor laminations is time-consuming. VW Kassel is automating this test process for rotors, as well as reducing development costs and increasing product quality, by building simulation applications with the COMSOL Multiphysics® software.

BALANCING ELECTROMAGNETIC AND MECHANICAL REQUIREMENTS

IN 2015, VOLKSWAGEN began developing a modular system to optimize EV design and make the manufacturing process more efficient, called the Modular Electrification Toolkit (MEB). The MEB accounts for the torque, power, and speed for the main rear-wheel drive and for the optional front-wheel drive that is used in all-wheel drive versions (Figure 1). Among other requirements, such as the ratios for the axles, drive units, weight, and wheelbases, the design and placement of the high-voltage drive battery plays a major role in the overall MEB concept. While the MEB helps to optimize individual components and the system as a whole, balancing these requirements takes careful consideration on the part of the designer, especially when accounting for new technologies like digitalization, autonomous driving, and electric drives.

From the very beginning of the electric drive development process, there has been close cooperation between staff involved in design, simulation, and testing at VW Kassel. First, the simulation experts review the performance specifications for an electric drive and use simulation to investigate how to best approach the design. For example, modeling the drive greatly reduces the number of variants, and distributing a simulation application based on this model enables the designers to then benchmark different variants and choose the best one.

This collaboration is vital and beneficial to all, as simulation cannot cover all of the real-world issues. Hence, the test process plays an important role in the development process. In addition, the experimental test procedure helps to improve the simulation models.

"In the development process of electrical machines, one has to fulfill

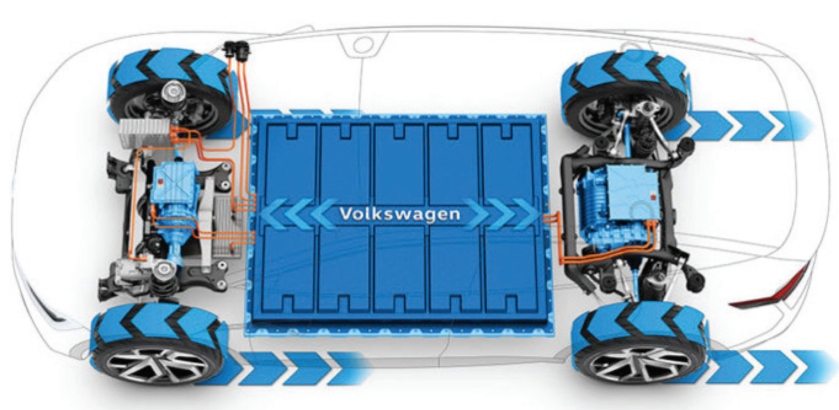

Figure 1. Schematic of the MEB, with the optional all-wheel drive (left, front of the vehicle) and the main drive (right, rear of the vehicle).

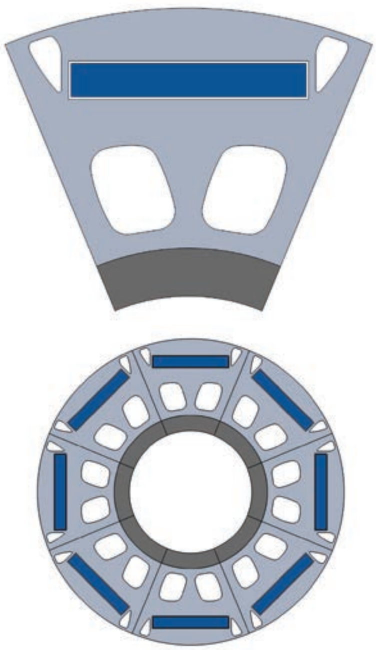

Figure 2. A typical rotor setup with the rotor plates, shaft, and magnet.

many requirements," explains Dr. Steffen Rothe, simulation engineer of component development at VW Kassel. "On one hand, the machine has to match electrical requirements for the torque and power. On the other hand, the rotor has to possess a certain durability, where the centrifugal force is the major load for the rotor."

Further, balancing dual requirements can be challenging, as they are sometimes at odds. For example, while it is better to use thin, weblike structures for the electromagnetic requirements, thicker structures are preferable for mechanical durability. It is important that these requirements are addressed early on in the development process. One way to do so efficiently is to simulate all of the load cases covering the requirements. "Simulation," Rothe says, "plays a major role in accelerating the design process."

"Many industrial simulation programs are designed as a black box, whereas COMSOL Multiphysics® is unique in its transparency. It enables users to view and modify the implemented equations, or even add your own," says Rothe. Furthermore the software is designed as a multiphysics tool from the beginning and enables users to simulate different physical fields simultaneously. Hence, the user can combine different physical fields to do something completely new.

However, analyzing complex physical problems such as these can be challenging, even for a simulation expert. The team needed a way to communicate with colleagues and enable nonexperts in mechanical simulations to test certain parameters. The designers were able to meet these needs by using the Application Builder, a built-in tool in COMSOL Multiphysics®, to create simulation applications that predict the stresses in a rotor.

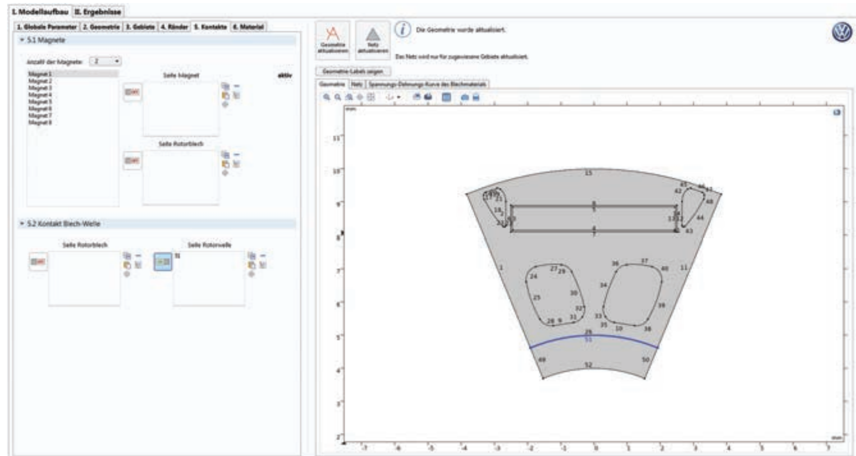

Figure 3. An example of the simulation application's user interface.

» IMPROVING EV PRODUCTION WITH SPECIALIZED APPLICATIONS

TO DESIGN AN APPLICATION for colleagues to evaluate the strength and durability of rotor laminations, simulation experts Marie Hermanns and Steffen Rothe considered which part of the model could be automated, which model parameters were variable, and which results the application should show.

For a typical rotor setup (Figure 2), the simulation experts concluded that they could automate the load testing to include interference, temperature, and operating speed. These are parameters that colleagues in other departments would benefit from being able to change themselves. General variable parameters include geometry, area, interference, contacts, number of active magnets, and materials. These considerations helped Hermanns put together an intuitive user interface for the application (Figure 3) that colleagues could use to automate the calculations needed.

"The idea was to create an application for colleagues to enable an easy and fast way to benchmark different designs," Hermanns says. "Additionally, one can create a tool for a specific problem with an intuitive user interface. In this case, the user does not have to learn the details

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of how the simulation works."

STANDARDIZING DEVELOPMENT TO SERVE COMPANY AND CUSTOMER NEEDS

IN ADDITION TO AUTOMATING the development process among departments at VW Kassel, specialized simulation applications help the engineers standardize their benchmarking process of rotor laminations.

The application shortens the time it takes to perform common tasks such as applying boundary conditions, materials, and loads, and is standardized and combined into a user interface. A further benefit is the automatically generated report, which includes a strength rating for laminated rotor sheet sections and helps to standardize the report summaries across teams (Figure 4).

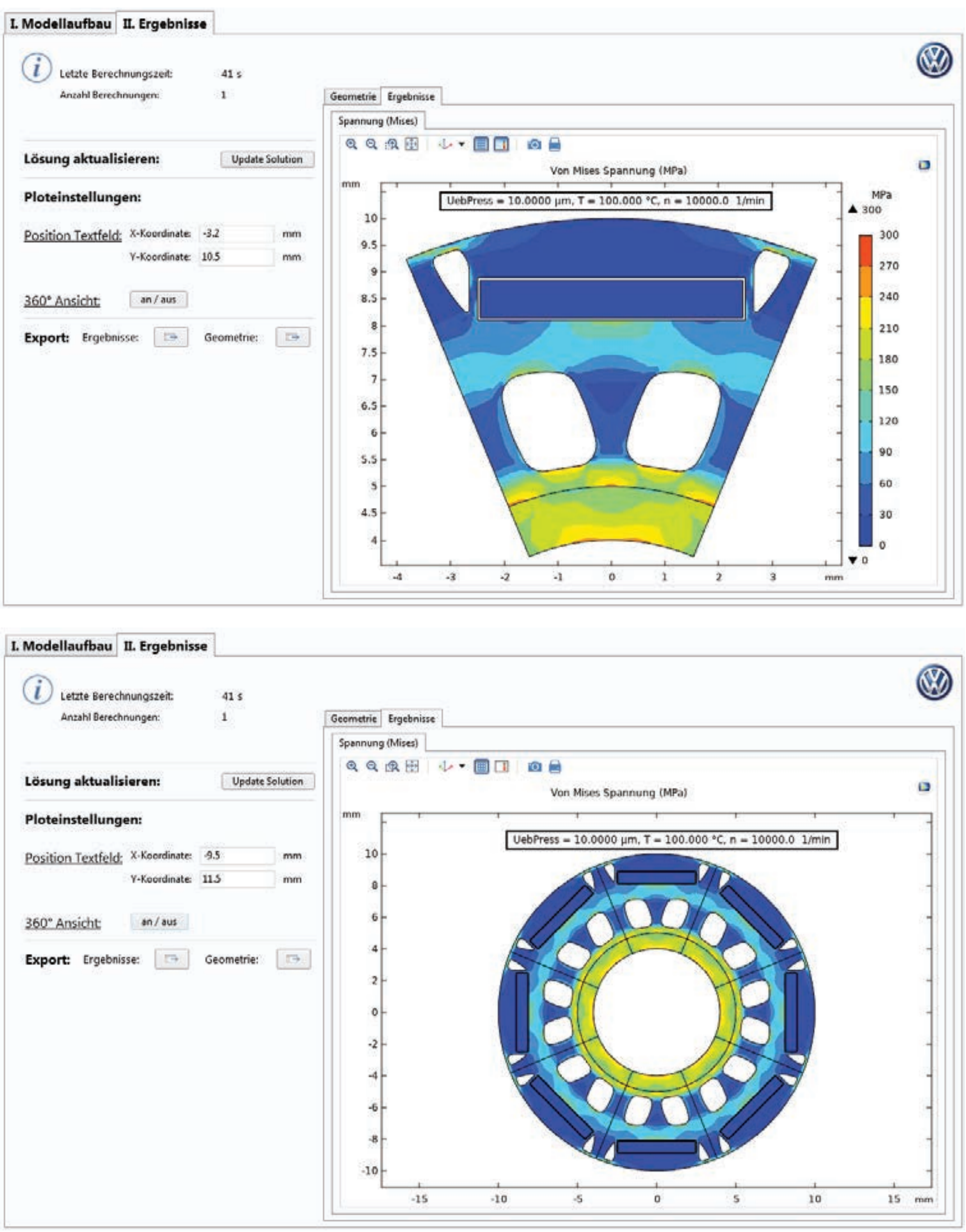

Figure 4. Standardized stress results for the rotor.

Through the stress analysis of rotor laminations using simulation applications, engineers at VW Kassel are able to save time and money during the development process of electric drives. The applications also contribute to increasing product quality by helping simulation experts and nonexperts alike automate the lengthy model construction process and standardize models and results, shortening the distance it takes to get from model to concept vehicle to commercially available EV. ◎

Top: Marie Hermanns (simulation engineer). Bottom: Steffen Rothe (simulation engineer).