Keeping It Real

As engineering simulation software becomes pervasive and instantaneous, the technology will have a disruptive impact on the profession.

BY AHMED K. NOOR

Designing an automobile body is as much an artform as anything. On top of an underlying armature of metal and foam, a layer of clay is applied and shaped until the designer feels he has captured the essence of a sports car or SUV. The full-scale model is then sent to a wind tunnel to check the aerodynamic flow over the surface.

One advantage, the modelers say, is speed and efficiency. Whereas it has taken hours to update a large computer-aided design model and rerun a computational fluid dynamics simulation, the clay model can be revised with a knife and the flick of a wrist.

In the face of some entrenched resistance, however, new technology is improving on this method—and for good reason. Real-world road conditions provide different aerodynamic performance compared to wind tunnel testing because of open-road wavering caused by cross winds, traffic, and other unsteady effects not seen in wind tunnels. And thanks to some recent advances in modeling and simulation software, models can be altered and simulations can be rerun very quickly or, in some cases, in real time.

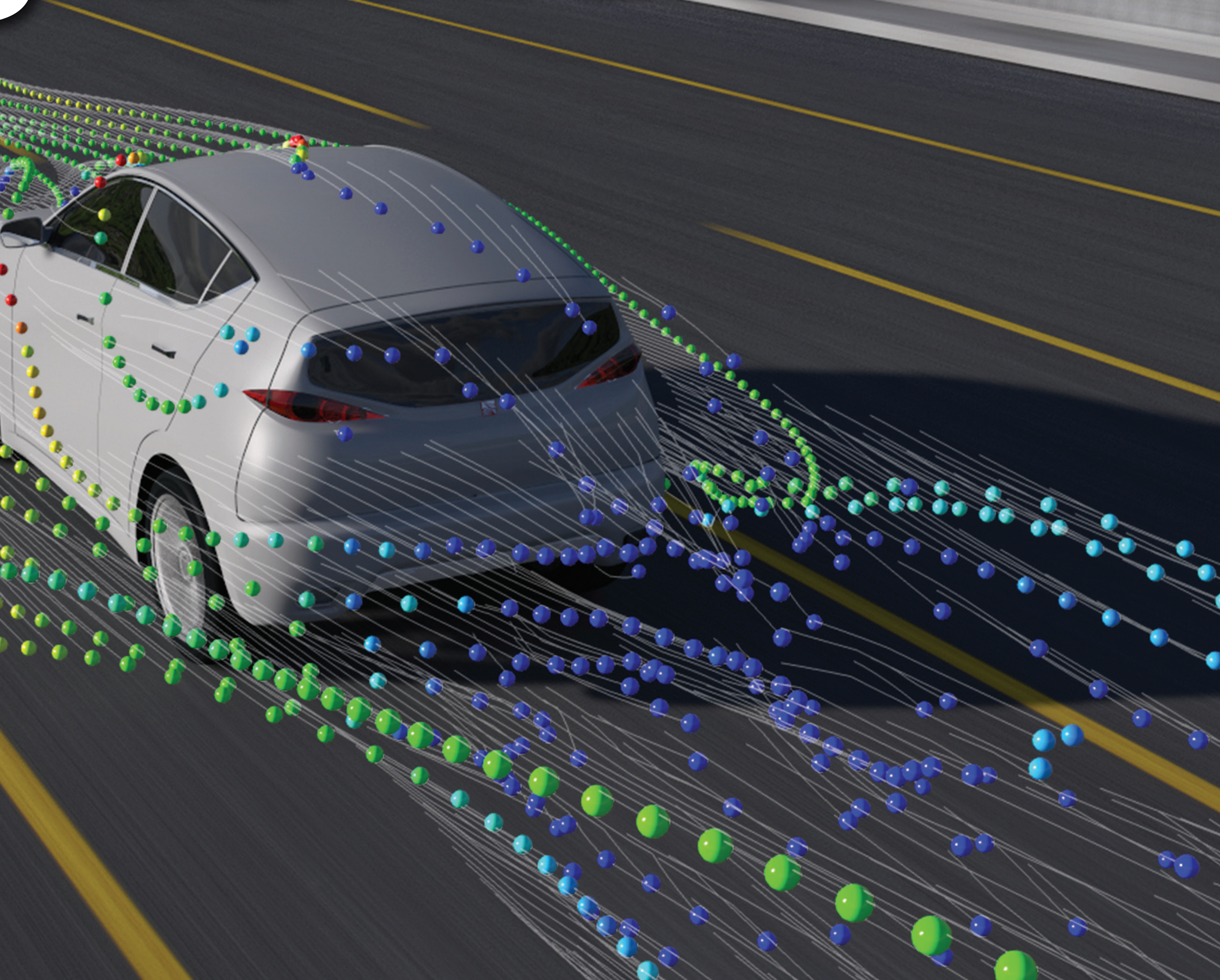
The current wave of digital transformation has produced a rapid expansion of engineering simulations across the entire product lifecycle, beginning with digital exploration, continuing to digital prototyping and then operations and maintenance.

In addition, dramatic improvements have been made in various modeling and simulation technologies and facilities. These include the use of high-performance multicore and GPU processors, incorporation of AI and machine learning facilities, novel user interfaces, and new tools for better interaction and visualizing simulations.

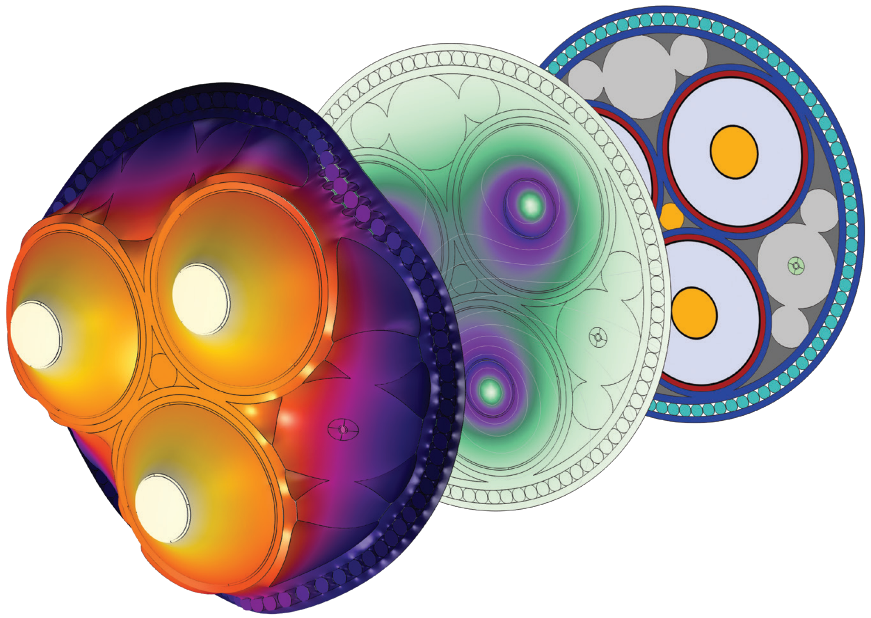
Thanks to these improvements, simulation software is more powerful than ever before, advancing across a number of different dimensions. The models are more accurate, able to consider multiple physical forces in an integrated fashion to more closely represent real conditions and enable engineers to simulate entire system's performance. Second, the combination of software and hardware has increased the speed at which these models operate. Third—and related to speed—many of the applications enable engineers to explore models interactively and can respond to changes in real time.

Finally, the software has become powerful enough and integrated with artificial intelligence that no longer does one need to be an expert to obtain superior results.

Simulation software is now more pervasive and increasingly ingrained into the DNA of mainstream engineering. It provides engineers a faster, simpler way to explore and design digitally. And coupled with seamless and connected workflows with the core design tools in the market, simulation will enable engineers to make educated design decisions.



The real-world aerodynamic performance of a vehicle can be better simulated in computer models such as SIMULIA than in wind tunnels. *Image: Dassault Systèmes.*



A visualization displays both temperature (left) and magnetic flux denisty norm (center) in the cross section of an industrial-scale cable (right).
Image: COMSOL

At the moment, each of the leading simulation vendors is pursuing a slightly different path. However, these differences illuminate the contours of what is on the horizon and point to the future of software-enhanced engineering.

Interactive Interface

One company that has seen a glimpse of the future is Wibotic, a maker of battery charging platforms for mobile robots and drones. The company was looking for a way to redesign the charging station to better dissipate the heat produced during charging.

The design team turned to ANSYS Discovery, a suite of products that provides an interactive interface for manipulating geometry, materials types, or physics inputs, then instantaneously displaying changes in performance. In about 10 minutes, Wibotic engineers were able to analyze a completely new model and test thermal characteristics and airflow. The ability to simulate multiple design iterations in a short amount of time resulted in reduced prototyping costs, while the time saved was spent on other tasks related to product development, like usability, aesthetic design, and design for manufacturability, as well as shortening the time to market.

ANSYS has optimized speed in its Discovery suite—the software takes advantage of the computational power of NVIDIA graphics processing units and CUDA, parallel GPU programming tools. According to the company, an engineer can start seeing simulation results in seconds after importing a geometry, with no need for a high-performance computing system, and can change the design and physics and immediately view the results. For instance, a user can apply a combustion force to a model of a piston cylinder and see the stresses throughout the entire 3-D volume of the engine—in just seconds. In a single afternoon, an engineer can explore countless design options with near real-time feedback on structural, thermal, or fluids performance.

Other new approaches in the ANSYS Discovery suite include tight coupling of simulation with geometric modeling, which allows for instant modification and results update from a single graphical context, and new automated solver and discretization methods that make all decisions about time step, meshing, and convergence based on physics conditions and behavior without user interaction.

Other software vendors are also looking to update their interfaces. COMSOL, the provider of an integrated software environment for creating physics-based models and simulation apps, has introduced the Application Builder for its multiphysics software. The Application Builder allows for customized user interfaces to multiphysics models as well as a means for communicating complex design ideas across multiple simulation and process departments. The goal is to allow app users to easily explore the outcomes of proposed designs.

The potential for this feature is illustrated by work done by researchers at the Manufacturing Technology Centre (MTC) in Coventry, England, to communicate their work into shaped metal deposition, an additive manufacturing technique where sheets of molten metal are slowly deposited, layer by layer, building up a surface in a process similar to welding. In SMD, thermal expansion can deform the cladding as it cools, so such deformations must be kept to a minimum.

MTC built an app using the Application Builder available in COMSOL Multiphysics to allow users to experiment with the deposition process. Geometries, heat sources, materials, and deposition paths can all be altered using the app to test whether a viable end product is produced. The app allows an end user, who may be oblivious to the underlying model complexities, to test the system for specific customer needs and projects. Since MTC's modeling experts are not needed to run these simulations, their time is freed up, while end users can interact and thoroughly test the system to their satisfaction.

In another advance in multiphysics simulation, COMSOL has introduced a hybrid boundary element method-finite element method technology that enables computation of acoustics and acoustic-structure interactions. With this new capability, users can analyze the full range of acoustic frequencies, from the lowest bass notes to ultrasound, while tying up fewer computing resources than running a finite-elements simulation alone. Along with this capability, users can also leverage all the possible multiphysics couplings available in the software.

Multiscale Capabilities

As mentioned earlier, automobile manufacturing can benefit tremendously from advanced simulation. As an alternative to wind-tunnel testing, for example, a detailed computer model of a vehicle can be placed in a SIMULIA PowerFlow computational fluid dynamics simulation. The simulation can virtually test and optimize designs against real-world scenarios—some of which cannot be reproduced in a test chamber. SIMULIA is a part of Dassault Systèmes and is available in the company's 3DEXPERIENCE suite of computer-aided design, 3-D digital mock-up, and product lifecycle management software.

In addition to multiphysics, Dassault's applications boast multiscale capabilities, able to handle everything from atoms and molecules to airplanes and even large cities in a single simulation. That capacity can be seen in an automobile design simulation concerning electronic connections within and between cars.

Today's cars contain an increasing number of electronic systems, all of which need to be connected either via cables or wirelessly. Many systems require antennas such as the navigation system, distance radar, keyless entry, or tire pressure monitors, just to name a few.

There is a large variety of different antenna types, too: window glass antennas for radio, rooftop antennas for communication and GPS positioning, and many other antennas for connectivity, either vehicle to vehicle or vehicle to the environment, including the connection of user's mobile phone to the entertainment system. In addition, there are many antennas related to driving assistance or autonomous drive systems such as the 77 Ghz long range distance radar.

All together there are dozens of antennas in a car which need to be installed at the right positions. Ideally these antennas should be invisible and must not interfere with other antennas or electronic systems in the car.

The ability to model multiple physical parameters over multiple scales enables Dassault's applications to examine very short wavelength waves over a large space within the car. This allows designers to ensure that there is enough space to place each antenna while positioning them in locations that

SIMULATION INTERFACES

Advanced modeling software is creating real-time dynamic simulations. Novel interface technologies are creating new ways to present these simulations to users.

The most market-ready technology is extended reality headset. Extended reality is an umbrella term for virtual, augmented, and mixed reality, and blurs the line between the physical and simulated worlds. Perhaps the greatest potential for XR is in delivering shared and collaborative experiences as the next mobile computing platform.

Existing XR platforms include the Qualcomm XR smart glasses powered by the company's Snapdragon XR1 processor, introduced in late May 2018, and the Microsoft Hololens, which I wrote about in *Mechanical Engineering* in October 2016. The next version of HoloLens—the HoloLens 2 headset, code named Sydney—is planned for release in 2019, will feature an improved field of view, and will be much lighter and more comfortable to wear. The HoloLens 2 will also include Microsoft's latest generation of the Kinect sensor, and a custom AI chip to improve performance.

Looking further out, some recent work has looked to linking extended reality to the ultimate computing platform—the human brain. Attempts are being made to develop brain-computer interfaces that allow users to scroll menus, select items, launch applications, manipulate objects, and even input text using only their brain activity.

Examples of recent efforts include Neurable, a brain computer interface for mixed reality that enables the user to navigate only with thought. Neuralink is a neurotechnology company working on developing ultrahigh bandwidth brain-machine interfaces to connect humans and computers. The interfaces will enable human brains to directly interface with software and hardware, effectively bypassing low-bandwidth mechanisms such as speaking or texting to convey the thoughts.

are able to withstand small bumps and jolts. Additionally, the design must be mindful of the effects of sensors getting dirty or covered with water or ice, so the simulation must take air flow into account.

The complex nature of products today—that they are not purely mechanical but rather mechatronic—is pushing multidiscipline simulation into the forefront of many applications. One software publisher, Siemens PLM, is addressing the changing role of simulation by providing Simcenter, a complete portfolio of simulation and test solutions for the entire development cycle. For example, Simcenter provides full end-to-end durability testing, combining data collection and analytics into one single environment in its newly released Simcenter Testlab application. It covers every step of a typical test, from channel setup and measurements, to validation, consolidation, analysis, and reporting.

Researchers at Siemens also are looking at several methods involving new approaches to grids and voxel-based analysis. The goal is to provide real-time solvers in high-dimensional design spaces that can generate both the design and the model for analysis, so that they can be used for the creative processes. The first step will be interactive cause-effect simulations for non-experts that would bring the simulation process into the initial design stages, but still require referral to high-end solvers and analysts for final verification. The analyses of these complex, high-dimensional design spaces would be presented either on a screen or through VR headsets.

In addition to traditional 3-D models from CAD and CAE systems, Siemens is facilitating the creation of digital twins—dynamic virtual replications of products and physical assets such as factories or power plants—through a variety of other solutions in its portfolio. Among these solutions are Simcenter Amesim, a multi-domain platform for system-level modeling and analysis, including software-in-the-loop and hardware-in-the-loop testing; Polarion, which manages complex configurations of embedded software through application lifecycle management; and Teamcenter, the central repository and workflow engine for managing the requirements, functional, logical, and physical aspects of a product.

SIMULATION AND AI

Artificial intelligence can augment human productivity and enable effective collaboration between intelligent tools, chatbots, and human designers. In the field of advanced simulation, the AI components can be directly embedded in the simulation model to allow testing and forecasting within digital twins and what-if analysis systems. Applying AI to optimization is another key opportunity in simulation modeling. Agent-based systems often have a lot of parameters and require impractical run times to explore all their permutations. AI can speed up calibration and deliver more efficient optimization.

Simulation facilities can be developed incorporating deep learning to replace rule-based models. This is possible when considering human behavior and decision making. The deep learning components can either be used in simulation models to reflect the real system, or simulation models can be used to train the AI components. By generating the data sets necessary for neural network training, simulation models can be a powerful tool when deploying deep learning.

Down the line, neuromorphic computers that are built from artificial neurons and synapses on a small-scale wafer—essentially brains on a chip—will be able to produce instantaneous, very large-scale complex simulations. Such simulations may very well blur the line between model and reality.

Holistic System Simulations

The use of digital twins and simulation models in production, operation, and service has been increasing in recent years. The consulting firm Gartner predicts that half of large industrial companies will leverage digital twins by 2021, resulting in those organizations gaining a 10 percent improvement in effectiveness.

Engineers have employed these dynamic detailed simulations to construct, evaluate, and validate designs in the product creation process, since they provide designers the ability to optimize deployments for peak efficiency and create other what-if scenarios. Unlike physical models, digital twins enable globally distributed, multidisciplinary teams the detailed information they need to evaluate opportunities and predict asset performance.

In several industries the design verification and product creation process is moving away from a major reliance on physical testing to almost a full virtual simulation product verification process. That covers detecting and isolating faults, performing diagnostics and troubleshooting, recommending corrective action, determining the ideal maintenance schedule, optimizing asset operation, and generating insights to improve the next generation of the product. Digital twins also have been used in model predictive control or simulation-based assist systems.

Many major software vendors have embraced the demand for creating digital twins. ANSYS, to take one example, includes a feature in its latest releases that enables engineers to quickly build, validate, and deploy these digital representations of physical products. The creation of holistic system simulations via twin building is further supported by pre-existing simulations of industrial controller software, as well as a combination of other modeling tools for plant simulation. Examples of those applications include flight control and engine control systems, landing gear systems, automatic pilots, cockpit displays, and emergency tracking systems. Together, those multifunction and multiscale simulations empower users to perform diagnostics and troubleshooting, determine the ideal maintenance programs, optimize the performance of each asset, and generate insightful data to improve the next generation of their products.

A digital twin is a virtual representation of a real product during its entire lifecycle—from design to manufacture and then performance.
Image: Siemens PLM Software

The company estimates that these digital twin features could cut maintenance costs by about 20 percent. The company is now working to develop means to create comprehensive and precise digital models of products and production operations to manage the complexity of future smart products and smart production operations.

At Siemens, the digital twin is viewed in the context of the entire lifecycle—a virtual representation of a physical product, its production processes, and its performance. For example, a digital twin is enhanced with mathematical models to enable electric motors to undergo something like a virtual X-ray: A virtual sensor developed by Siemens researchers estimates the temperature of the motor's interior, in real time, without the aid of a real physical sensor installed there. This information makes it possible to prevent unnecessary downtimes—a change that can dramatically lower operating costs

And users of Dassault Systèmes' 3DEXPERIENCE platform can develop a digital twin to provide a virtual representation of a product in order to better understand how it will be manufactured, delivered to market, and whether it can serve its users needs as it was designed. The goal is to optimize the entire value chain and increase both manufacturing and operational efficiency.

The current trend of using simulation tools pervasively throughout the product design cycle as a proven, effective means of streamlining the product development process will accelerate over the next few years. The convergence, and synergistic coupling, of a number of disruptive technologies—including artificial intelligence, extended reality, novel human-technology interfaces, multicore and quantum computing, cognitive cyber-physical systems, and Big Data prescriptive analytics—will usher in a new era providing exponential acceleration of disruptive solutions to the most challenging digital exploration problems.

Innovative organizations have to put in place processes to avoid the pain of transformation. They must rethink their strategies, retool their capabilities, and revitalize their workforce for stronger, longer-lasting success. ME

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