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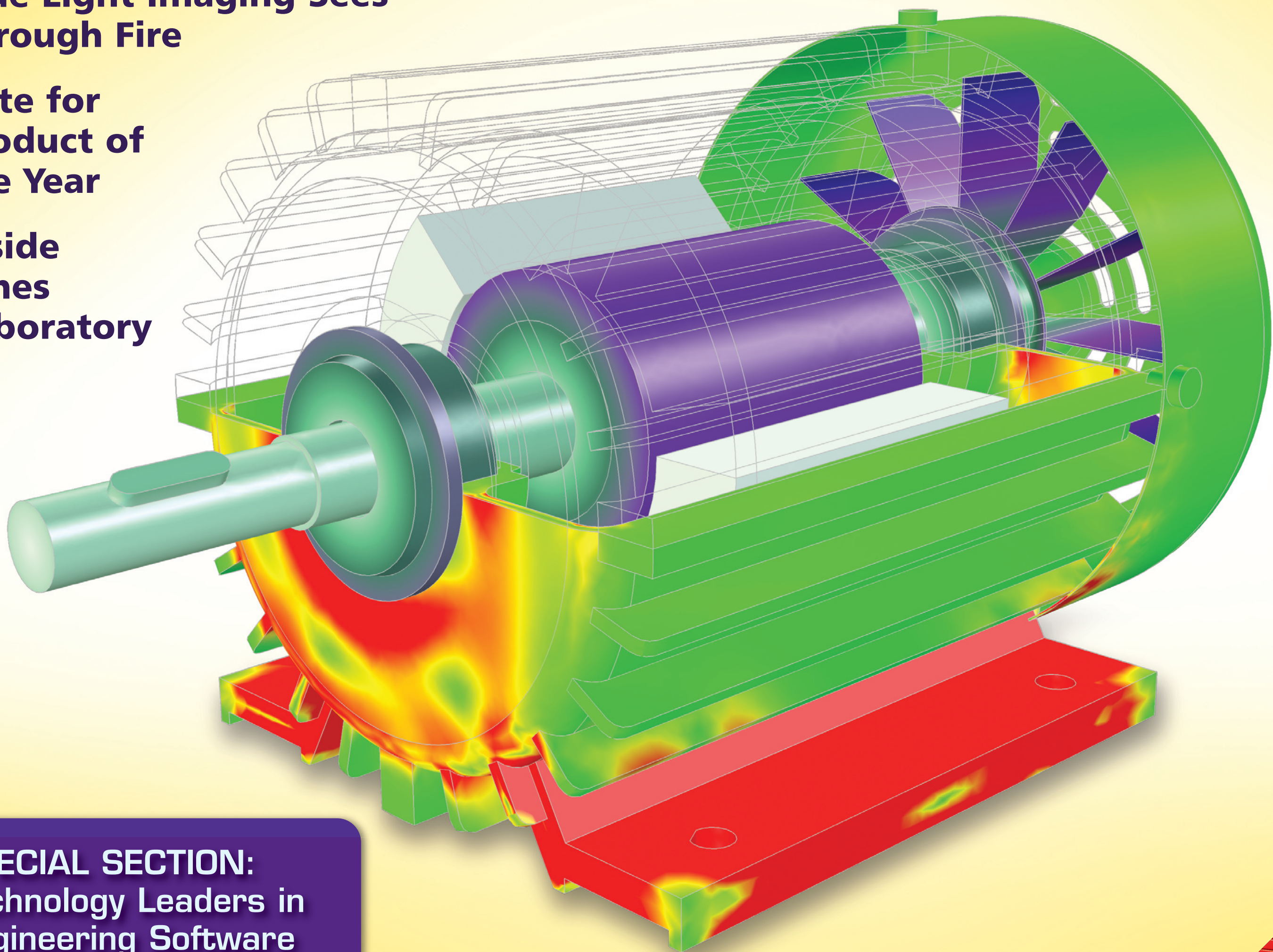

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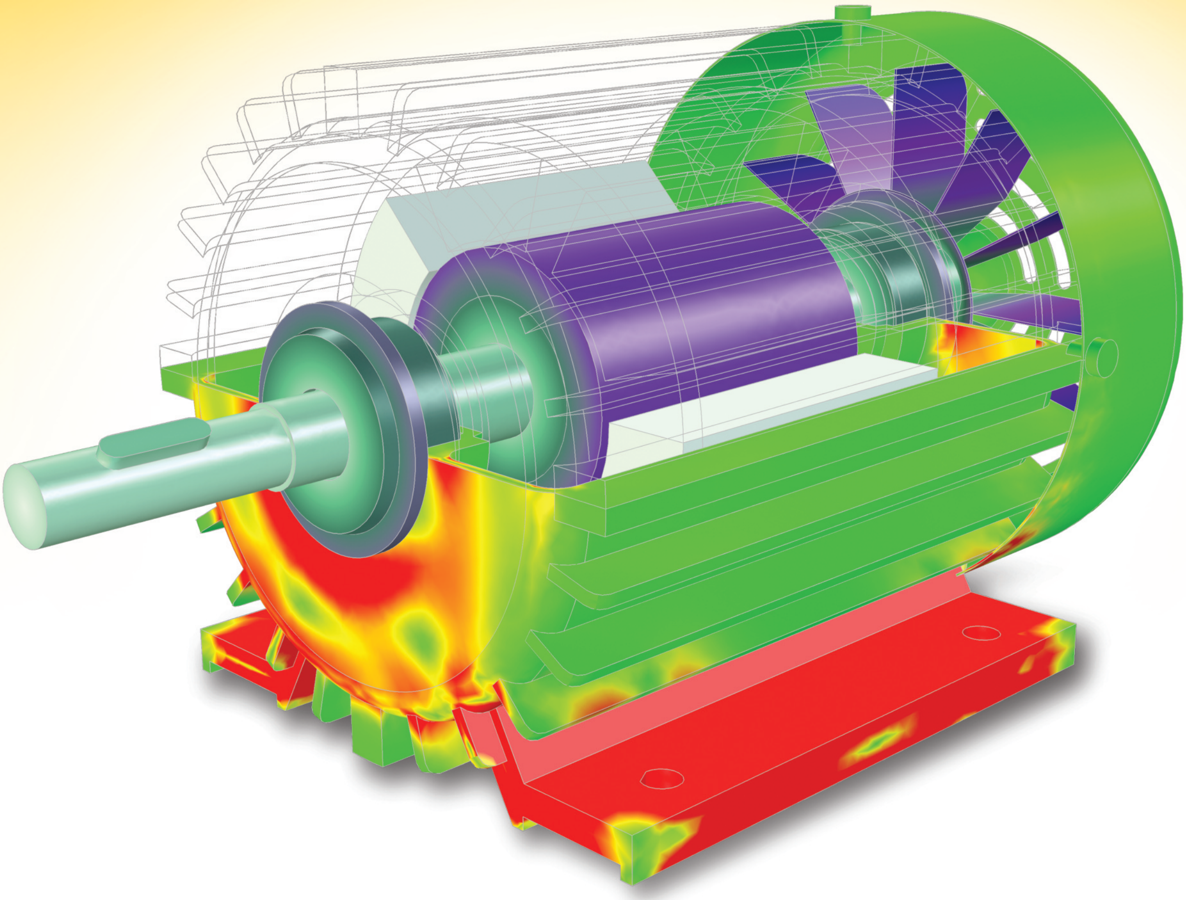

Simulation *for Everyone*

With the computational power and software available today, numerical simulation is a real option to quickly get answers to complicated technical, scientific, and engineering questions. Not only has the hardware doubled computing capacity every 18 months or so over the past decades, but the numerical algorithms have improved at the same rate.

The graph in Figure 1 shows the rate of increase in processing performance over the number of years. Note that the vertical axis is logarithmic scale. From 1968 to 2005, the combined rate of performance increased a mind-boggling 10^{14}. Both Moore's Law and the improvement of numerical algorithms have kept improving since 2005 — the reason we are at this point in history when so many previously out-of-reach problems can be solved.

Accurate multiphysics models consider a wide range of possible operating conditions and physical effects. This makes it possible to use models for understanding, designing, and optimizing processes and devices for realistic operating conditions.

Enabled by these multiphysics models of the products they want to design and a culture of collaboration with the convenience of simulation apps, designers and engineers are pushing the limits of technology while reducing the need for physical prototypes, resulting in better business and engineering solutions for everyone in the enterprise.

Topology Optimization

In recent years, engineers in many industries have adopted simulation to cut prototyping costs and speed time to market. One example is the medical device industry.

"In multiphysics modeling, we solve problems involving multiple physics that are coupled together. This is of great importance for medical device design and bioengineering," said Nagi Elabbasi, principal engineer of Veryst Engineering (Needham, MA). "In the human body, you cannot decouple blood flow from the compliance of the blood vessels. Additionally, if you have a tissue-ablation medical device, you cannot decouple the temperature field from the electric field when examining the tissue damage. The same principles apply when looking at the opening and the closing of the heart valve, which affects the blood flow and vice versa (Figure 2). The valve materials experience large deformations and strains, and have to be very reliable once put in place. Being able to model all of the physics is imperative to designing safe and innovative products," Elabbasi said.

Topology optimization — typically used in the conceptual stage of design — treats the distribution of material as a design variable and inserts or removes structures to improve the objective function. Due to the high number of design variables, only gradient-based optimization is practical. Topology optimization has, of late, dramatically increased in importance as a structural analysis method thanks to new and more affordable additive manufacturing methods. The geometrical shape that a topology optimization analysis generates is typically not suitable for traditional manufacturing methods, but is attainable with additive manufacturing methods.

Mainly used in structural mechanics, topology optimization is also used for thermal, electromagnetics, and acoustics applications. Topology optimization within structural analysis can answer the question: Given that you know the loads on the structure, which distribution of the available material maximizes stiffness? Or, conversely, how much material is necessary to obtain a predefined stiffness, and how should it be distributed?

Such investigations typically occur during the concept design stages. The conflicting goals of stiffness maximization and mass minimization lead to a continuum of possible optimal solutions, depending on how you balance the goals against each other.

The topology optimization example in Figure 3 demonstrates how to obtain an optimal distribution of a fixed amount of material in a steel hook such that stiffness is maximized. Changing the amount of material available leads to a different solution that is also Pareto optimal, representing a different balance between the conflicting objectives.

Materials Simulation

Thanks to the improved strength and reduced weight as compared to conventional materials, composite materials have many potential use cases in diverse

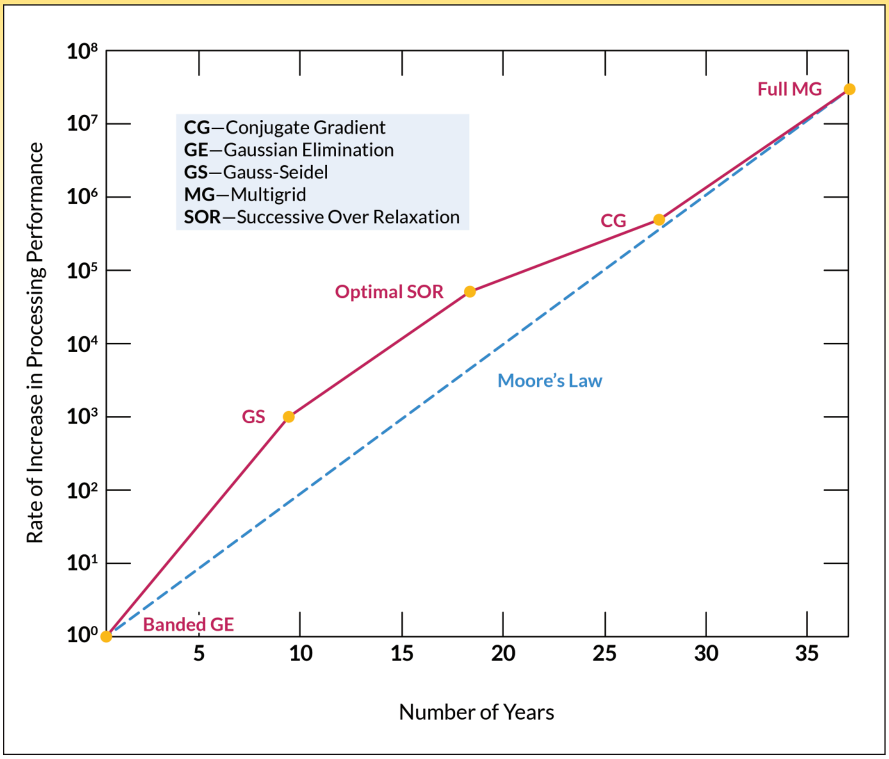

Figure 1. Rate of increase in processing performance.

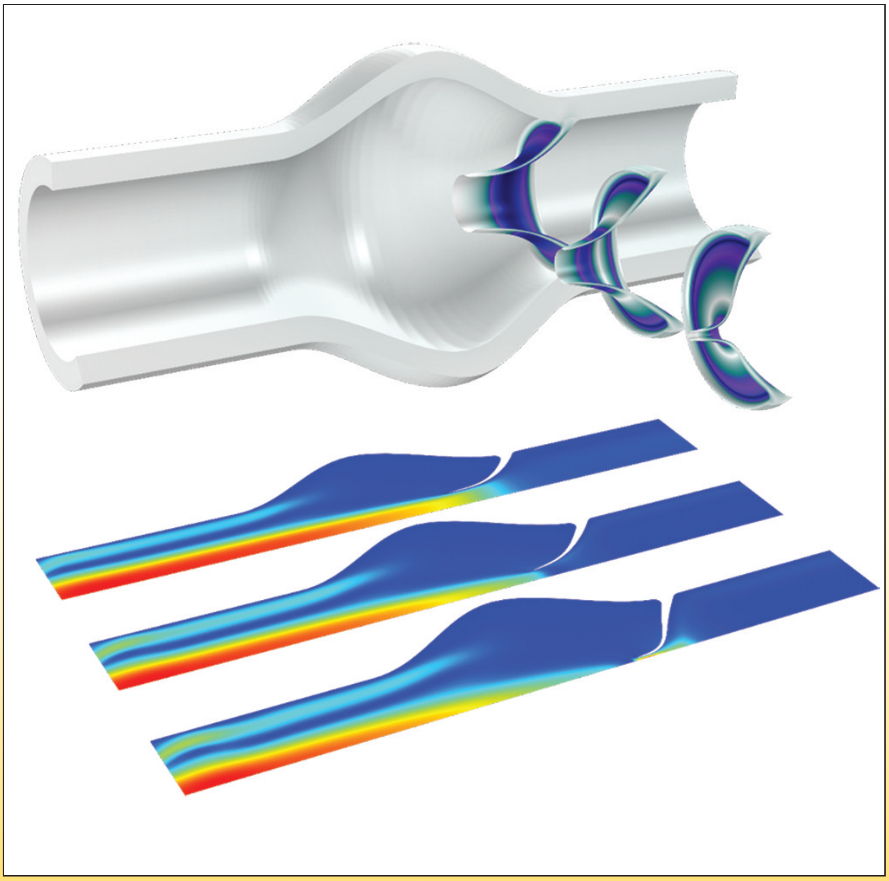

Figure 2. Fluid-structure interaction analysis of an idealized heart valve, including contact modeling and nonlinear material modeling. Deformation, von Mises stress, and velocity magnitude are shown.

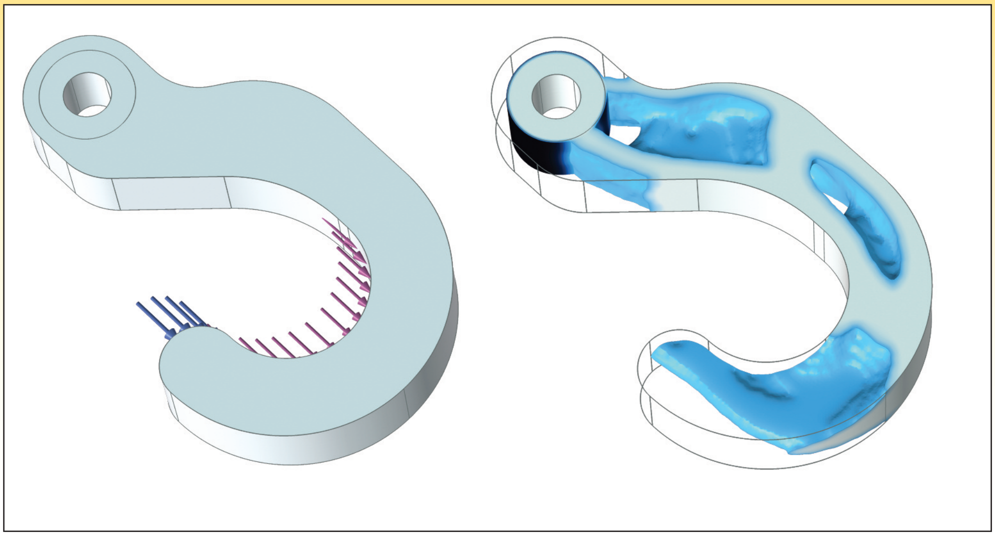

Figure 3. The optimal material distribution in a steel hook. The material distribution is optimized when subjected to two distributed load cases: one at the tip of the hook and one along its lower inner curve.

fields. Development efforts are underway in industry to embed functionality like sensing, actuation, computation, and communication into composite materials known as smart composite materials. A thorough understanding of the behavior of such materials is necessary in order to design the most accurate and reliable composite structures.

Composite materials such as carbon-fiber-reinforced polymer (CFRP) have outstanding properties. CFRP is a lightweight material with high stiffness and high temperature tolerance and is therefore used in the aerospace industry, civil engineering, and for high-end sporting goods.

The example shown in Figure 4 illustrates how carbon crystals form flat ribbons. Large numbers of these ribbons are bundled together and woven in different structures as required by the application area. The bundles have anisotropic thermal material properties; the thermal conductivity along the fiber axis is much higher than perpendicular to it.

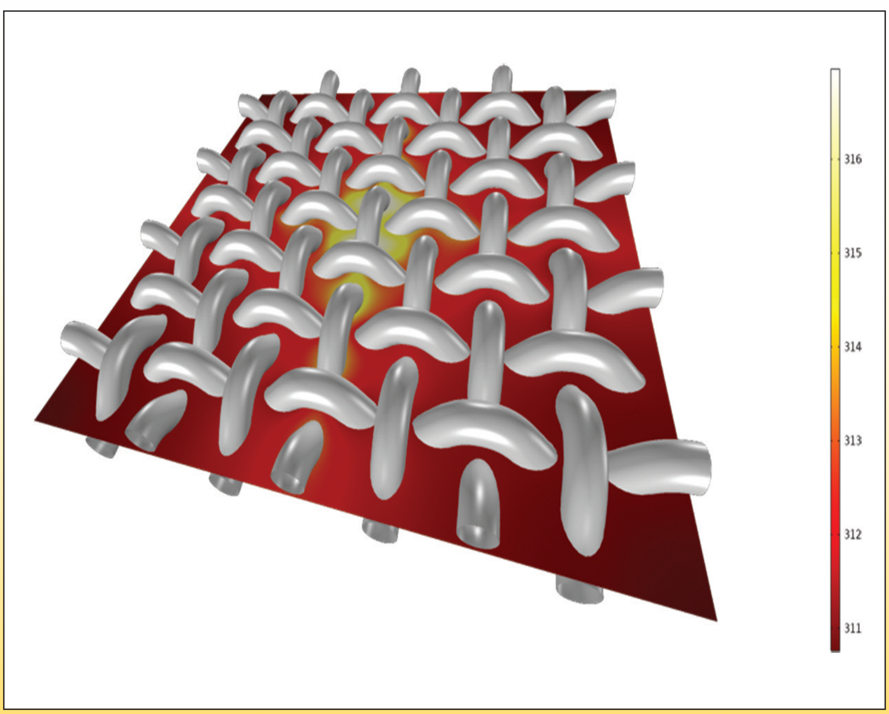

Figure 4. A heat transfer simulation of a cutout of a carbon-fiber-reinforced polymer embedded in an epoxy matrix.

This type of thermal behavior is desired in applications where cooling needs to be provided laterally rather than through the thickness of the material; for example, to efficiently transport heat from electronic components in contact with the composite material. Modeling anisotropic materials in fibers is challenging and requires a coordinate system that "follows" the curved CAD geometry. Such a curvilinear modeling tool is included in COMSOL Multiphysics.

Adopting Simulation

Creating accurate digital prototypes and deploying simulation apps has become standard practice among industry leaders. Digital prototypes push the limits of technology and reduce the need for physical prototypes, as well as create simulation apps to empower colleagues and customers worldwide to test new ideas.

Often, the key to successful engineering simulations is developing experimentally validated models that replace the use of experiments and prototypes alone and give a deeper understanding of the studied design or process. Compared to running experimental methods or testing prototypes, modeling allows for quicker and often more efficient and accurate optimization of processes and devices.

New groups of engineers are continually adopting simulation as a tool. Design engineers add physics to drawings and study the effects and optimize the geometry under physical constraints. Onsite field technicians are able to obtain answers to questions such as: Does this road need repaving now? Where exactly is the water leak in this pipe system? Reverse engineering of a product can enable engineers to assess why and how something breaks and accidents happen.

The list of ways simulation will make the world a better place is endless. With new software to create standalone simulation applications, evolution will take a leap. Researchers and scientists can now make customized applications that are easy to use for everyone.

This article was written by Svante Littmarck, President and CEO of COMSOL, Inc., Burlington, MA. For more information, visit ***http://info.hotims.com/69513-122***.