Multiphysics:

THE FUTURE *of* SIMULATION

As part of its comprehensive set of solutions for engineering simulation, ANSYS introduces new technology developments that make multiphysics simulations faster, more seamless and higher-fidelity — as well as more accessible than ever.

By Chris Wolfe, Lead Product Manager for Multiphysics, ANSYS

Engineering simulation plays a role in designing the buildings we live and work in, the cars we drive, the smartphones we carry, the medical devices that keep us healthy, our computers, our food and much more. Since ANSYS first introduced simulation software more than four decades ago, it has dramatically grown in its adoption by engineering teams around the world, in every industry, in every discipline.

Today, the majority of the world's engineering teams apply simulation tools and methods in the design phases of product development, replacing costly physical prototyping and testing with advanced numerical analyses.

Historically, engineers had to apply some degree of simplification to their simulations to meet product deadlines while improving those aspects of performance most valued by users. This often meant focusing on the single most important physical phenomenon affecting the product.

For example, designers of Formula 1 cars traditionally devoted resources to improving aerodynamics via computational fluid dynamics (CFD) simulations. Designers of construction or agricultural equipment leveraged mechanical simulation software to optimize products' ability to withstand heavy forces. Manufacturers of printed circuit boards (PCBs) invested the majority of their efforts in ensuring signal integrity.

This historic focus on a single physics yielded useful insights into critical product characteristics, often resulting in significant performance gains — at a lower investment of time and money than traditional experimental and physical prototyping methods. But, as competitive pressures have increased and consumers have become more sophisticated in their demands, today it is rare to achieve the best-possible product design when optimizing a product's response to a single physical force. To understand every force at play, and accurately predict if the product can perform well as a result, all the relevant physics need to be considered.

Being able to simulate all physics at the same time — and perform parametric optimization using multiphysics results — allows engineers to quickly gain important insight into product performance, target optimal designs faster, and release products to market earlier.
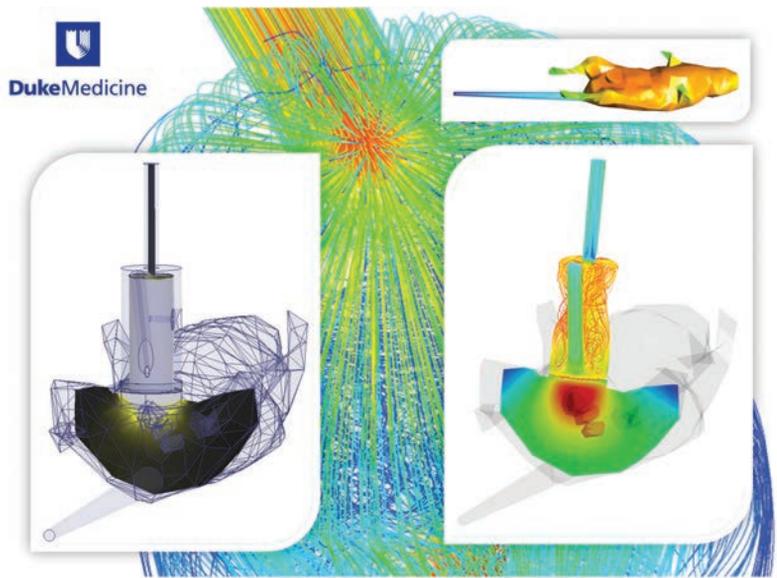
▲ The Hyperthermia Group at Duke University relies on multiphysics simulation to develop new, non-invasive approaches to treat bladder cancer. Researchers leveraged ANSYS HFSS to design a miniature water-loaded microwave antenna that is used to investigate how to deliver chemotherapeutics to the bladder in a heat-activated manner. The simulated power deposition pattern is then incorporated in ANSYS Fluent, where engineers model the effects of biological mechanisms such as blood perfusion and metabolism — which are critical to analyzing heat transfer in biological systems. To avoid overheating tissues, the antenna is cooled with a circulating fluid modeled in ANSYS CFD. All physics analyses are coupled to optimize selective heating of the bladder region.

As a result of applying these tools and processes, today's Formula 1 engineers gain new insights on how to balance aerodynamics with high power, structural integrity and low weight. Heavy equipment manufacturers eliminate not just structural weaknesses, but thermal stresses that can cause part deformation and failure. And PCB product designers go well beyond investigating EMI, focusing on how heat affects multiple components and solder joints.

PRODUCT COMPLEXITY: A GROWING CHALLENGE

In virtually every industry, multiphysics studies enable engineers to address an even greater challenge: the growing complexity of their product designs.

Modern product development trends — such as increasing power density of electronic devices, product miniaturization across industries, consumer demand for smart products, growing use of advanced materials and increased emphasis on sustainability — have created special challenges.

Densely packed electronics need adequate cooling, which is often provided by fans and heat sinks that must be carefully engineered. Chip manufacturers need to understand the impact of heat on the circuit board and solder joints — especially thermal deformation caused by temperature fluctuations — to develop robust electronic products that don't fail under on-design or off-design conditions.

Medical devices — which are increasingly designed for operation at nano scale — must perform flawlessly in the presence of strong fluidic and body forces. The individual patient's geometry, blood vessel contraction, blood flow patterns and characteristics of surrounding internal organs must all be accounted for simultaneously when predicting the behavior of a particular device or procedure.

New advanced composite materials comprise layers of fibers, some of which have unique thermo-electric properties. Car bodies and airplane hulls made of such materials must be optimized not only for thermo-electric performance, but for aerodynamic performance, vibration response, energy efficiency and long-term reliability.

These and other trends make it more and more challenging for engineering

Rarely can engineers achieve the best-possible product design when optimizing a product's response to a single physical force.

teams to answer essential product development questions:

- What are all the potential sources of product failure?

- How can we achieve the best trade-off among multiple performance requirements?

- Can the specified materials withstand all the expected fluidic and mechanical forces?

- Is the amount of cooling sufficient, given the potential for thermal transfer among components?

- Can this product be produced time- and cost-efficiently — while also minimizing material, energy and waste?

Growing design complexity is making it harder to answer these questions with absolute confidence. At the same time, it has never been more crucial to eliminate product failure and deliver reliable performance.

MULTIPHYSICS ANALYSIS: A FLEXIBLE, ACCESSIBLE APPROACH

Multiphysics simulation, once considered an advanced engineering strategy leveraged only by experts, is becoming a standard part of today's product development toolkit in many industries. By using multiphysics studies to predict and verify product performance under a wide range of operating conditions — accounting for the effects of various physical forces — engineering teams can eliminate many sources of real-world product failure.

While multiple physics historically have been considered via a series of unconnected single-physics studies — focusing separately on fluids, structural, thermal and electronics effects — engineers today increasingly recognize that the interactions among physics are
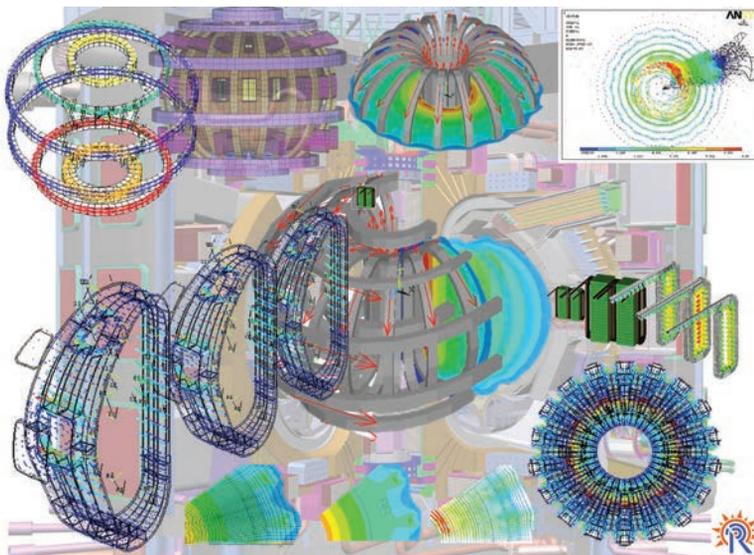
▲ The Institute for Plasma Research (IPR), part of India's Under Department of Atomic Energy, leverages the power of multiphysics simulation to investigate how nuclear fusion can be accomplished via magnetically confined plasmas. While fusion is possible, a substantial energy barrier of electrostatic forces must be overcome before it can occur. The components for fusion machines are specifically designed for very large loading conditions and are very complex in their design. To address this complexity — and to reflect very demanding operating conditions — IPR researchers conduct a large number of iterative simulations that bring together structural, thermal and electromagnetic analyses.

significant enough to require deeper investigation.

In anticipation of this need, ANSYS created a flexible, user-friendly range of capabilities that make multiphysics studies more accessible than ever. Engineering teams often begin to link multiple physics by transferring data from a previously completed physics simulation or experiment, for use as either initial or boundary conditions. Results transferred as boundary data one time — or at multiple times during the simulation — form the basis for one-way multiphysics analysis. Enabled by ANSYS software, this highly accurate transfer of initial and boundary data increases the fidelity of each sequential simulation.

Sometimes, the physics are inherently strongly coupled, and important interactions cannot be captured with sequential simulations. Examples include designing

valves, modeling deformable bodies in the presence of aerodynamic forces, and analyzing conjugate heat transfer. In these cases, concurrent simulations that exchange data at specified intervals — called two-way cosimulation — are needed to solve multiple physics simultaneously while considering the tight interactions of all physical forces.

The flexible range of multiphysics options supported by ANSYS allows engineering organizations to deploy their resources strategically. R&D teams can choose the multiphysics coupling that gives them the right amount of insight to solve the problem that they have today — as well as the ones that they need to address in the future. All levels

AUTOMOTIVE POWERTRAIN FLUID–STRUCTURE INTERACTION
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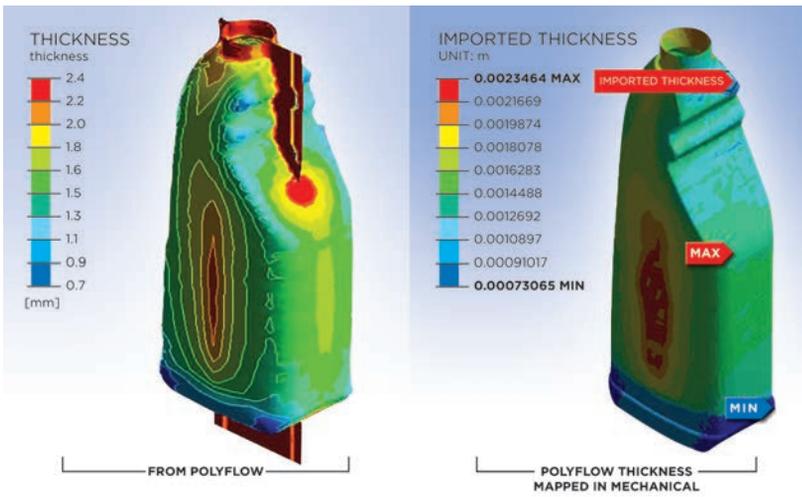
▲ Multiphysics studies help engineers to solve complex challenges — such as designing plastic packaging that is both strong and lightweight while also meeting user needs. ANSYS Polyflow enables simulation of the manufacturing blow-molding process, using inputs including geometry, material and process conditions. Next, the liquid dispensing process is modeled via a fluid–structure interaction simulation with ANSYS Fluent. This simulation simultaneously employs ANSYS Mechanical to model bottle wall deformation during squeezing. Any thickness variation in the bottle's material from the blow-molding process can be mapped from ANSYS Polyflow to the ANSYS Mechanical model.

▲ Space-based communication satellite dishes operate under challenging conditions. Electromagnetic losses — caused by induced high-frequency surface currents — lead to partial, asymmetric heating of the structure, which results in stress and deformation. Researchers use multiphysics simulation tools from ANSYS — specifically ANSYS HFSS and ANSYS Mechanical — to comprehensively analyze all these effects. The resulting deformed structure is brought back into the electromagnetic simulation tool, HFSS, to determine how any stress-induced deformations affect the antenna pattern.

Simulating all physics at the same time enables engineers to quickly gain important insight into product performance, target optimal designs faster, and release products to market earlier.

NEW MULTIPHYSICS SIMULATIONS USING ANSYS ICEPAK
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of ANSYS multiphysics simulation support a robust design optimization strategy aimed at ensuring uncompromising product quality.
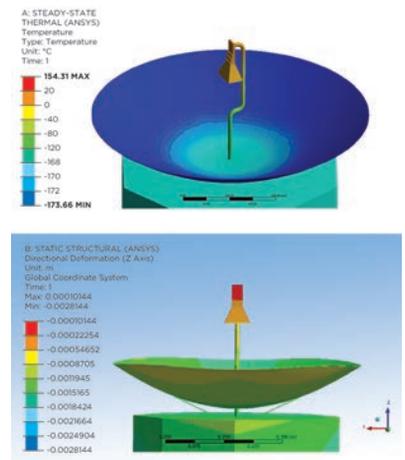
EQUIPPED FOR MULTIPHYSICS SUCCESS

To support customer success, ANSYS delivers continued technology leadership in every individual physics area, including fluid dynamics, structural mechanics, thermodynamics and electronics. This technology leadership is critical. Simulation software must provide accurate and robust results for each individual physics before it is able to capture the complex interactions among them.

Anticipating the growing need for multiphysics simulation as part of a robust design process, ANSYS developed powerful capabilities to facilitate multiphysics studies by making them faster, more streamlined and more intuitive. The leadership of ANSYS in individual physics, coupled with its support for parametric design optimization, makes ANSYS the perfect solution set for solving today's complex design challenges — including fluid–thermal and fluid–mechanical systems, robust electric machines and electronics, and product applications for advanced materials.

Ongoing improvements in ANSYS Workbench have produced an easy, adaptable multiphysics simulation solution right out of the box. Drag-and-drop coupling in Workbench makes it easy to set up a range of multiphysics studies,

supporting both one-way sequential simulations and two-way cosimulations.

With flexible, open, automated and accurate data exchange capabilities, Workbench allows experimental data, data from third parties or data from another physics simulation to be used for the current simulation. In addition, data exchange with external software solutions can be facilitated using the ANSYS Application Customization Toolkit (ACT), which includes the Workbench Software Development Kit (SDK). These tools allow a range of customization to optimize specific simulation capabilities, including information transfer with external technology solutions. Whether data is exchanged among ANSYS solutions or with external software, advanced methods and validation processes support both speed and accuracy.

The deep, sophisticated solver technology underlying ANSYS Workbench
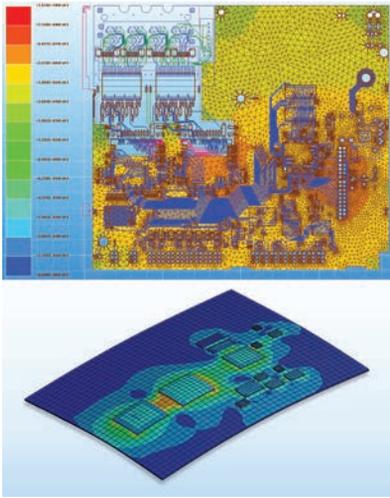
▲ To ensure a long product life, printed circuit boards must be optimized for electrical, thermal and mechanical reliability. This requires multiphysics studies that consider not only individual physics but also their interactions. Thermal simulations in ANSYS SIwave and ANSYS Icepak ensure that power dissipation is optimized to deliver high performance — while preventing current overloads. ANSYS Workbench enables the mapping of temperature fields to ANSYS Mechanical, so that PCB engineers can evaluate the potential for thermal stress, fatigue and deformation. Design decisions, such as connecting locations, component placement and clamping loads, can be evaluated in ANSYS Mechanical, minimizing the potential for thermally induced product failures.

MULTIPHYSICS COUPLING VIA ANSYS WORKBENCH CONSIDERING LF ELECTROMAGNETICS
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includes high-performance computing (HPC) capabilities and parallel scalability that accelerate the solution of numerically large multiphysics simulations. Industry-leading ANSYS solver technology can easily accommodate large geometries with high mesh counts as well as the enormous amount of data generated during detailed multiphysics analyses. Workbench manages the complex interaction between physics solvers during cosimulation.

A COMPREHENSIVE ANSWER TO TODAY'S SIMULATION CHALLENGES

In addition to providing these foundational capabilities, ANSYS offers an array of simulation platform services that help product development teams to support robust design optimization via multiphysics simulations.

ANSYS DesignXplorer enables engineers to explore, understand and optimize their designs via parametric analysis. They
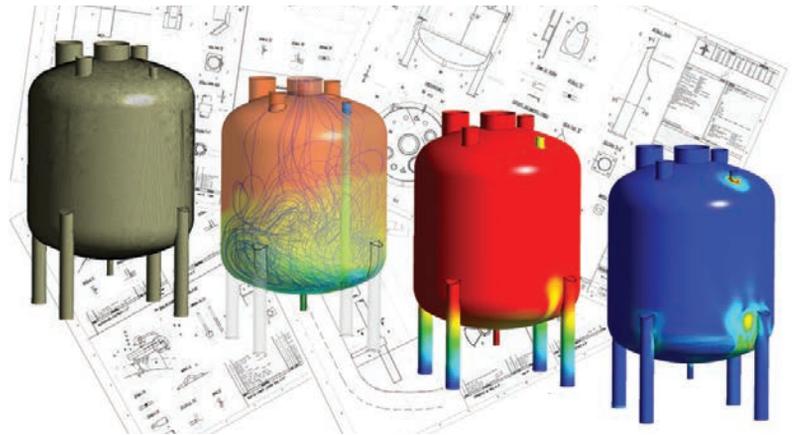
▲ ITMA Materials Technology — a Spanish company focusing on applied research and development in the field of materials science — uses multiphysics simulation to optimize materials performance. An engineering team at ITMA used ANSYS CFD and ANSYS Mechanical software to perform fatigue analysis of a storage tank. Because this tank has to perform reliably under extreme temperature changes, ensuring its structural integrity is critical. Using the physics integration capabilities in ANSYS Workbench, ITMA researchers first conducted transient analyses of the tank's start-up and shut-down cycles in ANSYS CFX, then transferred the temperature distributions to ANSYS Mechanical.

can zero in on optimal designs faster, while deeply investigating the interactions of all relevant physics via multiphysics analysis.

ANSYS Engineering Knowledge Manager (EKM) helps product development teams manage the large scale and scope of information that is generated by multiphysics studies. ANSYS EKM addresses the many critical activities associated with managing simulation data, including backup and archival, traceability and auditing, process automation, collaboration and capture of engineering expertise, and intellectual property protection.

In addition, reduced-order modeling (ROM) methods from ANSYS can transform a series of complex multiphysics simulations into 0-D or 1-D models that represent the dynamics of the multiphysics simulation in a systems-level analysis — while avoiding the high costs associated with rerunning simulations for each operating point. Whether product development teams require the extreme high fidelity of 3-D modeling or the broad view and rapid results of lower-order simulation, ANSYS offers an unmatched level of scalability.

BE INSPIRED BY THE BEST IN CLASS

If conducting multiphysics simulations seems out of reach for your own engineering team, this issue of *ANSYS Advantage* should serve as a powerful inspiration. The following pages show firsthand how engineers in every

industry apply ANSYS software and best simulation practices to realize significant improvements in their development processes via multiphysics studies.

One-third of ANSYS customers are already performing multiphysics simulations in an effort to optimize their product development processes. That number will no doubt increase dramatically over the next few years, as more and more engineers recognize the benefits — and ease — of coupling physics.

Many engineering teams were reluctant to cross the digital threshold and embrace the power of simulation when it was first introduced — yet today, simulation has become a standard engineering practice in every industry. Multiphysics simulation represents the future of product engineering, soon to become an industry standard as development teams seek to manage complexity, increase confidence, and further drive time and costs out of both the design cycle and production processes.

We hope that this issue of *ANSYS Advantage* encourages you to increase the use of multiphysics simulation within your own product development organization — so that you can benefit fully from this new revolution in engineering. **∧**