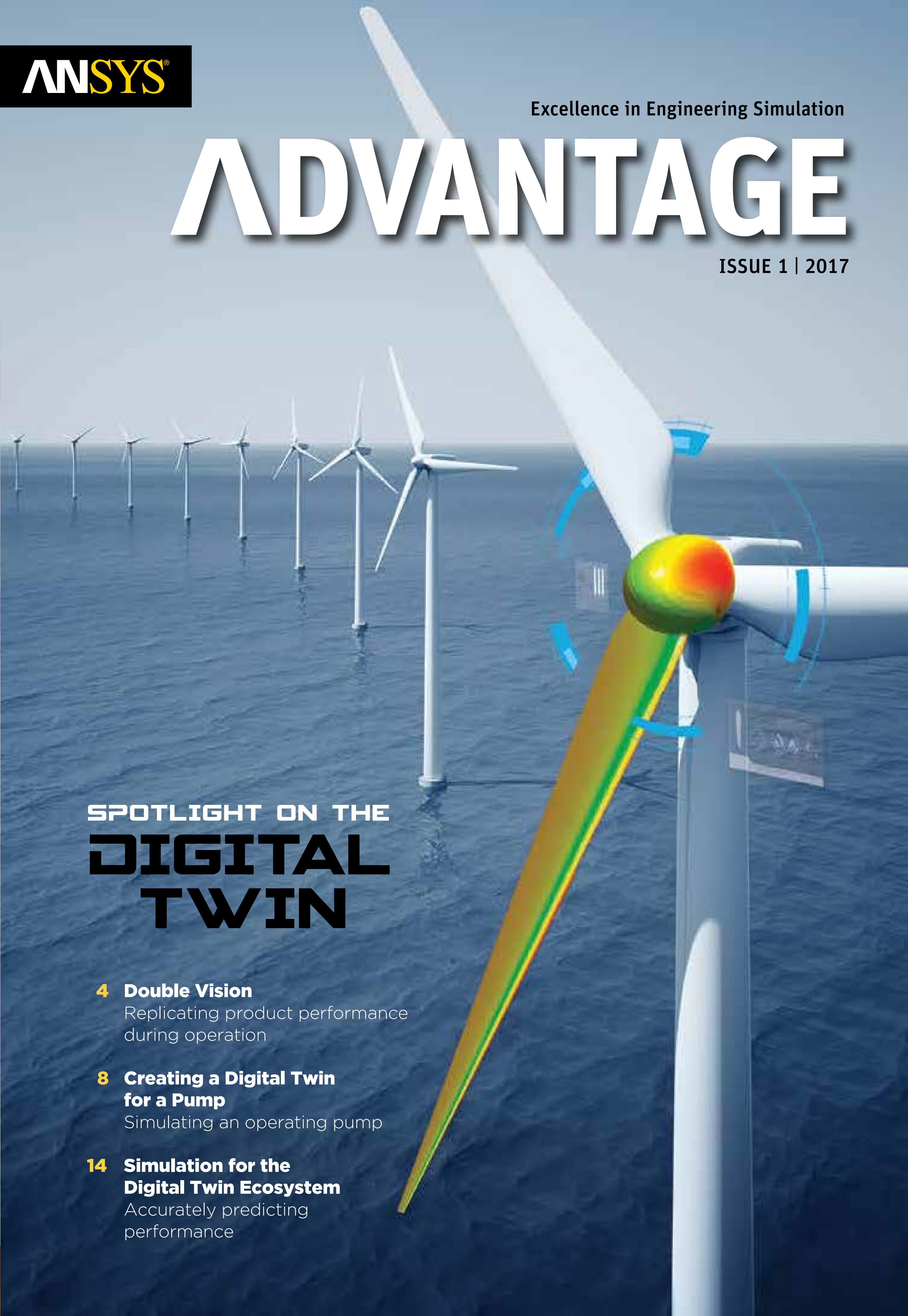


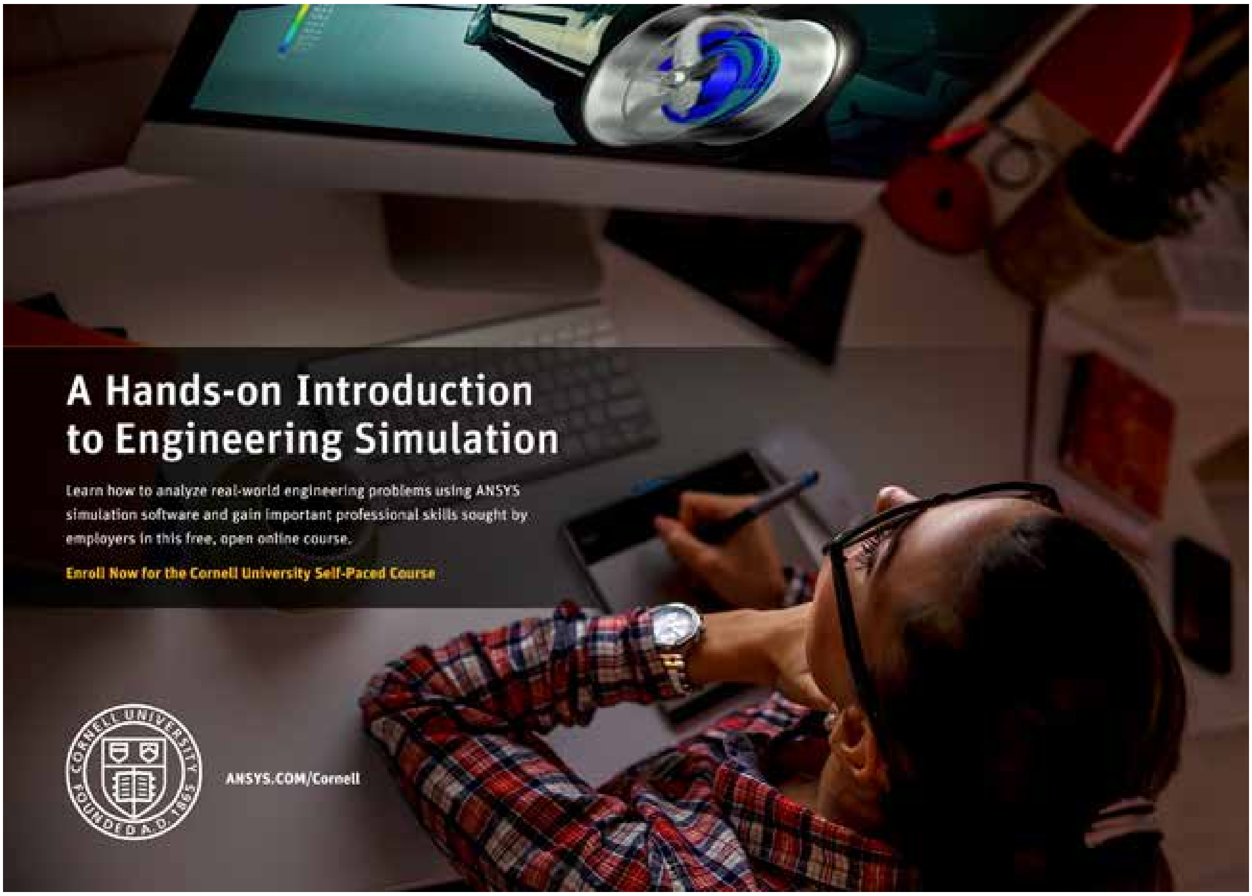
ANSYS

Excellence in Engineering Simulation

ADVANTAGE

ISSUE 1 | 2017

SPOTLIGHT ON THE DIGITAL TWIN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A NEW ERA IN SIMULATION

Combining real-time operational data from working products with digital information about those products enables the digital twin and promises to take simulation into a new era.

By **Ajei Gopal**, President and CEO, ANSYS

For over 40 years, engineering simulation has helped product development teams around the world deliver game-changing innovations, accelerate product launches and reduce the costs associated with design and development

While the process of creating highly engineered products has never been easy, today's product development organizations are faced with challenges that could not have been imagined 40 years ago. Existing products are growing in complexity, with smart functionality and more embedded software. Disruptive products are operating in design spaces that have not been explored before. These products are expected to perform in more extreme physical conditions. Consumers are demanding bigger and more frequent innovations that are delivered affordably. And, in some cases, customers no longer demand just a product such as a wind turbine, they demand an outcome like kilowatt hours.

The good news is that simulation technology improvements provide answers to these growing challenges. Simulation software has expanded in depth and breadth, enabling the modeling of multiple physical forces — electromagnetic, structural and fluid — as well as embedded software and systems using an integrated simulation platform. Semiconductors can now be designed with simulation leveraging full chip–package–system models so that deficiencies are discovered long before prototyping and sign-off. Improvements in computing capability and the advent of the cloud have led to the emergence of high-performance computing (HPC) capabilities that streamline and accelerate even the largest simulations and empower diverse global engineering teams to collaborate. Digital prototypes and digital exploration are easier and faster to employ than ever before.

“Simulation is the only way to fully realize the tremendous value contained within the digital twin.”

But it does not end there. The Internet of Things (IoT) brings with it technology and practical cost models to install sensors on a vast array of products and to stream the huge amounts of real-time data generated. The emergence of IoT software platforms empowers the integration of real-time operational data with all of an organization's digital information for that specific product. This enables the realization of a digital twin.

Simulation is the only way to fully realize the tremendous value contained within the digital twin.

Field product performance data (and other relevant information) can be merged with the results of engineering simulation to predict the future performance of that product within its operating environment. This predictive capability could, for example, optimize maintenance schedules and reduce unplanned asset downtime, as well as significantly enhance operational performance.

But digital twins have an even more important strategic benefit: Product development teams can apply insights from the twin directly to their ongoing product development efforts. Future versions of the product or process can be designed with new features, new shapes and new materials that directly address any shortcomings identified through the digital twin process. This promises to radically accelerate new product innovation and insertion.

Already in use by leading companies, digital twins represent the future across many industry sectors.

The use of digital prototypes and digital exploration for increasing product complexity, ever-expanding design spaces and the emergence of the digital twin propel the use of simulation into the hands of new users and develop links with operational products. We are on the cusp of a new era that will take us beyond simulation-driven product development and into simulation-driven engineering.

I hope this issue of *ANSYS Advantage* will help you learn more about the potential of digital twins — and begin to imagine the enormous impact they may have on your business in the not-so-distant future.

Creating a Digital Twin Video
ansys.com/digital-twin-video

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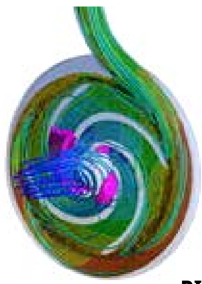
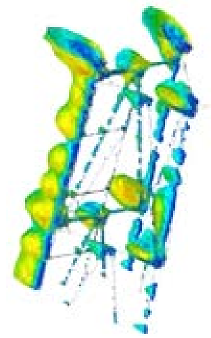
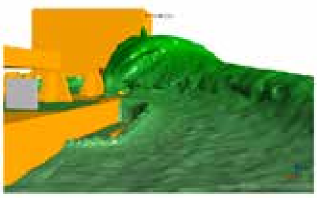




Simulation@Work

ABOUT THE COVER
A digital twin of a physical product or process can monitor real-time prescriptive analytics and test predictive maintenance to optimize asset performance. Simulation is vital to the accuracy of a digital twin.



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ANSYS is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.

DOUBLE VISION

The digital twin provides a new layer of engineering insight by replicating the performance of products in operation.

By **Eric Bantegnie**,
Vice President & General Manager
ANSYS Systems Business Unit, and
Sudhir Sharma,
Director High-Tech
Industry Marketing, ANSYS

Today, most product development teams rely on engineering simulation for innovation and to bring their solutions to market quickly and cost-effectively. By exposing their design to a range of virtual forces in a low-cost, risk-free digital world, engineers can optimize performance, launch products faster and minimize financial investments. Historically, the role of simulation has primarily been in this product development function. However, the digital twin promises to extend the value delivered by simulation beyond product development to the entire life cycle of a product — enabling it to be studied under its actual operating conditions in its unique working environment. By creating a replica of the actual product system in a digital environment, engineers can anticipate and address potential performance and maintenance issues before they occur. The real-time, real-world insights collected via these digital twins can also accelerate future design iterations, leading to continual product improvements.


"At ANSYS, we're *committed* to *partnering* with the leaders of the digital twin revolution."

WHAT IS A DIGITAL TWIN?

A digital twin is the combination of all the organization's digital information on a specific product with operating data streaming live from the product as it is being used in operation. Merging physics-based understanding with analytics delivers the insights that unlock the true value of the digital twin.

Using these insights, engineers can understand the operational failure modes of the product, prevent unplanned downtime, improve product performance and seed the next product generation.

The digital twin is able to leverage multifidelity simulations from detailed 3-D physics to reduced-order models (ROMs) to compress simulation times and demonstrate key product performance aspects. For example, a digital twin of a gas turbine installed in a power plant might be designed to highlight energy efficiency, emissions, turbine blade wear or other factors of particular importance to the customer and thus the product development team.

By studying the digital twin, engineers can determine the root cause of any performance problems, improve output, schedule predictive maintenance, evaluate different control strategies and otherwise work to optimize product performance — and minimize operating expenses — in near real time. This is becoming increasingly important as customers shift from buying a product to buying an outcome, with the performance risk passed to the product developer.

"One of the most exciting aspects of digital twins is that we can now look at an individual product system — such as a wind turbine — and isolate just that one product," notes Marc-Thomas Schmidt, chief architect of the Predix® analytics platform for GE Digital. "We're not talking about a general class of turbines, but that one turbine. We can study the weather patterns that affect it, the angle of its blades, its energy output, and optimize that one piece of machinery. If we do this across all our product systems in the field, imagine the impact on overall product performance. This clearly represents a revolution in product engineering."

CAPITALIZING ON THE IOT

Digital twins have been made possible by a number of technology developments, including improvements in simulation software, hardware and processing speeds. The most important enabler has been the emergence of the Internet of Things (IoT). The implications of the IoT for our everyday lives have been well documented, and the growth of consumer devices is not slowing down. In fact, by 2025 sales of connected devices are expected to reach $11 trillion per year.

However, the industrial sector has been slower to capitalize on the IoT. While early applications have been fairly straightforward — such as turning a piece of equipment on and off — today the business world is beginning to recognize the enormous potential of IoT devices to capture real-time data that has great strategic potential.

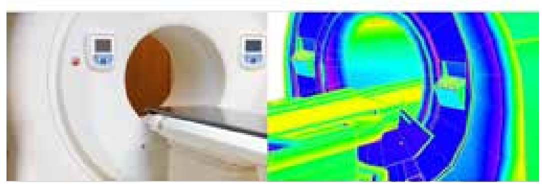
By placing small, relatively low-cost sensors on products as they're operating in the field, engineers gather a wealth of daily performance data. By combining this new information with the power of physics-based simulation, the engineering team can examine and address any performance issues, foresee the need for product maintenance or repair, and ensure that future versions of the product are optimized for day-to-day operating conditions.

“Engineers can understand the operational failure modes of the product, prevent unplanned downtime, *improve product performance* and seed the next product generation.”

“What ANSYS brings to the table is exciting: the ability to simulate failure. Simulation is applied in both the upfront engineering — the digital twin might include information about the stress level before something broke, or how thin a wall can be —and during operation in the field,” notes Andrew Timm, chief technology officer for PTC. “If something breaks you can test potential solutions in the simulated model and feed that information back to resolve the problem.”

MAKING THE VISION A REALITY

While digital twins are primarily being used by large industrial manufacturers with complex product systems, continuing technology advances are making this best practice accessible to more businesses, with a broader range of product applications.



At ANSYS, we’re committed to partnering with the leaders of the digital twin revolution to bring this capability to every product development team. For example, we’ve worked closely with GE to integrate our industry-leading simulation software with Predix, GE’s proprietary cloud-based platform for industrial data and analytics. This collaboration matches day-to-day operational data with powerful analytics, ensuring that strategic insights are generated. These insights are made visual and actionable via engineering simulation.

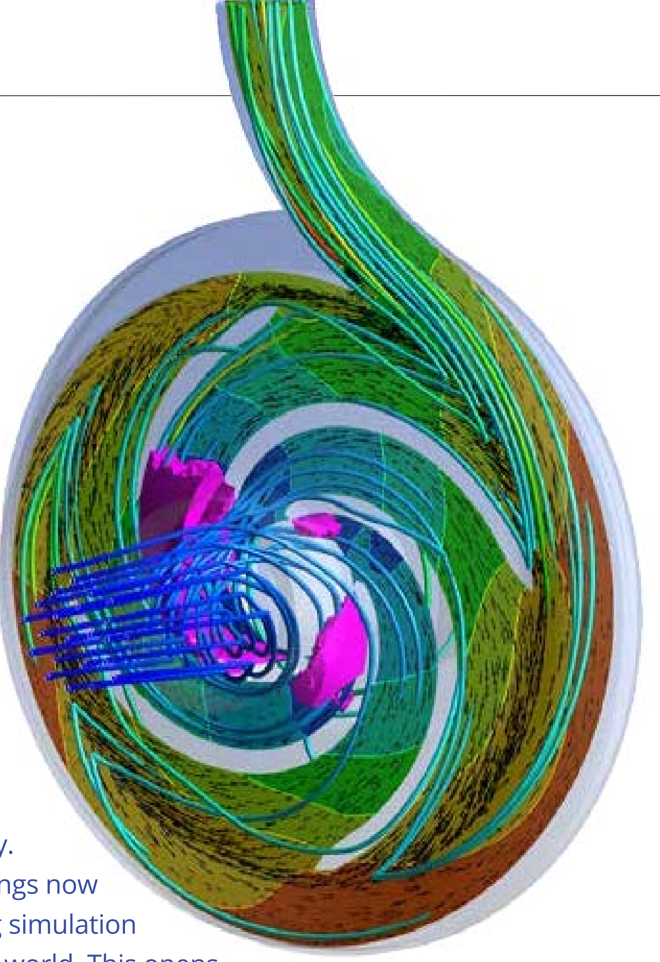
ANSYS also collaborates closely with PTC, developer of ThingWorx® — an IoT platform that forms a gateway between remote sensors and simulation software. Via machine learning and augmented reality, PTC displays the important insights gathered from the IoT and connects that data to ANSYS software.

And because our simulation platform is highly customizable, it can be adapted to integrate with other IoT platforms and those that have yet to emerge on the market.

As ANSYS releases future versions of our simulation software, we will continue to focus on enhancements that allow seamless integration with other core technologies — making digital twins more affordable, more accessible and easier to master for product development teams. There’s no doubt that digital twins hold enormous potential, and we believe our job is to give every ANSYS customer the opportunity to capitalize on that potential.

Digital Twin Web Page
ansys.com/digital-twin

Creating a DIGITAL TWIN for a Pump



Simulation has long been an integral part of the product development process; it greatly improves product performance, reduces development costs and gets the product to market much more quickly. The technologies that underpin the Internet of Things now make it possible to go a step further by integrating simulation with products as they exist and operate in the real world. This opens up a whole new era in value creation for companies to optimize operations and maintenance, as well as further accelerate the new-product development process. ANSYS worked with PTC, Flowserve, National Instruments and HPE to demonstrate this, showing how a simulation model of an operating pump can diagnose and solve operating problems faster than was ever possible before.

By **Chris MacDonald**, Senior Director, Analytics GTM Strategy & Business Development, ThingWorx Analytics, PTC; **Bernard Dion**, Chief Technical Officer, Systems Business Unit, ANSYS; and **Mohammad Davoudabadi**, Principal Engineer, ANSYS

Companies that leverage simulation during the product development process have dramatically improved product performance, reduced engineering and manufacturing costs, and delivered their products to market more quickly. The Internet of Things (IoT) is now making it possible to capture real-time data about an operational product and integrate it with the organization's digital information about the product, including simulation models, to optimize the current state of the product or asset. This is called a digital twin of the product. The example of a pump typically used in process plants shows how a digital twin processes sensor data generated from an instrumented asset and leverages simulation to predict failures and diagnose inefficiencies. This enables an organization to take action to immediately correct problems and optimize the asset's performance.

OPERATIONAL DATA AND INTERFACE

The pump was equipped with pressure sensors at its inlet and outlet, accelerometers on pump and bearing housings to measure vibration, and flow meters on its discharge side. An actuator controlled the discharge valve while the valve on the suction side was manually controlled. The sensors and actuators were connected to a data-acquisition device that sampled the data at 20 KHz and fed it to a Hewlett-Packard Enterprise (HPE) IoT EL20 edge computing system. The PTC ThingWorx® platform created an ecosystem to connect devices and sensors to the IoT, reveal the value of IoT data, develop enterprise-level IoT applications, and empower end users through augmented reality. ThingWorx was used as the gateway between the sensors and the digital data, including the simulation model of the pump. A machine-learning layer in ThingWorx running on the EL20 monitored the sensors and other devices, automatically learning the normal

> “Companies can use digital twins to detect and isolate faults, perform diagnostics and troubleshooting, recommend corrective action, determine the ideal maintenance schedule, optimize asset operation, and generate insights to improve the next generation of the product.”

state pattern of the pump in operation, identifying operational anomalies, and generating insights and predictions.

The ThingWorx platform was also used to create a web application that displays sensor and control data as well as analytics. For example, the app displayed inlet and outlet pressure, and predicted bearing life. An augmented-reality front-end superimposed sensor data and analytics as well as parts lists, repair instructions and other persona-based information on an image of the pump seen through a user’s smartphone, tablet or smart glasses.

^ The real pump connects to its digital twin using ThingWorx.

SIMULATION: THE “SECRET SAUCE” OF THE DIGITAL TWIN

The team from ANSYS built a reduced-order, system-level model of the pump using ANSYS Simplorer design software running on the HPE edge computer. The system model connects to sensor data through PTC ThingWorx and mimics the hydraulic system’s operation. The system model also connects to a human–machine interface (HMI) developed using ANSYS SCADE software with the same gauges and dials as the physical pump. With this configuration, the system model can be disconnected from the physical pump and operated offline to explore proposed operating scenarios.

The system model could also be instrumented using virtual sensors to measure, for example, pressure downstream and upstream of the valves. ANSYS developed a detailed 3-D computational fluid dynamic (CFD) model of the pump that runs in the cloud and links to data coming from the asset (if online) or the system model (if offline). Along with being the source for pump performance curves used for rapid systems-level simulations, this 3-D model is the basis for more-detailed interrogation and diagnostics of off-design operation and performance assessment in anomalous conditions.

DELIVERING INSIGHT

To demonstrate the value of the digital twin, the pump initially was operated normally. An anomaly was manually introduced by closing the suction valve to 50 percent. The sensor readings showed that the suction pressure, discharge pressure and flow rate decreased drastically, while the accelerometers showed high levels of vibration. Red alerts were issued, and the predictive analytics indicated that the projected life of the pump bearing dropped to only a few days if this condition persisted. But the sensor readings and analytics did not explain the effect of anomalous flow conditions on the pump’s operation, why the pump was vibrating or what possible solutions could be considered.

The connected system model showed the same HMI readings as the physical pump, with reduced inlet pressure, outlet pressure and flow rate. To understand

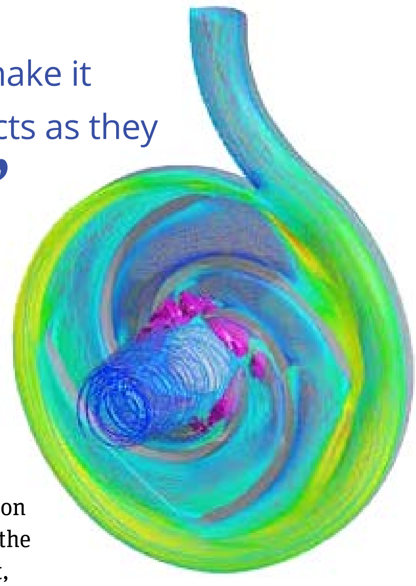
^ A Flowserve pump highlights the benefits of a digital twin.

> "The technologies that underpin the IoT make it possible to integrate simulation with products as they exist and operate in the real world."

the root cause and provide insight on exactly why the vibrations occurred and what the effect was of the change of flow condition on pump operation, a 3-D simulation model in the cloud connected to the physical pump was triggered by activating a "3-D simulate" button on the system model HMI. The 3-D simulation showed that the drop in pressure inside the pump caused cavitation, forming vapor bubbles. In the pump's higher pressure regions, bubbles imploded and generated vibration.

By disconnecting the system model from the physical pump, the system model's HMI could be used to try various potential fixes. For example, the system model predicted that opening the inlet valve would solve the problem. To validate this potential fix, a second 3-D simulation was performed on the offline system model with the opened valve. The 3-D results showed no vapor bubbles. The fix was implemented by opening the inlet valve on the physical pump, and performance returned to normal.

The IoT allows simulation models to connect to operating products using a platform like ThingWorx so that industry can better understand and optimize product performance. Companies can use these digital twins to detect and isolate faults, perform diagnostics and troubleshooting, recommend corrective action, determine the ideal maintenance schedule based on the specifics of the individual asset, optimize asset operation and generate insights that can improve the product's next generation. The potential benefits of digital twins are significant. The low-hanging fruit is in optimizing maintenance and operational troubleshooting. But as customers begin to demand outcomes and not just products, the digital twin has the potential to be the key to unlocking this additional value for both product manufacturers and their customers.



^ **A 3-D simulation model shows that cavitation, as visualized by the purple vapor bubbles, is the effect of a faulty valve and the cause of a vibration problem.**

How Simulation-Based Digital Twins Improve Product and Process Performance
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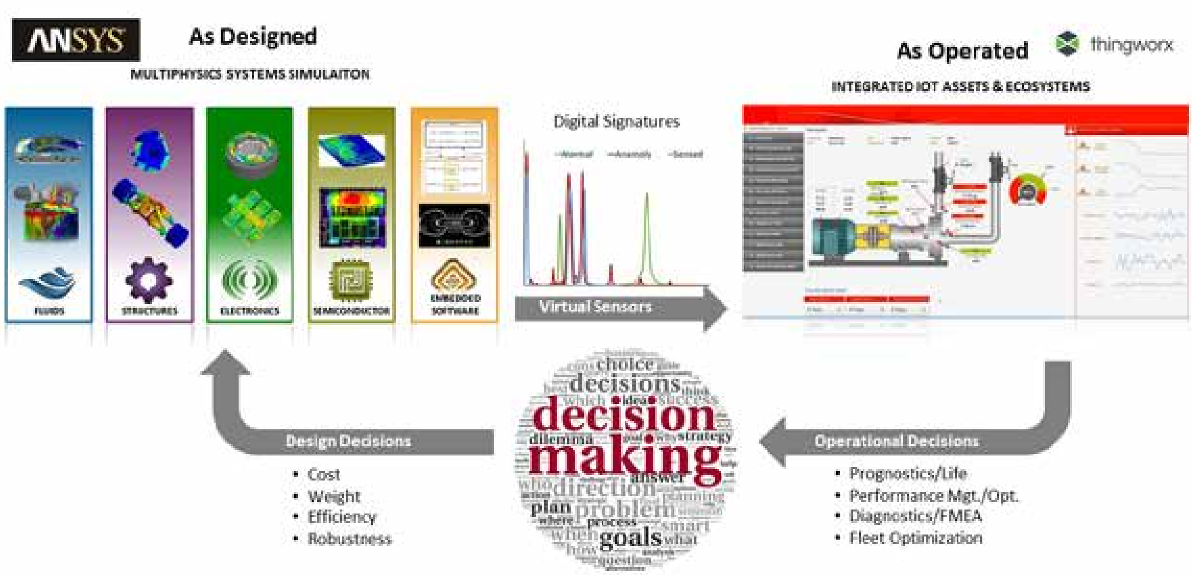
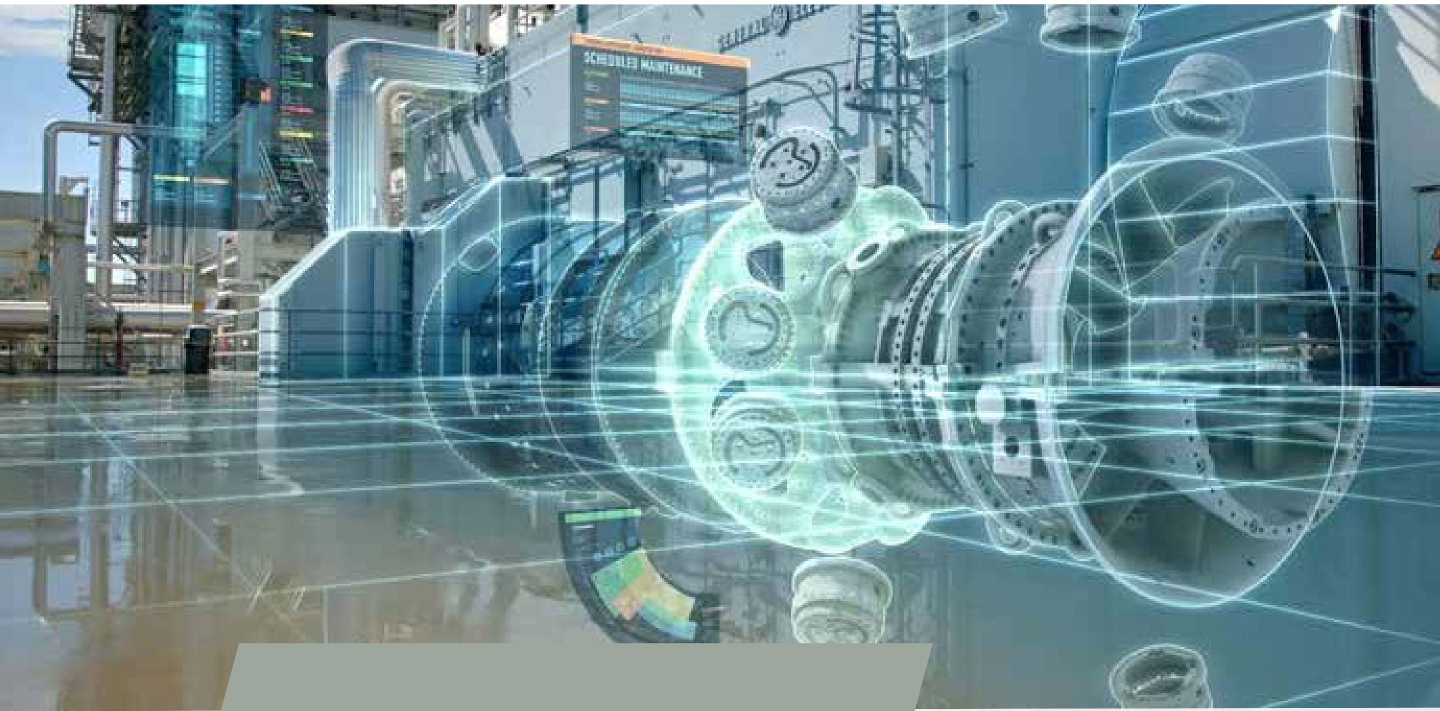


^ Digital twin benefits

PIONEERING the INDUSTRIAL INTERNET



GE has transformed itself into the world's leading digital industrial company, and its GE Digital group is playing an integral role in leading this charge by providing companies with valuable insights to manage assets and operations more efficiently. But that is just the start. According to Jeff Immelt, chairman and CEO of GE, "If you went to bed last night as an industrial company, you're going to wake up this morning as a software and analytics company."

To learn more about what the company is doing, **Rob Harwood**, ANSYS industry director, spent time talking with GE Digital Chief Marketing Officer **John Magee**.

Harwood (RH): We hear a number of buzzwords and phrases industry, such as Internet of Things, Industry 4.0 and Industrial Internet. Can you shed some light on the differences between these terms?

John Magee (JM): The Internet of Things is all about the technology trend of connecting physical devices over the internet in the same way that we have been connecting people for the past several years. This could be everything from a personal fitness device to your sprinkler system to a power plant to a jet engine. So when you think about the Internet of Things, it really is applicable across a broad swath of the economy. The Industrial Internet is the part of the Internet of Things that focuses on complex, capital-intensive equipment that powers

> **"One of the most *powerful tools* fo bringing organizational data together is something called a *digital twin.*"**

the global industrial infrastructure — everything from transportation to healthcare to power generation. This is where GE is focused. Industry 4.0 is an initiative that has some similar technology objectives, but its center of gravity tends to be in Europe and focuses on manufacturing and automation systems.

RH: How is this type of connectivity different from traditional forms of equipment monitoring that companies have been doing for a long time?

JM: We can now put sensors in places they have never been before and embed compute capability into places never previously reached. The cost models are falling into place not just for super-high–value assets, but for every pump, motor, valve, machine or piece of hospital equipment, and these cost models can be broadly optimized across all of that equipment. And, we can more readily marry this sensor data with a broader set of digital data about the asset, so we can become much more predictive and prescriptive and much less reactive.

RH: Do you see opportunity to leverage the power of the Industrial Internet across all industry sectors?

JM: We have been very bullish on the potential for the Industrial Internet to transform not just the industries that GE plays in today, but others such as autonomous vehicles, intelligent cities, logistics, agriculture and more. All of these areas are ripe for optimization and for new ways of doing things. So across the board, there is a lot of potential for optimization and new business models made possible by the Industrial Internet.

RH: Integrating sensor data from a connected asset with other organizational data about that specific asset — such as that information held by engineering (CAD, simulation, PLM, etc.), manufacturing, operations and maintenance, marketing and sales, and others — brings the possibility of a digital twin. Can you expand on this concept?

JM: One of the most powerful tools for bringing all this organizational data together is something called a digital twin. This is a software representation of every physical asset out there so that we can understand everything about it — from the time it was manufactured, to its performance in service, to the way users interact with it, to how it performs under different conditions, and much more. We are no longer talking about a digital blueprint of an ideal design of a generic class of assets, but an actual real-time digital twin of each specific asset.

RH: Can you give a practical example of a digital twin at GE along with some of the benefits you have realized?

JM: At GE, we have piloted the tools, technologies and processes needed to create a digital twin and have put these into practice in our own manufacturing and design service businesses. For example, for jet engines we create the digital twin model at the time of design and engineering, and that same model is used through all phases of product development and asset life-cycle management. We now have all of the data. That lets us do very predictive things around maintenance and operations. By working with our airline customers, we can help them operate more effectively, and the net result has been improved internal efficiency for GE and substantial benefits to our customers, who are subsequently able to operate their equipment and operations more effectively.

RH: To create the digital twin requires a new way of collecting and integrating digital information from multiple sources. How is GE handling that?

JM: From an information and technology perspective, managing, creating, modeling and supporting digital twins is different from traditional business computing platforms. For enterprise resource planning systems, there are relational databases, and we can model the different ways we record

GE and ANSYS Partner on Digital Twins
ansys.com/ge-digital-twins

information around orders and employees and transactions. We not only need all of that for the Industrial Internet but we require the ability to capture these digital twins and their nested hierarchical data structures. There is a new approach for tools and for the way we process information, and we must also map the asset models to sensors that collect the data feeding into that twin. Then this information can be holistically provided to users who access the twin information and to developers who build applications against those twins. It requires a whole new kind of industrial platform to really take advantage of the benefits of digital twins.

At GE, we saw early on that to go faster with the Industrial Internet and to accelerate what we are doing in healthcare, in transportation and in power, we would need new kinds of tools. And for us that led to the development of what we call the Predix platform. Predix is a software platform for building, managing and monetizing Industrial Internet applications, and it includes a number of unique capabilities optimized for the requirements of the Industrial Internet as opposed to the broader Internet of Things.

RH: To enable a digital twin to become predictive and prescriptive, accurate modeling and simulation that is connected to the Predix platform must be important. Can you explain this connection?

JM: One of the big opportunities with the Industrial Internet is the ability to have enough data about operations, equipment, assets and people to be able to do predictive modeling and to ask what-if questions. Modeling and simulation, therefore, become hugely important tools once we have the data. The secret sauce to actually achieving innovation is to be able to marry the physics-based models with statistical and machine-learning approaches, so you get the best of both worlds. With a physics-based model, you can now understand what the parameters are, discover the normative patterns, and you can go much faster. You do not need as much data to really gain key insights. This means that we can give decision-makers the right information to be able to understand the trade-offs required to operate capital-intensive infrastructures, to achieve business value for their operations and to make the right decisions.

RH: ANSYS and GE have worked together for a long time. How important are partners and an ecosystem to being successful in the Industrial Internet and digital twin space?

JM: ANSYS has been a great partner for us by providing the modeling and simulation capability, working with the Predix team, integrating with the Predix platform, and using the data we collect to provide that decision-making insight.

RH: The Industrial Internet and the concept of the digital twin are still new or unknown quantities for many. What advice would you give to those about to embark on the journey of digital industrial transformation for their business?

JM: We are working with a lot of our industrial customers on their own transformation, and we actually use a transformation playbook based on best practices that we have developed. There are a few key takeaways:

- Match up the technology with the business values — so having the right stakeholders at the table early on is important.
- Take an architectural approach in which you think about not just one or two applications but, if you are really going to transform your business, what your overall platform strategy is going to be to manage the data, to collect the data, to analyze it, to deliver all these applications that you want to be able to deliver and how that is going to interoperate with your infrastructure.

With our Predix platform, those are things we have had to think about ourselves as we have ramped up GE across all of these large, diverse businesses — and that is where we are now: working with customers to help them on that journey. Λ

About John Magee

John Magee is the chief marketing officer for the Predix platform at GE Digital. He leads product marketing, developer relations, and training and enablement programs to help Predix customers realize the full potential of the Industrial Internet. He has over 22 years of experience in enterprise software; prior to GE, he held executive management positions at Oracle, Symantec and EMC.

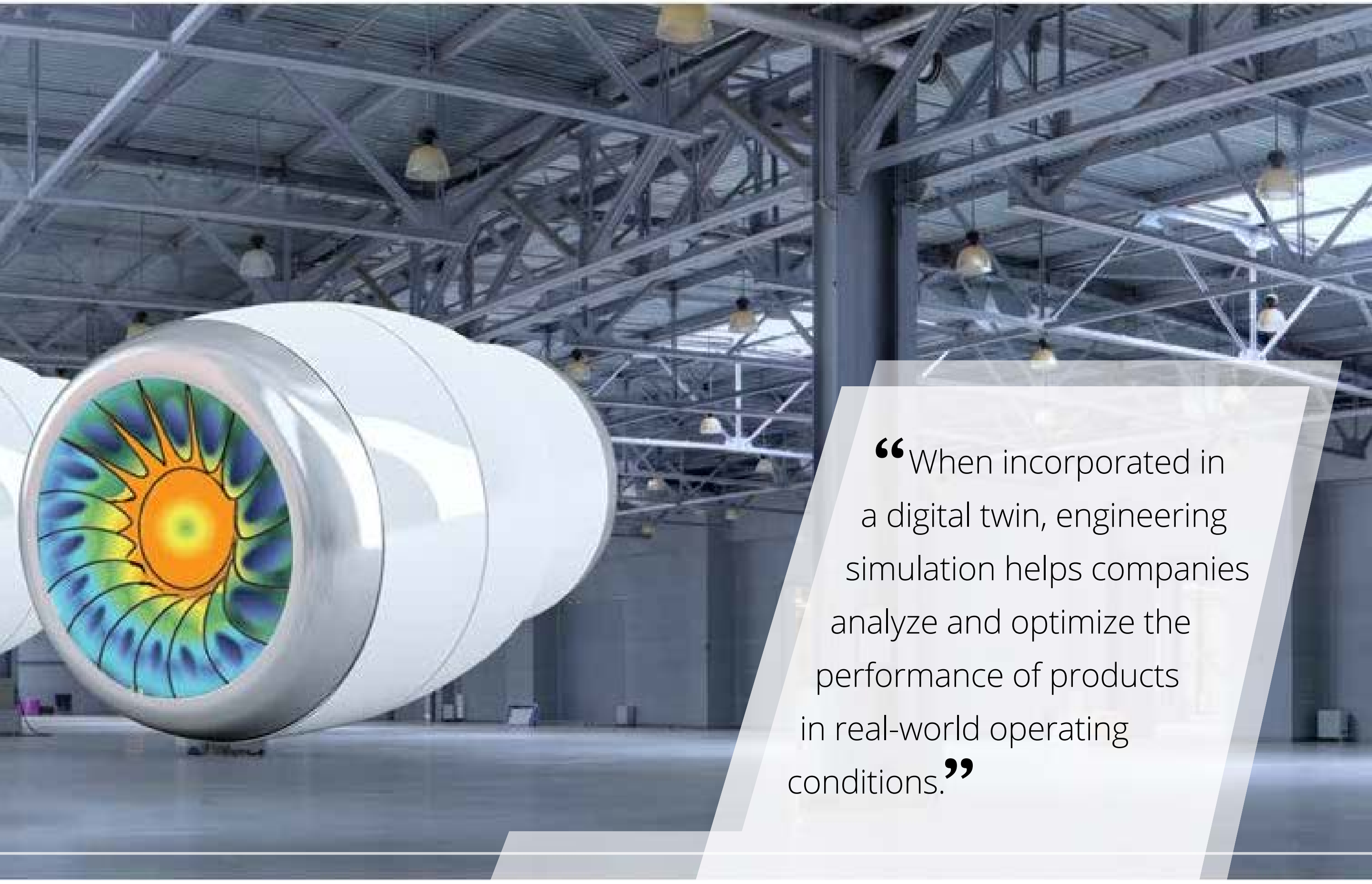
SIMULATION FOR THE DIGITAL TWIN Ecosystem

To fully understand a machine during operation requires connecting the full-featured virtual model to actual operational data from the machine; the virtual model is then called a digital twin. Simulation is a valuable tool for companies creating digital twins, as it allows them to accurately predict how the machine might perform and how changes will affect it during its lifetime. ANSYS has a full suite of tools to enable a digital twin to deliver accurate, insightful and reliable results that can have a real impact on operation — improving output, decreasing downtime and extending longevity. By understanding real-world product behavior using simulation, the next-generation product can be significantly improved while reducing its time to market.

By **Sameer Kher**,
Director of Systems and Digital Twins,
ANSYS

Digital Twin — Web Page
ansys.com/digital-twin

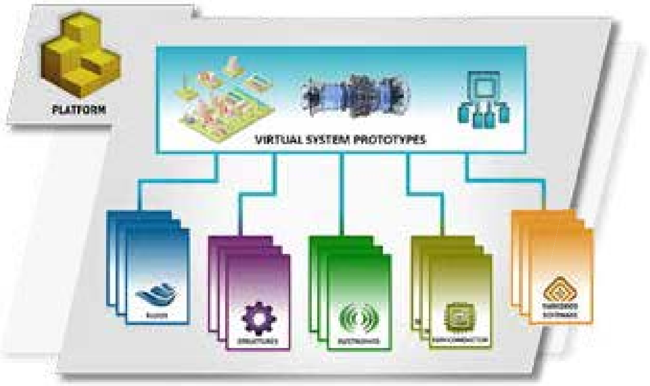
Tens of thousands of high-value machines are currently hard at work around the world generating electrical power, manufacturing automobiles, transporting people and goods, producing oil and gas, supplying clean water, picking orders for consumers and businesses, and performing many other vital functions. Most of these machines were designed using physics simulation to optimize structural, fluid flow, electromagnetic, thermal and other physical properties. However, as assets age and are modified, few are operating under the conditions envisioned when they were designed. Until recently, the people responsible for keeping these assets running at maximum efficiency had no way to understand the effects of operational and environmental changes on asset performance. Is the machine headed for a breakdown that could cost tens of thousands of dollars per hour in lost production? Is it being run at sub-optimal conditions that will reduce its life over the long run? Are there opportunities to improve its performance



“When incorporated in a digital twin, engineering simulation helps companies analyze and optimize the performance of products in real-world operating conditions.”

by making changes to its operating conditions or upgrading its capabilities?

For many high-value assets, such as jet engines, companies have been using sensors to collect data for many years. However, these data are not always collected in real time, and the vast amount of data has made it difficult to extract actionable insights. The Internet of Things (IoT) makes it possible for the first time to use sensors to capture data from these assets to understand and optimize their performance instantaneously. By combining this operational data with other information on how the machine works — including maintenance records, PLM information and simulation results — together with analytics and machine learning to form an ecosystem, a fully featured model called a digital twin can be built. Using a digital twin, it is possible to diagnose complicated problems that involve interactions of multiple subsystem and factors. Simulation is critical to a digital twin as it supplies answers to questions like “What if we change this?” and “Why did that happen?” and “How do we improve the design?”

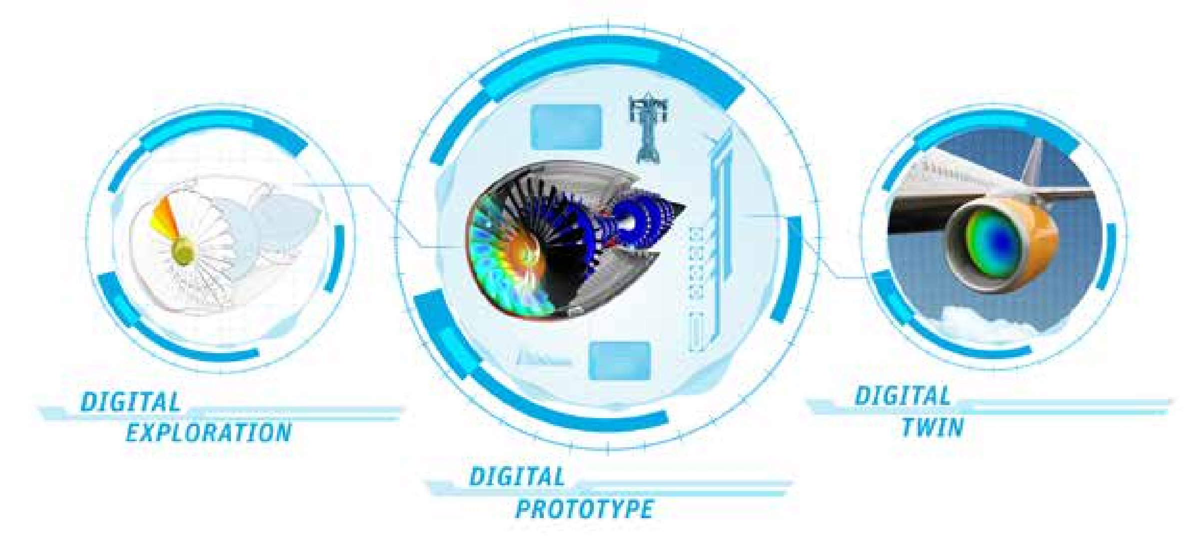


^ ANSYS enables a simulation-based digital twin — from comprehensive component-level design and simulation to complete systems simulation.

SYSTEMS-LEVEL SUPPORT

The ANSYS Simplorer system-level modeling tool makes it possible to build digital twins that accurately describe complicated interactions between components, subassemblies and subsystems. The subsystems in the model can be defined to the desired level of

PERVASIVE ENGINEERING SIMULATION



fidelity ranging from high-level behavioral models to detailed physics-based simulation models. The subsystems and components of system-level models often consist of reduced-order models—compact representations of 3-D physics-based models—that accurately represent the physics while providing results in much less time.

PHYSICS-BASED SIMULATION

The full potential of the digital twin concept is realized by using physics-based models that can duplicate the operation of complex assets in enough detail to fully understand their performance, even when facing never-before-seen conditions. The digital twin often contains a simulation model that duplicates the operation of the asset and can diagnose unforeseen situations by analyzing the basic physics to predict how the asset will perform. It should include a simulation model that has been developed to duplicate the current condition of the product or process, such as by incorporating wear or modifications into the simulation model. The data from sensors connected to the product or process are used to provide real-time boundary conditions for the digital twin. The digital twin results can be calibrated based on the operation of the actual asset.

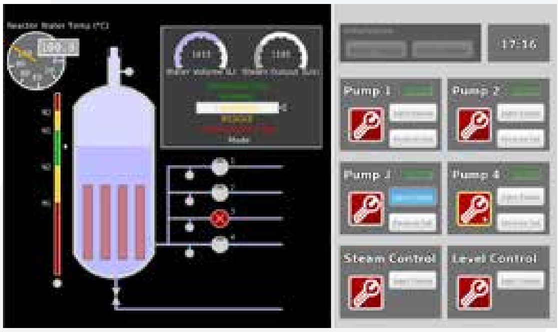
CONTROL SYSTEMS

ANSYS SCADE can control the digital twin and develop a human–machine interface (HMI) using the same control software and HMI used on the real physical asset.

An engineer can then virtually test different scenarios or operating conditions on the digital twin to see how it will perform using the same interface as that employed to control the physical asset.

COMPLETE TECHNOLOGY PLATFORM

ANSYS provides a sophisticated platform to improve the digital twin experience that integrates many



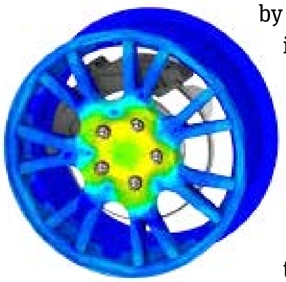
^ Human–machine interface for a chemical processing asset developed using ANSYS SCADE

different simulation tools. One of the key tools is the ANSYS Engineering Knowledge Manager (EKM), which greatly simplifies the process of connecting multiple digital twins to the IoT. For example, if there are 100 individual implementations of a particular asset, EKM can store a digital twin of each asset that reflects the

> *“Simulation is critical to a digital twin as it supplies answers to questions like “What if we change this?” and “Why did that happen?” and “How do we improve the design?”*

“ANSYS is the only company with a full suite of simulation solutions that span platform, depth and breadth of trusted physics, and systems functionality.”

differences between them (such as their age and operating conditions) and then connect incoming data from a particular asset with the associated digital twin. The ANSYS simulation technology platform also includes ANSYS DesignXplorer to explore numerous conditions or geometric variables and quickly evaluate a wide range of operating conditions, helping engineers determine the conditions that deliver the best performance. Engineers can use DesignXplorer offline to come up with the best possible solution to a challenge before implementing it in the operating asset.



^ Physics-based simulation provides insight into the digital twin, such as stress on a wheel.

INTEGRATING THE DIGITAL TWIN ECOSYSTEM

The ANSYS simulation platform is already proven to work in tandem with a wide range of popular IoT platforms such as PTC’s ThingWorx® and General Electric’s Predix®. For example, ANSYS worked with PTC to demonstrate how a simulation model of an operating pump can help diagnose and solve operating problems faster than the usual trial-and-error approach.

Simulation has long been used to improve the design of nearly every physical product or process by evaluating complex physics that are impossible to fully understand through physical testing. ANSYS is the only company with a full suite of simulation solutions that include platform, depth and breadth of trusted physics capabilities, and systems functionality. ANSYS simulation solutions help engineers move to the next level of insight through digital twins. When incorporated in a digital twin, engineering simulation helps companies analyze and optimize the performance of products in real-world operating conditions and make confident predictions about future performance to improve product operation and productivity, and reduce the cost and risk of unplanned downtime. Λ

Comfortable

Regulations and customer demands put pressure on rail designers to deliver passenger coaches with comfortable climates. In the past, Siemens engineers spent about four months testing passenger coaches in a climate wind tunnel to validate the design of the heating, ventilation and cooling (HVAC) system. Now they use ANSYS Fluent computational fluid dynamics (CFD) software to validate the design before building the first coach to reduce the testing time and cost by up to 50 percent.

By **Thomas Plinninger**,
Systems Engineer, Siemens Mobility,
Munich, Germany, and
Alexander Hildebrandt,
Group Leader, Siemens Mobility,
Krefeld, Germany

^ Siemens' new ICE 4 train was recently approved for operation in Germany.

Rail Travel

“Siemens engineers *get the design right* the first time, which makes it *possible* to *reduce the amount* of wind tunnel testing by *50 percent* – a two-month reduction.”

In many countries around the world, train travel is pervasive. For example, in Europe, passengers traveled over 475 billion kilometers by train in 2014, and in Asia and the Middle East the number was more than five times greater. [1] Climate control of rail passenger coaches is increasingly important due to growing government regulations and mounting customer demands. For example, European Standard 13129 (EN13129) sets out strict requirements for controlling the air temperature, relative humidity and air speed within passenger compartments. Designing the HVAC system of a new passenger coach to meet this standard used to require four months of testing and modifying the HVAC system design in a climate wind tunnel that costs thousands of euros per day for rental fees alone. In addition, simulation time was limited due to tight deadlines for coach delivery.

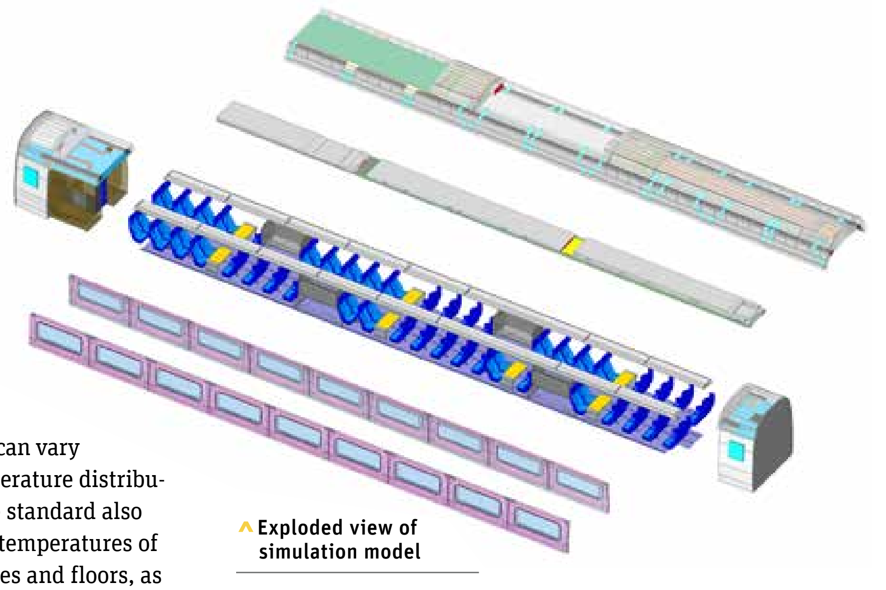
Over the last few years, Siemens engineers have succeeded in accurately simulating the complete passenger coach using ANSYS Fluent CFD software and producing detailed results that closely match physical measurements. Simulation results can be generated in a fraction of the time required for testing. Engineers can evaluate more design iterations than was possible in the past, often resulting in superior HVAC performance. The passenger coach still must be tested to validate conformance with the standard, but testing time has been reduced by 50 percent on the latest products, saving significantly in wind tunnel rental expenses, as well as considerable additional savings in personnel and equipment costs.

> "Siemens engineers succeeded in accurately simulating the complete passenger coach using ANSYS Fluent CFD software and producing detailed results that closely match physical measurement."

HVAC Design Challenges

The European standard prescribes wide-ranging and challenging requirements for climate control in intercity passenger coaches. The mean interior temperature can vary by no more than +/- 1 C from the temperature setting. The horizontal temperature distribution in the car measured at 1.1 meters from the floor can vary by no more than 2 C. The vertical temperature distribution can vary by no more than 3 C. The standard also specifies requirements for the surface temperatures of walls, ceilings, windows, window frames and floors, as well as interior temperatures in corridors, bathrooms, annexes and other parts of the train. Finally, the standard defines requirements for relative humidity and fresh air flow.

In Siemens passenger coaches, warm air is delivered by a complex channel system over the side walls to the floor. Cold air is delivered by a central channel in the ceiling with approximately 30,000 4-mm-diameter air inlet holes. In the past, Siemens relied upon experience and very expensive experiments to validate the HVAC system's ability to meet the requirements of the standard. Due to the high costs of building a complete passenger coach, building a prototype is out of the question. This means that feedback cannot be obtained



^ Exploded view of simulation model

Occupancy tests check the functionality of a fully occupied train. With red heating pads simulating the body warmth of passengers and humidifiers simulating their transpiration, the proper functioning of all systems can be tested for a fully occupied train under realistic operating conditions. A seated passenger radiates around 120 watts of heat. The Siemens engineers take this and other factors into account when designing and adjusting the ICE 4's air conditioning system.

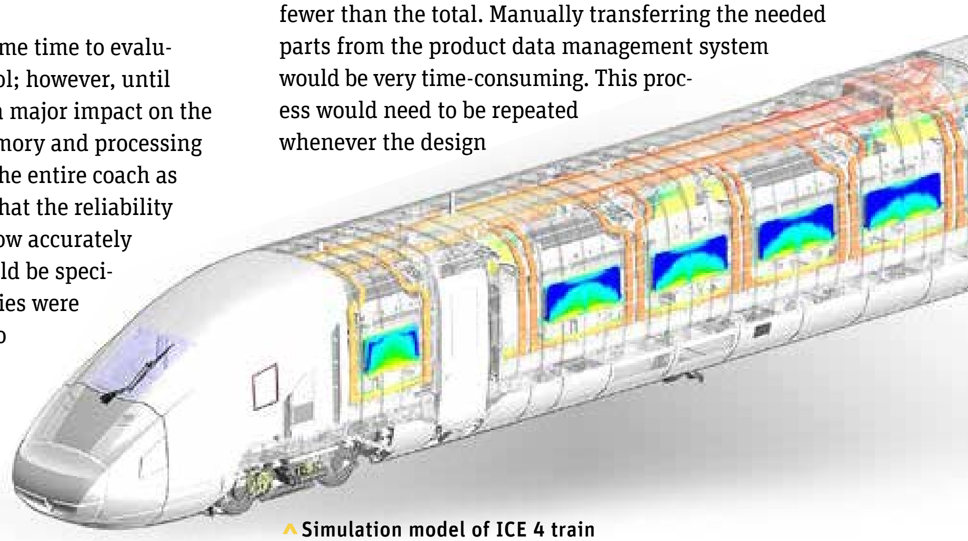
on the performance of the HVAC system until the first product has been built, at which point the customer is usually anxious to take delivery. The coach must be instrumented with 500 to 800 sensors, which takes about two weeks. Then about 14 weeks of testing are required to fully evaluate the compliance of a single coach design with the standard under many different climatic conditions. A typical cooling test would be run, with every seat in the car occupied at 40 C ambient temperature, at 15 km/h driving speed and at an interior temperature set point of 27 C.

Implementation of Simulation in HVAC Design

Siemens has used CFD for quite some time to evaluate passenger coach climate control; however, until recently, simulation did not have a major impact on the design process. Limitations in memory and processing power made it impractical to use the entire coach as the solution domain. This meant that the reliability of the results was dependent on how accurately the boundaries of the problem could be specified. Unfortunately, most boundaries were in areas where it was impossible to accurately determine them with measurements or theoretical calculations. For example, many trains have internal doors with openings for return flow. The only way to accurately predict the airflow through these openings is to include the room on the other side of the door in the solution domain.

Over time, Siemens climate control engineers were able to demonstrate the value of simulation to their management and marshal the computing resources needed to enlarge the scope of their models until they encompassed the entire coach. The boundary of the computational domain was moved from the wetted surface of the extracted fluid interior to the exterior wall of the vehicle. The outside walls were included in the model as solids using conjugate heat transfer. The walls are usually a multilayer structure consisting of materials such as plastic, insulation and aluminum; each layer must be modeled. The ambient conditions are defined by the standard. Occupant heat sources are added to the model as specified by the standard.

Each car has over 150,000 components. The number of parts required for the HVAC simulation is greater than that for a structural simulation, but still much fewer than the total. Manually transferring the needed parts from the product data management system would be very time-consuming. This process would need to be repeated whenever the design



^ Simulation model of ICE 4 train

> “These savings also extend to earlier product delivery and increased revenues.”

The ICE 4 in the climatic wind tunnel

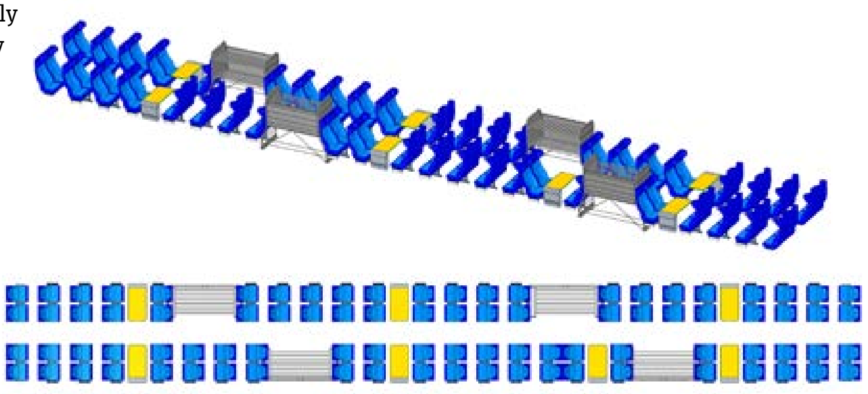
changed significantly. So Siemens engineers developed a routine that automatically exports selected data from the PDM system in native or neutral format and converts the data to ANSYS SpaceClaim format. Engineers then use SpaceClaim semi-automatic tools to clean up small parts such as bolts and bolt holes and complex supplier parts. All geometrically relevant details are explicitly modeled. Engineers create the inverse geometry needed for flow analysis.

Siemens engineers use ANSYS Meshing automated routines for both surface and volume meshing. They create approximately 200 different subdomains so that meshing can be optimized for different areas of the model. Tetrahedral meshing is the first choice for areas with complex geometry. Hybrid tetrahedral-hexahedral meshes with hexahedral elements in the boundary layer are used where especially high boundary layer accuracy is needed to precisely calculate heat transfer to a solid surface. Conjugate heat transfer simulation is used to predict surface temperatures of walls that may be touched by passengers and channels that exchange heat with the inside of the car. The result is a simulation model with typically 500 to 600 million cells, which is solved with ANSYS Fluent on a high-performance computing (HPC) cluster.

ANSYS CFD-Post assists engineers in examining simulation results such as volume flow rate and energy distribution, as well as more than 400 measuring points, including all seat positions in the cabin. Siemens engineers evaluate the simulation results in detail and compare them to the EN13129 standard and additional customer requirements. The simulation results provide a good understanding of the temperature and airflow distribution inside the cabin and indicate opportunities for improving the design. Engineers frequently manually perform parametric studies to determine the best way to operate the HVAC system.

Validation of Simulation Results

Validation of the simulation is a crucial requirement in the CFD process. Engineers performed this validation for a reference project that was simulated and also tested in a climate wind tunnel. The results of

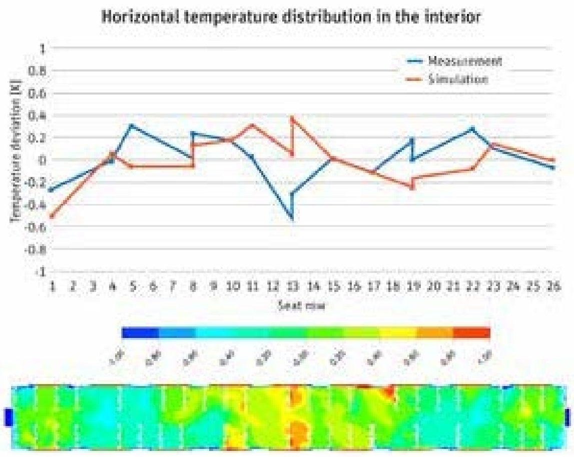


Detailed view of simulation model of coach interior

“Siemens engineers get the design right the first time, which makes it possible to reduce the amount of wind tunnel testing by 50 percent — a two-month reduction.”

the experimental investigation and the CFD simulation show good agreement but they also show areas where the process can still be improved.

The ability to accurately predict HVAC system performance with simulation enables Siemens engineers to validate conditions inside the coach with a high level of accuracy prior to building and testing the first product. In most cases, they are able to get the design right the first time, which makes it possible to reduce

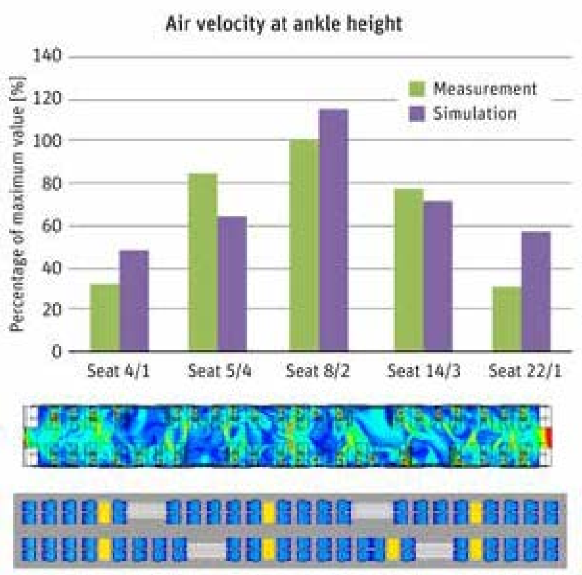


Comparison of horizontal temperature distribution simulation results with physical testing

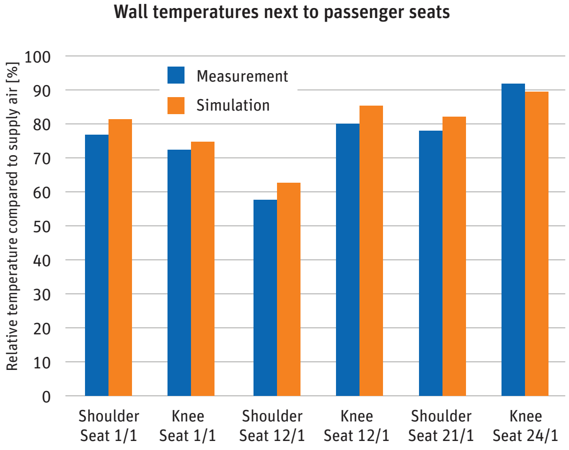
the amount of wind tunnel testing by 50 percent — a two-month reduction. This saves on wind tunnel rental fees, manpower and equipment. The ability to much more easily evaluate alternative designs often enables Siemens engineers to improve passenger comfort beyond the requirements of the standard and to eliminate the need for testing product variants. When the HVAC system is on the critical path for the program, which is not unusual, these savings also mean earlier product delivery and increased revenues.

Reference

[1] International Union of Railways, Railway Statistics 2014, http://www.uic.org/IMG/pdf/synopsis_2014.pdf



Comparison of air velocity simulation results with physical testing. The difference between simulation and measurement is around 20 percent, which is quite good considering this is a local point value of air velocity in a convective turbulent flow.



Comparison of wall temperature simulation results with physical testing

Climate Control Gets Elevated
ansys.com/climate-control

DECREASING DRILL DAMAGE

Machining expensive corrosion-resistant materials is tough on the cutting equipment. Researchers at the Technical University of Dortmund used fluid flow and structural analysis tools from ANSYS to analyze process coolant flow distribution and achieve longer tool life.

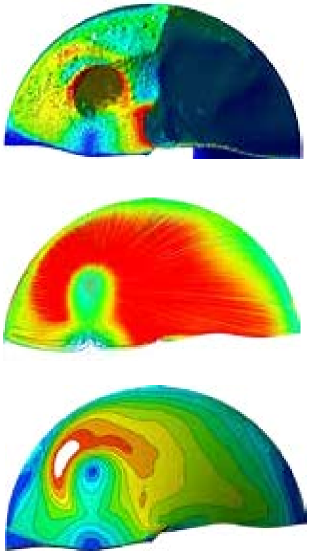
By **Dirk Biermann**, Professor, and **Ekrem Oezkaya**, Research Assistant, Institute of Machining Technology, Technical University of Dortmund, Dortmund, Germany

Life can be short for a drill. Machining materials such as Inconel, which is a group of superalloys made up primarily of nickel, chromium and iron, can be challenging. Inconel is part of a generation of superalloy materials used in gas turbines, heat exchangers, chemical reactors and rocket engines that can resist high temperatures, pressures and corrosion due to the hardening processes used to forge them. Because the act of working on

"To understand the *complex interaction* between the drill structure, the coolant fluid and the Inconel workpiece, the ISF team used *ANSYS tools* to perform FSI analysis."

them actually makes them stronger through plastic deformation, cutting or drilling into an Inconel alloy has to be carefully managed to prevent rapid wear and damage to the machine tools.

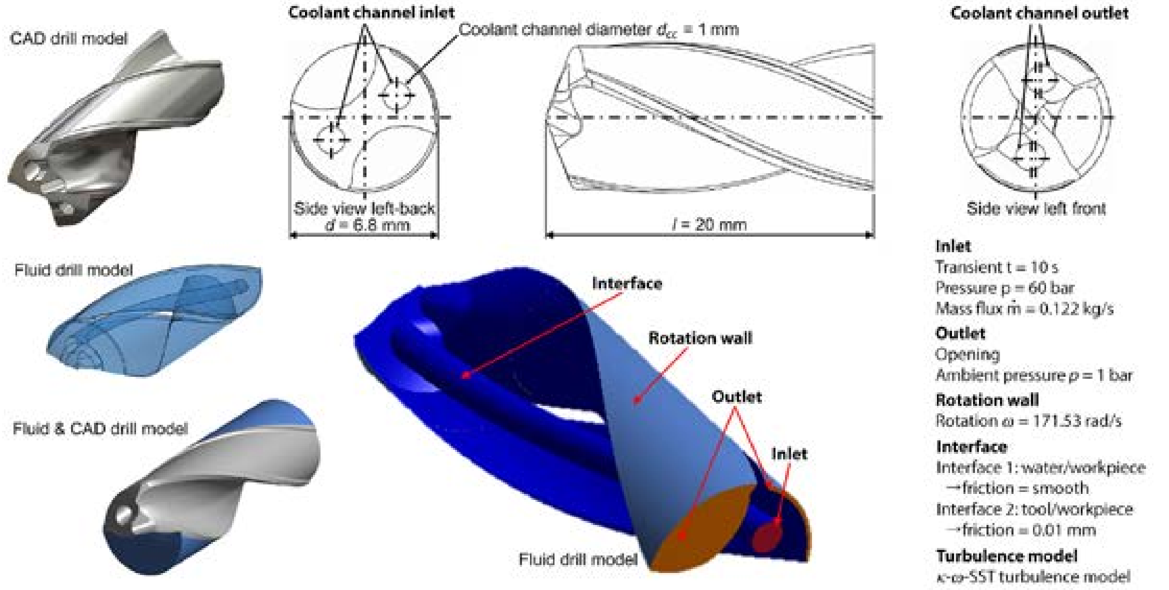
At the Technical University of Dortmund's Institute of Machining Technology (ISF), a research team analyzed methods to extend the life of drills for use on the superalloy Inconel 718. The low thermal conductivity of this alloy means that a large amount of heat must be transported away from the boring zone using external methods, or the tool can become deformed. This can lead to poor bore quality or breakage of the carbide drill bit. Relatively low drill speeds under 50 m/min are used to keep temperatures lower in the cutting zone, but a liquid coolant is still required. To direct the coolant fluid where it is needed, it is pumped through two tiny channels inside the land. (The land is the solid, helical pattern of the drill bit, while the flutes are the negative space through which the metal chips and fluid are evacuated from the bore hole.) If coolant is not distributed properly, dead zones can form along parts of the cutting edge, and the heat transport will not be as effective, which can lead to damage or burned coolant deposition.



^ End view of cutting area showing velocity contours of the coolant on the cutting tool surface (top), streamlines (middle) and velocity contours on the bore surface (bottom).

FLUID–STRUCTURE INTERACTION

Due to the extremely small diameters of the coolant channels, experimental measurements of the coolant flow distribution are not feasible. To understand the complex interaction between the drill structure, the coolant fluid and the Inconel workpiece, the ISF team used simulation

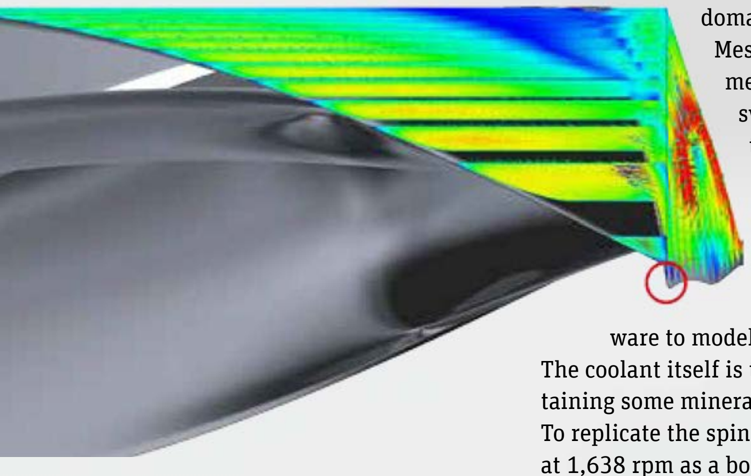


^ Geometry of solid and fluid zones, including flow boundary conditions

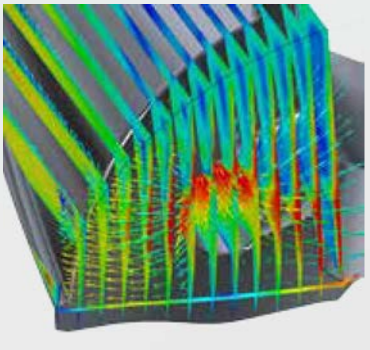
"Drilling into an *Inconel alloy* is carefully managed to prevent *rapid wear and damage* to the machine tools."

tools from ANSYS for process optimization by performing a fluid–structure interaction (FSI) analysis. To begin the process, ISF researchers built a 20-mm-long model of the interlocking solid and fluid domains by importing a CAD geometry file into ANSYS Meshing. For the fluid domain, the team created two mesh zones: a uniform coarse mesh generated by the sweep method for the flute space, and a very fine mesh to resolve the space at the main cutting edge between the drill's flank face and the bore bottom. Two variations were considered, with coolant channel diameters of 1 mm and 1.25 mm.

With completed fluid meshes, the engineers used ANSYS CFX computational fluid dynamics (CFD) software to model the distribution of coolant through the fluid domain. The coolant itself is typically a water-based metalworking lubricant containing some mineral oil, but the team modeled it as water for simplicity. To replicate the spinning of the drill, the entire flow domain was rotated at 1,638 rpm as a boundary condition corresponding to the drill's cutting speed of 35 m/min. The k-ω shear stress transport turbulence model was applied because of its accuracy in predicting both near-wall and far-wall distributions under such a flow regime. Further, the ISF team considered three different fluid inlet pressures (25, 40 and 60 bar) for both channel diameters. They assumed the flow field to be isothermal, because the heat transfer is strongly dependent on the flow characteristics, which are independent of the fluid temperature.



^ Side view of vertical planes showing the coolant velocity vectors



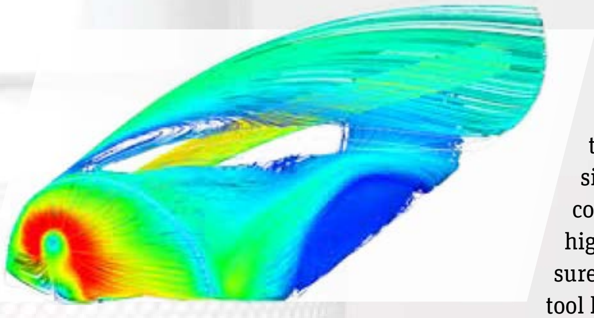
^ End view of vertical plane showing the coolant velocity vectors

On the structural side, the ISF engineers wanted to determine the impact of different coolant pressures and channel diameters on both the tool wear and the bore quality. In the cutting process, the downward force on the rotating drill translates into a mechanical load, or feed force, at the bottom of the bore hole. The team used ANSYS Mechanical with an added boundary condition of the coolant forces calculated by CFX to complete the FSI analysis. Including all of the different CFD and Mechanical simulations, ISF completed its computational analysis within four weeks.

USING SIMULATION TO DETERMINE DESIGN CHANGES

The fluid flow predictions indicated that increasing the channel diameters from 1 mm to 1.25 mm nearly doubled the coolant mass flow rate inside the channels. Increasing the inlet pressure led to increased coolant velocity in the direction of the flutes and higher flow rates near the cutting edge. This created better turbulent flow conditions for convective heat transport. But larger channel diameters did not lead to significantly greater heat transport, no matter what the pressure. The team's scanning electron microscopy

"The team modified its **cooling process** to **improve the tool life** by about 50 percent."



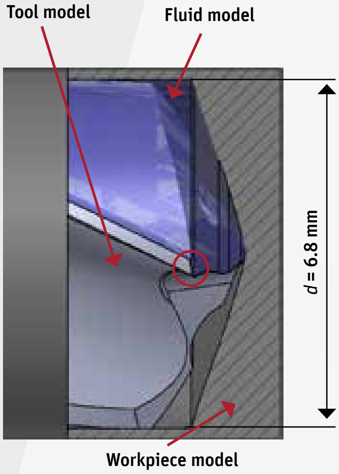
Simulation of flow distribution colored by velocity

(SEM) measurements of the tool wear and burned coolant deposition supported the simulation results, confirming that a higher coolant pressure achieved longer tool life and improved bore quality by producing better cooling conditions.

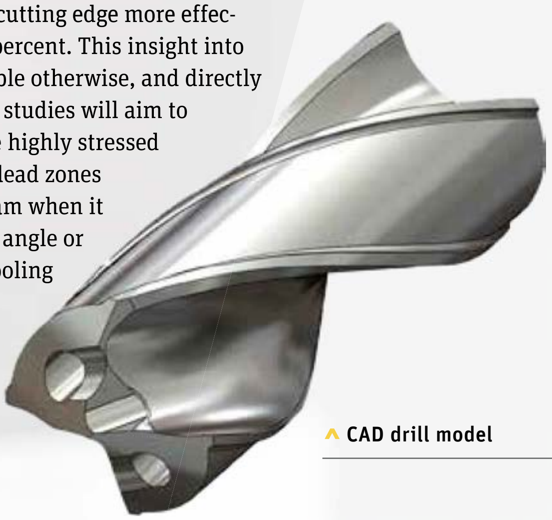
Complementing the CFD results, the Mechanical analysis showed that the highest stresses on the bore bottom occurred on the outer side of the coolant channels, where coolant velocities were highest. The team's comparison of the simulated and measured feed forces showed good agreement, indicating that a larger channel diameter caused much higher feed force due to the increased coolant flow rate. Such higher feed forces on the bore bottom were not desirable, and provided a further argument in support of using the smaller channel diameters.

At the conclusion of its work, the ISF team investigations proved that, when physical measurements reach their limits, simulation software is a suitable tool to support the design work for complex drilling processes. Because of the flow distributions predicted by the CFD simulation, the team was able to modify its cooling process to direct coolant to the cutting edge more effectively, and thus improve the tool life by about 50 percent. This insight into the machining process would not have been possible otherwise, and directly saved ISF 50 percent in tool material costs. Future studies will aim to increase the coolant flow rate in the vicinity of the highly stressed areas of the cutting edge to avoid the presence of dead zones as much as possible. This may further help the team when it considers strategies such as varying the clearance angle or redesigning the flank face to achieve additional cooling improvements.

The authors would like to thank Guehring KG, Albstadt, Germany, for supporting CAD models and this research.



Close-up view of cutting edge, including the solid tool zone, fluid zone and Inconel 718 solid workpiece zone



CAD drill model

Fluid–Structure Interaction
ansys.com/fsi

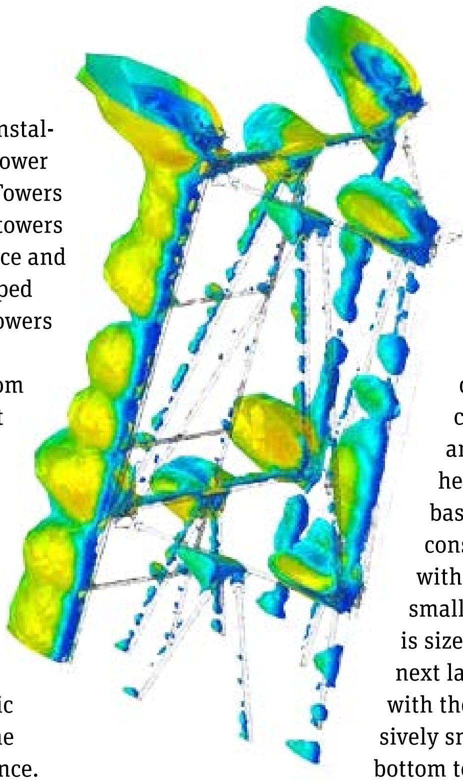
TOWER OF STRENGTH

Brazil's vast interior areas are so sparsely settled that conventional fiber optic cabling is often not economical. Wireless internet service providers (WISPs) are racing to erect towers to provide internet access to rural residents. Jet Towers used ANSYS AIM simulation software to design a line of truss tower modules that makes it possible for the company to build and install wireless towers in only one week, one-fifth the time required by conventional methods.

By **Ricardo Damian**,
Director of Engineering,
Jet Towers,
Santiago, Brazil

While optical fiber is the primary method of providing internet access to Brazilian city dwellers, it is not economical in most of the country's sparsely populated rural areas. Two decades after internet service first became available in Brazil, only 22 percent of residents of rural areas had access to broadband internet. A number of Brazilian WISPs are increasing this number by providing tower-mounted Wi-Fi to rural areas. WISPs that are competing to provide internet service to underserved areas face the challenge of quickly building towers and putting them into operation so they can sign up customers before competitors enter the market. In addition, cellular companies and radio stations are continuing to build out infrastructure, which requires even more wireless towers.

Design, construction, shipment and installation of a typical 45-meter wireless tower normally takes about five weeks. Jet Towers has a better way — a modular line of towers whose components are built in advance and kept in inventory so they can be shipped and assembled in about a week. Jet Towers design engineers used ANSYS AIM to optimize the design of its modules from a fluid flow and structural standpoint from within a single immersive user environment. Engineers then embedded the intelligence behind these designs in a spreadsheet so they can be configured by nontechnical staff to provide customers with a design and quote in a matter of minutes. Jet Towers engineers have also used ANSYS HFSS electromagnetic simulation to evaluate the effect of the tower structure on antenna performance.



^ CFD simulation of forces exerted by wind on the tower structure

WIRELESS TOWER DESIGN CHALLENGES

The main variables in designing wireless towers are the height of the tower and the size of the antennas. The height of the tower plays a key role in determining its range, and the size of the antennas determines how strong the tower needs to be to withstand wind loading. Traditionally, WISPs provide tower companies with their requirements and engineers use handbook equations or simple simulation software to design the tower and determine its manufacturing cost. If the WISP places an order, the tower company cuts steel beams and welds or bolts them together, delivers the tower to the site and erects it. The entire process takes about five weeks.

When the founders of Jet Towers started the company less than a year ago, they set out to help WISPs erect towers faster so they could beat their competitors to market. The founders decided to pre-engineer a series of standard six-meter-high modules that could be combined to produce any tower within a wide range of heights and antenna sizes. The basic idea is that the modules are constructed as triangular trusses, with a triangular base and a slightly smaller triangular top. Each module is sized to connect at its base with the next larger module and at its crown with the next smaller module. Progressively smaller modules are used from bottom to top because each module has less load to carry than the one underneath it.

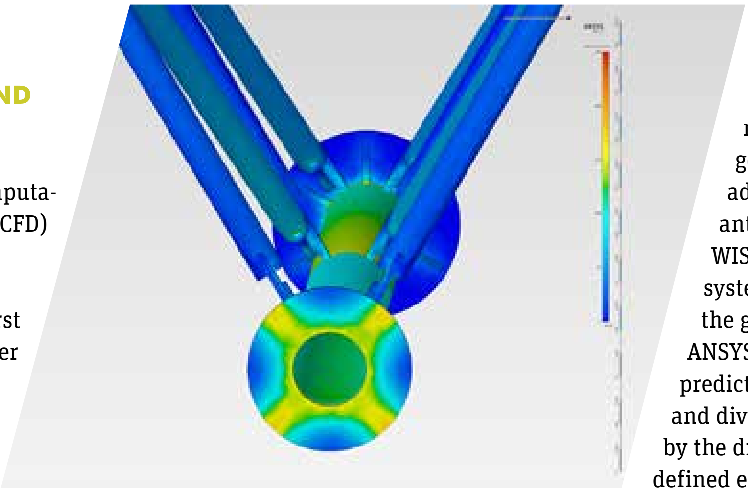
Antenna size affects the structure because the projected area of an antenna's profile — the sum of its profile minus shadow effects — determines the amount of force applied to the structure by the wind. The modules can be used to design towers for different sized antennas by making the components at the base of the tower larger or smaller, which in turn automatically increases or decreases the size of each subsequent module moving up the tower. The height of the tower is determined by the number of modules used to construct it.

Jet Towers Uses ANSYS AIM
ansys.com/jet-towers

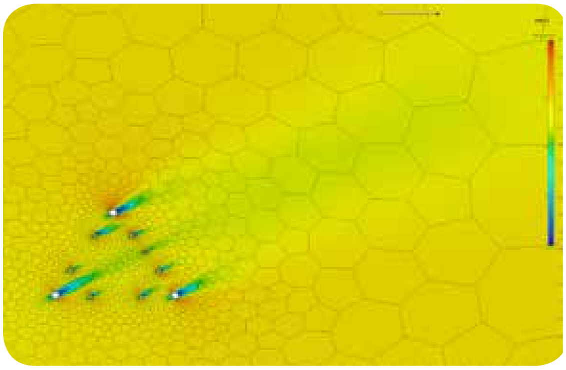
> "Jet Towers can simulate all aspects of wireless tower design by applying the ANSYS AIM easy-to-use graphical interface, eliminating the need for analytical specialists."

DETERMINING WIND LOADING

Jet Tower's only design engineer used AIM computational fluid dynamics (CFD) to determine the load generated by different tower structures. He first imported the truss tower structure from the 3-D CAD system, generated its inverse geometry to create the fluid domain, bounded the fluid domain by a large cylinder and automatically meshed the space. One wall of the cylinder was defined as an opening boundary condition with flow velocity representing the maximum wind that Brazilian towers must be designed to withstand. The engineer performed a mesh-independence study to determine how fine a mesh was required and how many prismatic layers were needed at the boundary layer. He compared the overall force value over the structure from the CFD analysis with the calculated force from the simple analytical formula in the Excel® spreadsheet. Then, he calibrated the beam's drag coefficients and projected area assumptions.



^ FEA used to compare connection methods in truss tower modules



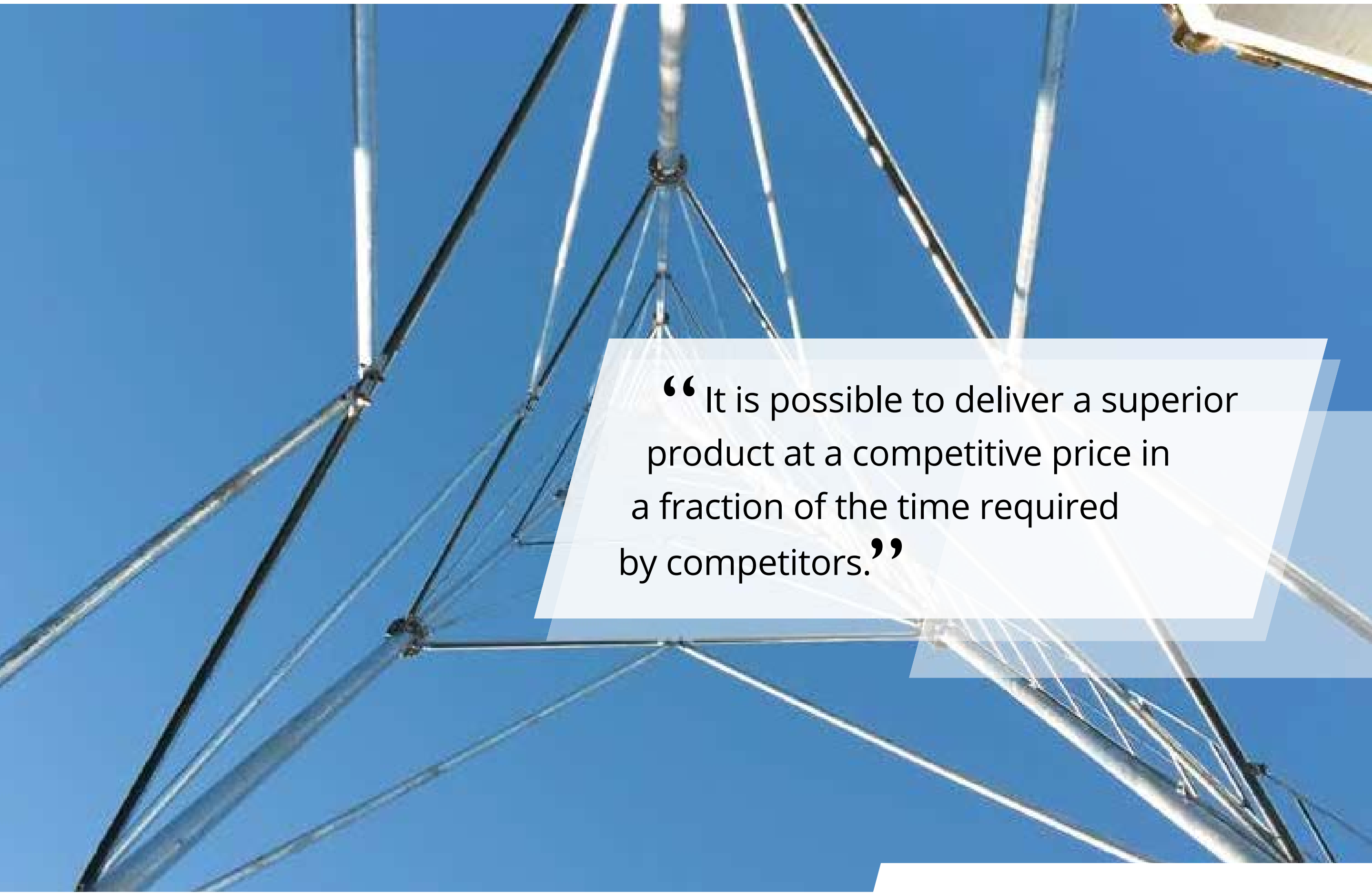
^ FEA simulation used to evaluate beam profiles and bracing types

Next, the engineer defined the geometry of several additional common antennas used by WISPs in their CAD system. He opened the geometry in ANSYS AIM, used CFD to predict the wind loading, and divided the loading by the drag coefficient defined earlier to determine the projected area of the antenna. The engineer simulated the common antennas used by most WISPs and used the drag coefficient to estimate loads for other antennas based on their projected areas.

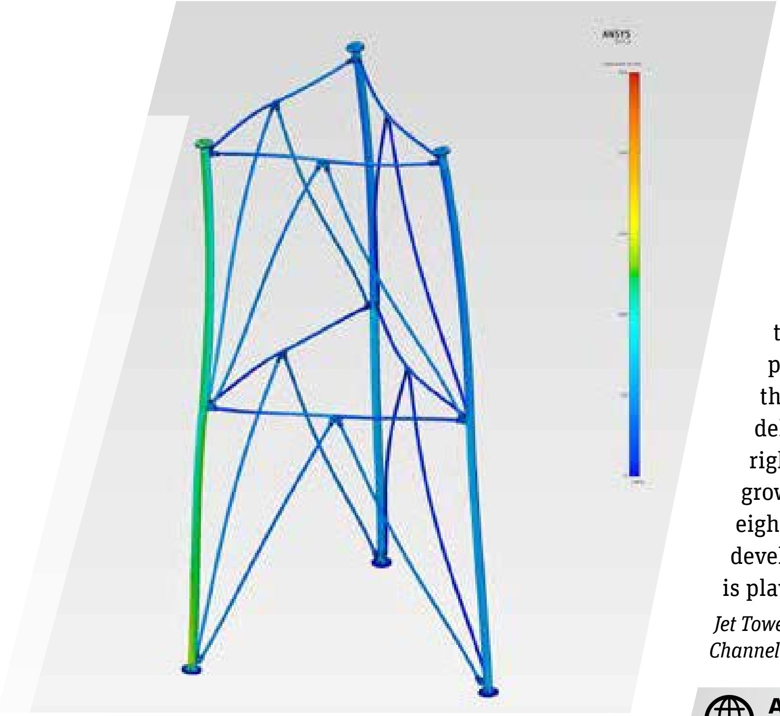
OPTIMIZING TRUSS TOWER DESIGN

The next step was using structural analysis to design modules that support the required loads with an adequate margin of safety, while keeping costs to a minimum. The engineer modeled the trusses using circular, rectangular, and L-, C- and V-shaped profiles, and then tried filling the enclosed profiles with concrete. He evaluated a wide variety of different connection methods, such as welding and bolting, and looked at different flanges.

The engineer manually simulated a wide range of different design alternatives and designed more than 20 modules to optimize the total installed cost of the tower, including materials, manufacturing expenses, freight, foundation and installation. Then he embedded the designs into a computer application so sales representatives and other team members having no engineering experience can simply enter key parameters (tower height, antenna size) into the spreadsheet. The spreadsheet then determines exactly which modules need to be combined to build the right tower for the application. The spreadsheet also determines the cost of the tower. Jet Towers keeps all of the different



“It is possible to deliver a superior product at a competitive price in a fraction of the time required by competitors.”



modules in stock so that the company can build and install a tower one week from receiving an order.

With ANSYS AIM, Jet Towers can simulate all aspects of wireless tower design in an easy-to-use graphical interface that guides engineers through the complete multiphysics workflow, eliminating the need for analytical specialists. Embedding the simulation results in a line of modular towers makes it possible to deliver a superior product at a competitive price in a fraction of the time required by its competitors. Shorter delivery time is what WISPs are looking for right now, so Jet Towers is experiencing rapid growth. The company built 35 towers in its first eight months of operation. Jet Towers is also developing several other products; simulation is playing a key role in their design as well.

Jet Towers is supported by ESSS, an ANSYS Elite Channel Partner.

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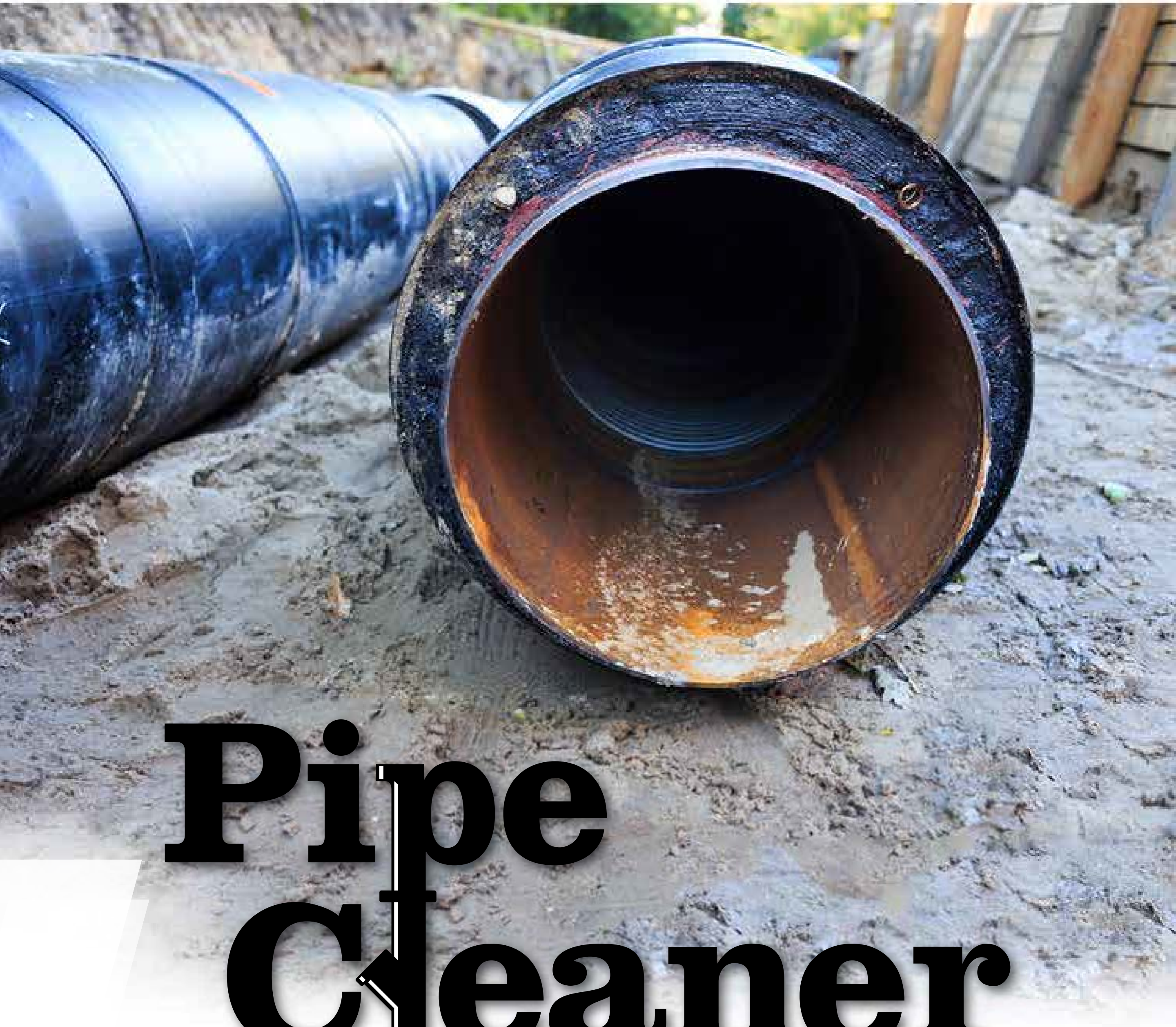


Pipe Cleaner

FMC Technologies cuts the weight of a reciprocating pump for sewer pipe cleaning in half while reducing its footprint and increasing its pressure output. This creates a highly competitive product.

By **Mario Ruvalcaba**,
Pump Product Engineer,
FMC Technologies, Texas, USA

A sewage pipe can become caked with grime and debris after long periods of use, reducing its internal diameter and limiting the volume of waste water it can handle at any time. Following a storm, it may become choked with dirt, rocks, branches, bottles, cans, plastic bags, and other natural and man-made debris. Routine maintenance using high-pressure water jetting is one way to remove the buildup and keep the pipes open for proper operation.

Trucks containing a large water tank and a high-pressure pump are often used to combat the clogging of sewage lines. In general, sewer pump pressures range from 2,000 psi to 4,000 psi. Lower pressure with high flow is used in larger sewer pipes, while high pressure with low flow is used for smaller pipes. High pressure (4,000 psi) is best used for removing root infiltration, because water at that pressure can cut the roots out of the pipe.

FMC Technologies designs and manufactures reciprocating pumps for this application. In recent years, the customers have been demanding smaller and lighter pumps so operators don't have to carry heavy equipment in the field. Reducing size and weight also makes pumps less expensive to purchase, easier to maintain and more energy efficient. But high pressures impart greater forces to smaller components, so the crankshaft, plungers, connecting rods, bearings and pump housings have to be stronger than the components of a larger pump.

"The simulation enabled FMC Technologies' engineers to make the reciprocating pump 50 percent lighter."

^ Crankshaft fatigue analysis using ANSYS nCode DesignLife

FMC Technologies' engineers had been using ANSYS solutions successfully for subsea oil drilling rig design, so they decided to use ANSYS Mechanical to optimize the size, weight, strength and lifetime of reciprocating pumps for sewage pipe cleaning without the loss of effective lifetime or pumping efficiency.

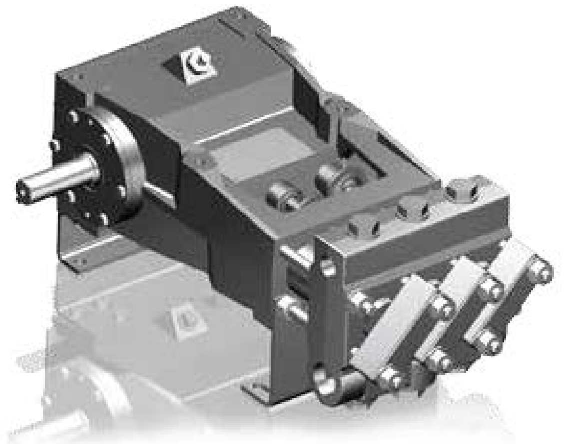
Reciprocating Pump Operation

Reciprocating pumps are part of the family of positive displacement pumps—they displace a fixed amount of volume for every stroke of the crankshaft, and work like a syringe. A plunger moves up and down; when you pull it up, it draws liquid in, and when you push it down, it drives the liquid out. On a reciprocating pump, every time the crank moves down, the plunger moves out and fluid is drawn in through the pump's suction port; when the crankshaft completes a full cycle, it moves up, pushing the plunger forward and the fluid out. The number and size of the plungers determine how many gallons per minute you can pump. In industry, three or five plungers are common. An electric motor or a diesel engine drives the crankshaft and moves the plungers to produce flow.

The discharge end of the pump is pressurized to the desired operating pressure —in this case 4,000 psi — by restricting the downstream flow with a valve or some other pressure control device. The high pressure is necessary to provide enough force to blast away the buildup inside the sewage pipe, but it also puts high stress on the pump's components. The crankshaft, plunger, connector rods, bearings and housing will all experience this high load. Optimal design is needed to ensure that components will not break during operation, thereby maximizing the pump's lifetime.

Simulating a Smaller, Lighter Pump

To design a pump that would be lighter than their standard 245 lb (111 kg) sewage-cleaning pump while increasing the outlet pressure from 3,000 to 4,000 psi, FMC Technologies' engineers modeled the



^ Former model of FMC high-pressure sewer cleaning pump

^ New sewer cleaning pump from FMC after redesign using ANSYS simulation solutions

complete, 25-component pump system, with special emphasis on the crankshaft. The crankshaft was modeled as a cast iron part with flexible structural behavior and approximately 200,000 elements in the mesh; the remaining 24 components — plungers, connector rods, bearings and housing — were modeled as rigid bodies. The model contained multiple contact joints, some of them with fixed behavior and others with one or two degrees of freedom. Each joint had one or two coordinate systems. Applied force and joint rotation were used as boundary conditions. The goal was a robust design in which the highest stresses were significantly below the material yield strength to avoid plastic deformation. Parameters of interest in the results were total deformation, maximum equivalent, maximum principal and shear stresses.

Because of the cyclic rotational nature of the crankshaft's movement, during which the load changes from a maximum to a minimum, engineers performed fatigue analysis using ANSYS nCode DesignLife to ensure a robust design safety factor for fatigue.

> "Engineers performed fatigue analysis using ANSYS nCode DesignLife to ensure a robust design safety factor for fatigue."

Optimized Designs for Fatigue Using ANSYS nCode DesignLife
ansys.com/fatigue

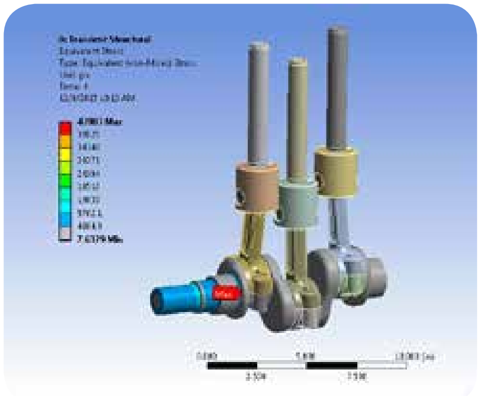
Simulation Challenges

Simulating a complex system with 25 components proved to be challenging. Even though the focus was on the crankshaft, FMC Technologies' engineers could not analyze it by itself because it is linked to all the other components. Furthermore, a crankshaft is a dynamic application: Every time it moves, each component is in a different position at a different angle, so the stresses vary widely. Such a dynamic application requires a dynamic analysis. Consulting with ANSYS support personnel, the team decided to manage this complexity by simulating the movement of the crankshaft through one complete revolution. Analyzing how the plungers moved up and down and how that changed the load on each part resulted in the necessary dynamic analysis.

Even with this strategy in hand, other challenges remained. On the first simulation run, the analysis did not converge as expected. After changing some simulation parameters, including boundary conditions that were overconstraining the model, the analysis did converge, but the calculated stresses were completely out of range — too high to be true, as confirmed by hand calculations.

One complication was the large number of joints linking all the components. Each of these joints has specific degrees of freedom because the components are in motion, and each has its own coordinate system tied to certain phases of the component. Failure to choose the right degrees of freedom for one component can adversely affect variables for the rest of the assembly.

Working with ANSYS support engineers on many simulation iterations over the course of a month and making systematic adjustments to the model based on the results of these iterations, an optimal design solution for the reciprocating pump emerged. Compared to the many months this design would have taken using the old build-and-test method, FMC Technologies saved much time and cost using ANSYS solutions.



^ Stress on pump crankshaft displayed in ANSYS Workbench

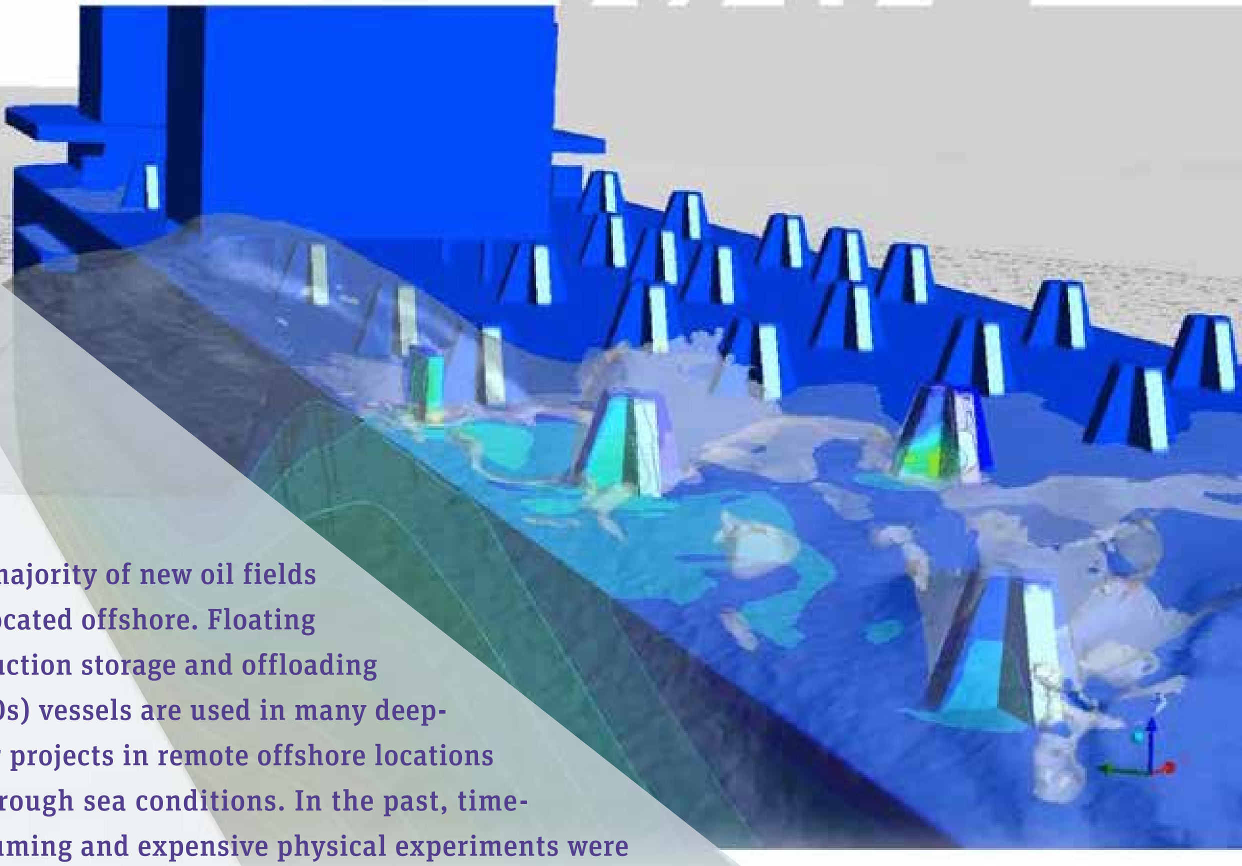
A Better, Competitive Pump

The final, nonlinear, transient-structural analysis using ANSYS Mechanical and ANSYS nCode Design Life took 36 continuous hours of simulation time on a 12-core computer. The simulation enabled FMC engineers to make the reciprocating pump 50 percent lighter, reducing the weight from about 245 lbs (111 kg) to approximately 130 lbs (59 kg). The pump's length was shortened by 25 percent, and the pressure was increased from 3,000 psi to 4,000 psi, providing much more blasting power to clean the sewer pipes.

Internally, the forged alloy steel crankshaft of the new pump is 12.75 inches long and only 1.625 inches in diameter. Even at this small diameter, it can withstand the 4,000 psi force for the lifetime of the pump — quite an achievement. The previous pump had two shafts: a pinion shaft that drives a bigger crankshaft with a gear. Producing a single-shaft design greatly helped to reduce the size and weight of the pump.

FMC Technologies can now offer the sewer cleaning industry a lighter, energy-efficient and highly competitive pump. Having analyzed every component with ANSYS engineering simulation tools to ensure that it would be robust, FMC Technologies' engineers can meet the demanding applications of today's sewer cleaning market. Λ

RIDE THE WAVE



The majority of new oil fields are located offshore. Floating production storage and offloading (FPSOs) vessels are used in many deep-water projects in remote offshore locations with rough sea conditions. In the past, time-consuming and expensive physical experiments were the only alternatives to ensure that vessels could withstand the highest possible sea states without damage. Petrobras uses ANSYS simulation to reduce the number of experiments required and obtain more detailed loading data.

By **Daniel Fonseca de Carvalho e Silva**,
Research Engineer,
Petrobras,
Rio de Janeiro, Brazil

The pre-salt layer is a geological formation on the continental shelves that was laid down before a salt layer accumulated above it during the breakup of the Gondwana supercontinent into the continents we know today. Discoveries in the pre-salt layer in the past few decades on the Brazilian continental shelf are estimated at 50 billion barrels of oil, four times greater than Brazil's previous reserves. These reserves present an enormous drilling challenge because they lie under up to 3,000 meters of seawater, 2,000 meters of rock and 2,000 meters of salt. And, because they lie in deep water up to hundreds of kilometers off the coastline where difficult weather and sea conditions are often experienced, bringing oil and gas to the surface presents special challenges for FPSO vessels used to receive these hydrocarbons from the wells, then process, store and offload them into a tanker or pipeline.

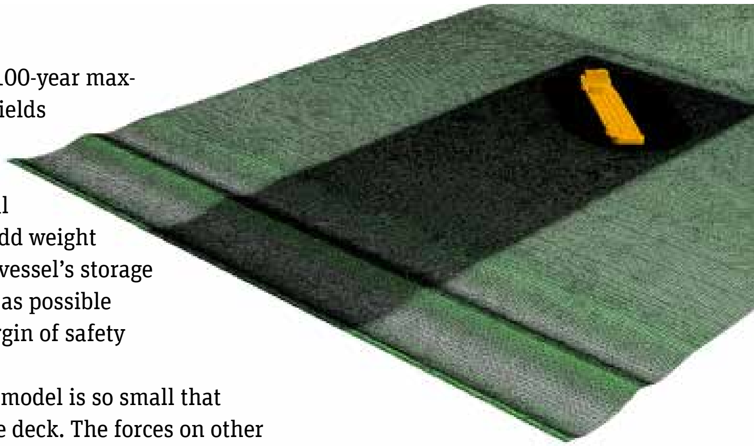
The worst-case scenario, called green water, occurs when unbroken waves roll over the deck of the FPSO. Green water is not a threat to the integrity of the vessel, but can damage critical equipment on its surface, such as control valves, cable trays, fire protection equipment, and the like. In the worst case, this may halt production for expensive repairs to be performed. The company could lose revenues of hundreds of thousands of dollars per day. Currently, oil companies primarily use scale-model experiments to evaluate loading under green-water conditions, but this approach is limited by the complexity of monitoring loads in very congested topside areas in model scale experiments. It is difficult to predict in advance where the highest loads will be imparted, so sensors are often not in the right positions. Petrobras has overcome these challenges by employing ANSYS Fluent computational fluid dynamics (CFD) software to predict forces on deck structures with a much higher level of resolution than can be achieved with physical testing.

> **"*ANSYS CFD software* predicts forces on deck structures with a much higher level of resolution than can be achieved with *physical testing*."**

DECK STRUCTURE DESIGN CHALLENGES

FPSO deck structures must be designed to withstand a 100-year maximum significant wave height of 12 meters in pre-salt fields gearing up for production, compared to 9 meters or less in post-salt fields. This upgrade may require the addition of features such as structural barriers and local reinforcements to on-deck equipment. These features add weight to the structure, which increase its cost and reduce the vessel's storage capacity. The goal is to quantify the loads as accurately as possible so that structures can be designed with a sufficient margin of safety but not overdesigned.

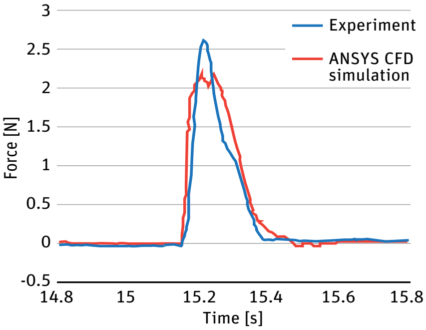
A problem with scale-model experiments is that the model is so small that only a few force measurements can be performed on the deck. The forces on other structures must be estimated, and these estimates must be high to account for uncertainty. Scale-model experiments also take about three months to plan and run, and are very expensive. One-dimensional hydraulic codes are sometimes applied to this problem, but since they don't account for the geometry of the structures, they also can only provide estimates of the relevant loading.



^ CFD mesh with refined area shown in black

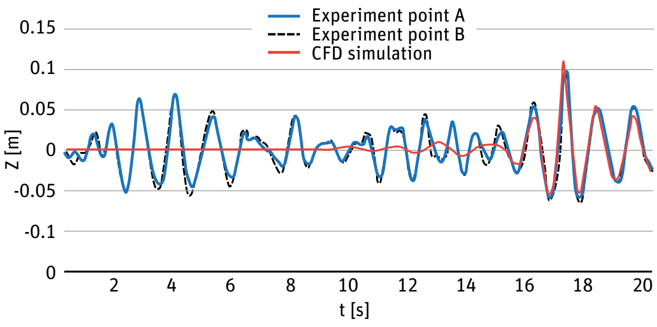
SIMULATING GREEN-WATER LOADING

Petrobras engineers recently set out to apply ANSYS CFD to this problem, starting with a simulation of a scale-model experiment so that the simulation results could easily be validated. The model test condition was carefully chosen to intensify the green-water effects; it does not represent a true operational configuration. In the physical experiment,



^ Validation of loading results

loads were measured at six locations and water elevation at 38 locations. Petrobras engineers captured a time series of the wave from the experiment, selected the most critical part and wrote a MATLAB program that runs a fast Fourier transform to represent the irregular wave interest interval as a combination of linear wave components. They wrote a Fluent user subroutine to impose the wave combination as a boundary condition on the CFD simulation. Engineers imposed the movement of the vessel as measured in the lab on the CFD simulation as another boundary condition, using a dynamic mesh to accommodate vessel movement. They used the Fluent volume of fluid (VOF) model to track the interface between the surface of the water and the air. The shear stress transport (SST) turbulence model solved a turbulence/frequency-based model (k–ω) at the wall and k-ε in the bulk flow.

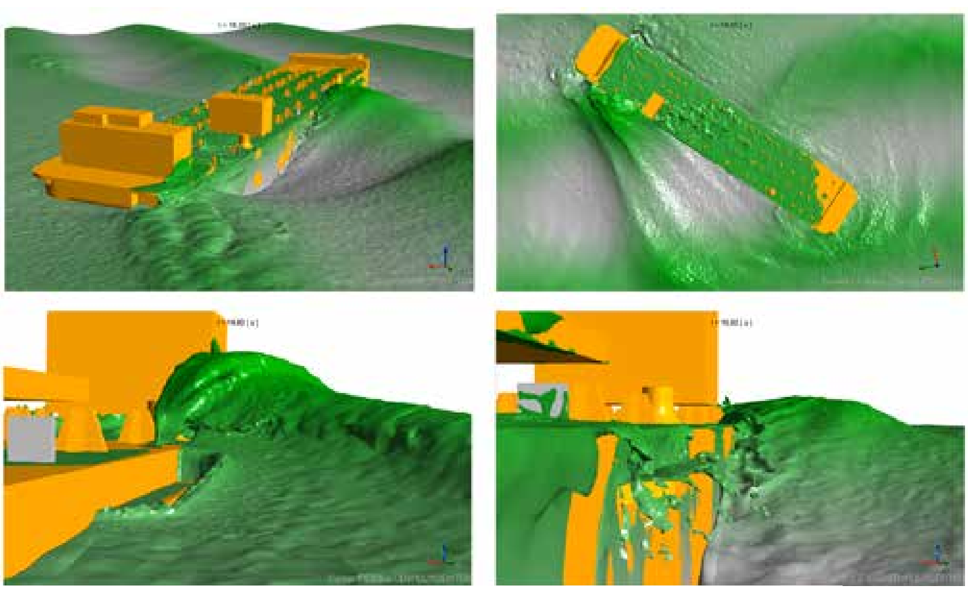


^ Validation of wave propagation results

A mesh refinement study was performed for a 2-D model to select the appropriate mesh refinement for wave propagation. Prior wave impact studies were used to define the surrounding vessel mesh. This combination leads to a mesh of about 40 million cells. Petrobras engineers validated the simulation by comparing the simulation sea state to the experimental results. After an initial transient phase of up to 14 seconds, the simulation data matched the physical testing results.

"*Physical experiments* take about three months; *simulation* can be completed in 10 to 50 days."

Engineers synchronized video images from simulation animations and experimental data to qualitatively compare the location, time and intensity of wave breaking effects. Additionally, fluid forces from wave impact were measured in a few locations and compared with the simulation results. Simulation compared well with experimental data except in the hard-to-model breaking wave regions. Even in these cases, simulation values were higher than measured values, demonstrating that they could safely be used to design the deck structures.



^ Simulation using different perspectives of a green-water wave event

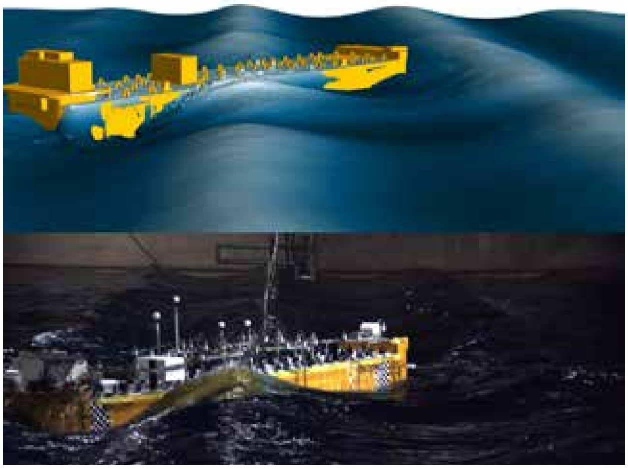
> “The *simulation results* provided considerable information that cannot *be measured* with physical experiments.”

SIMULATION PROVIDES ADDITIONAL DATA

The simulation results provided considerable information that cannot be measured with physical experiments. For example, simulation determined loading at every point in the deck structures and hull. Also, simulation provided, for the first time, sufficient measurements to determine the physical mechanisms involved in wave interaction with the hull, especially the velocity field.

Simulation will not replace physical experiments, but will save time and money by reducing the number of experiments that are needed. Setting up and running a physical experiment takes about three months, but additional time is often needed due to test basin availability. Simulation can be completed in about 10 to 50 days depending on problem complexity. This time frame can be reduced in the future by harnessing additional computing resources. Most important, simulation has improved Petrobras’ ability to ensure that FPSOs are able to withstand rough seas in lifting oil and gas in pre-salt deposits by providing more detailed loading predictions and other information that cannot be measured by physical testing.

Petrobras is supported by ESSS, an ANSYS Elite Channel partner.

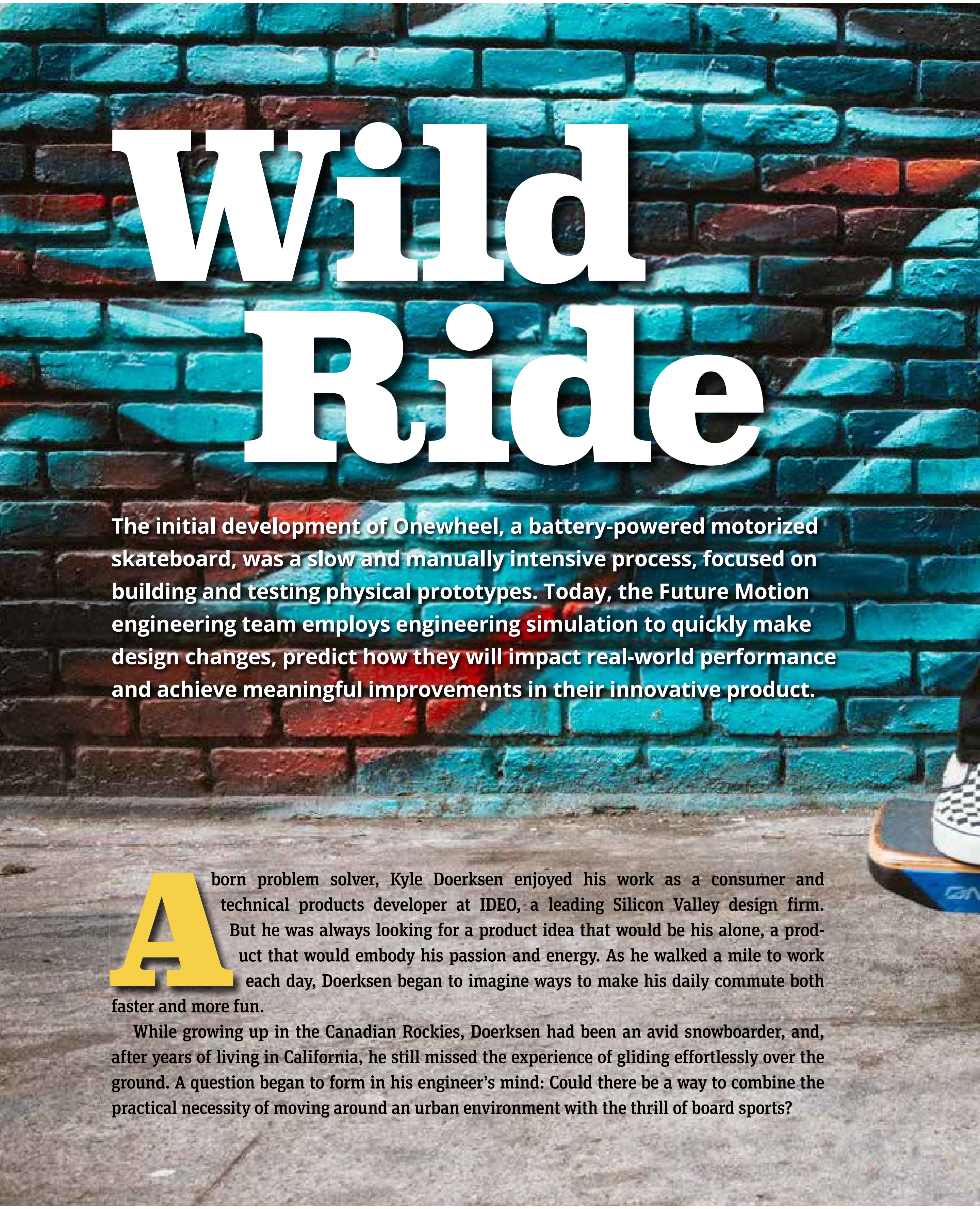


^ Simulation provided a good match to experimental results.

Reference

Silva, D.F.C.; Esperança, P.T.T.; Coutinho, A.L.G.A.
Green water loads on FPSOs exposed to beam and quartering seas, Part II: CFD simulations. *Ocean Engineering*, **2016**,

Introduction to Multiphase Models in ANSYS CFD
ansys.com/multiphase



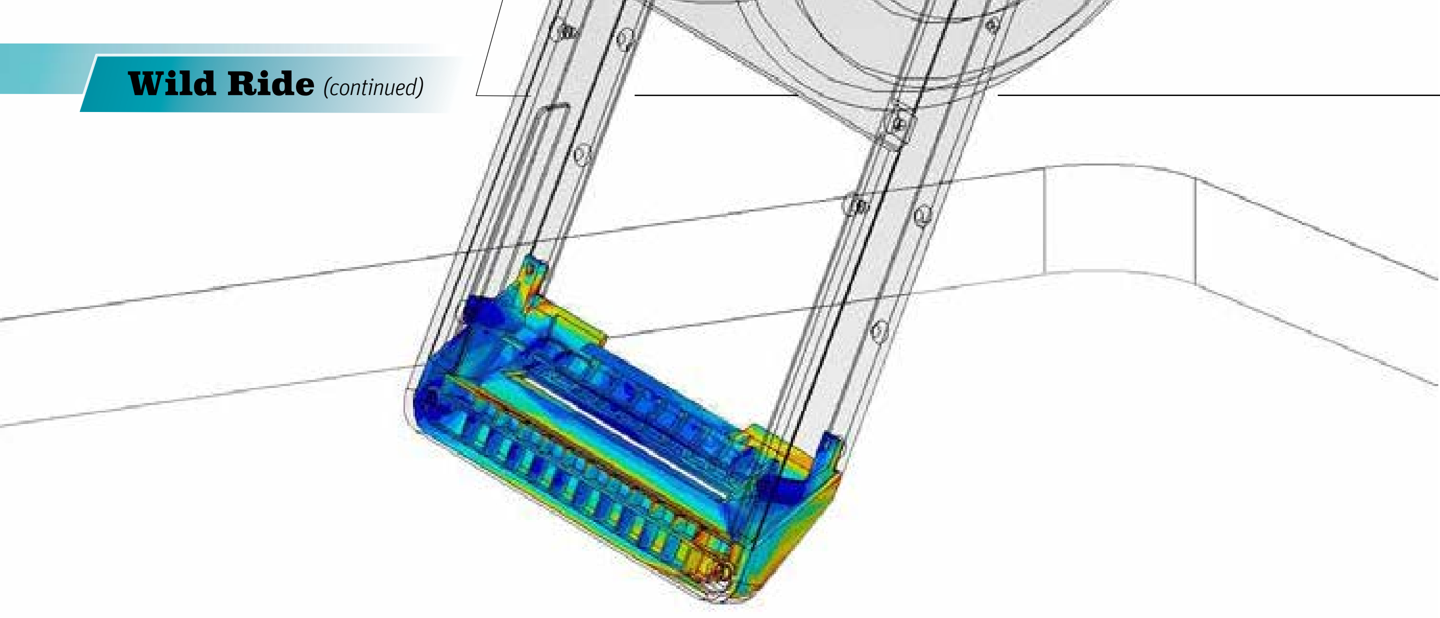
Wild Ride

The initial development of Onewheel, a battery-powered motorized skateboard, was a slow and manually intensive process, focused on building and testing physical prototypes. Today, the Future Motion engineering team employs engineering simulation to quickly make design changes, predict how they will impact real-world performance and achieve meaningful improvements in their innovative product.

A born problem solver, Kyle Doerksen enjoyed his work as a consumer and technical products developer at IDEO, a leading Silicon Valley design firm. But he was always looking for a product idea that would be his alone, a product that would embody his passion and energy. As he walked a mile to work each day, Doerksen began to imagine ways to make his daily commute both faster and more fun.

While growing up in the Canadian Rockies, Doerksen had been an avid snowboarder, and, after years of living in California, he still missed the experience of gliding effortlessly over the ground. A question began to form in his engineer's mind: Could there be a way to combine the practical necessity of moving around an urban environment with the thrill of board sports?

“ANSYS software is helping us quickly make design changes, ***predict how they will impact real-world performance*** and achieve meaningful improvements.”



"We estimate that it *costs about $10,000* to design, build and test a *physical prototype*."

That question was the genesis of Onewheel, a motorized skateboard equipped with a single 11.5-inch tire and a battery-powered 2-horsepower motor. Doerksen's concept was to bridge the worlds of sports and transportation by making it fun to move from one place to another. From the beginning, he designed Onewheel so it would be equally at home on pavement, grass, dirt and sand — built for both fun and practicality.

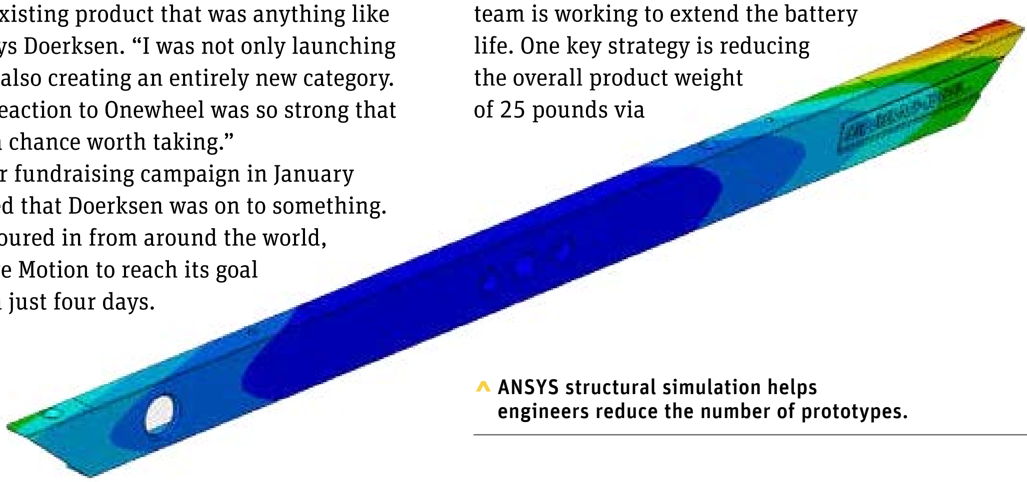
The engineering challenges were not insignificant. For example, to enable riders to control the movement of the board by shifting their weight, Doerksen had to incorporate pressure-sensitive, self-balancing sensors in the footpad. With two engineering degrees from Stanford University and years of hands-on design experience, Doerksen was up to these challenges. In 2013, he left his job and devoted all his energy to his new startup company, Future Motion, headquartered in the California beach town of Santa Cruz.

"Leaving the security of my job was a risk, because there was no existing product that was anything like Onewheel," says Doerksen. "I was not only launching a product, but also creating an entirely new category. But the early reaction to Onewheel was so strong that I knew it was a chance worth taking."

A Kickstarter fundraising campaign in January 2014 confirmed that Doerksen was on to something. Investments poured in from around the world, allowing Future Motion to reach its goal of $100,000 in just four days. By the end of the three-week Kickstarter campaign, the company had raised over $630,000 from more than 1,000 backers.

"The success of the Kickstarter campaign marked a significant milestone because it demonstrated that there was incredible interest in our product concept," recalls Doerksen. "But at the same time, it created enormous pressure on our engineering team. We had to go from prototype to mass production very quickly." Since then, Future Motion has shipped more than 10,000 products and earned rave reviews in media outlets, including *The Wall Street Journal*, *Sports Illustrated*, *Popular Mechanics* and NBC.

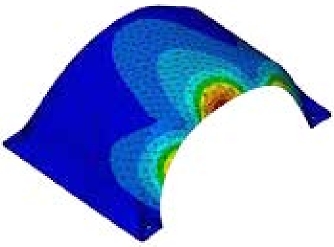
While the initial development of Onewheel was a slow and manually intensive process, focused on building and testing physical prototypes, today the Future Motion engineering team is leveraging the power of simulation to refine and improve Onewheel. For example, Onewheel has a battery range of six or seven miles, but the Future Motion engineering team is working to extend the battery life. One key strategy is reducing the overall product weight of 25 pounds via

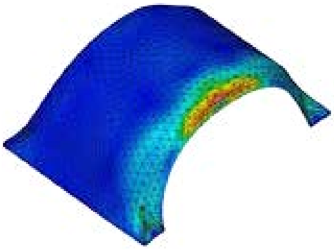


^ **ANSYS structural simulation helps engineers reduce the number of prototypes.**

"ANSYS software is helping us quickly make design changes, predict how they will impact real-world performance and achieve improvements."

— Kyle Doerksen,
Future Motion Inc. Founder and Onewheel Inventor





lighter materials and a new chassis geometry.

According to Doerksen, simulation via ANSYS engineering simulation software is making an enormous impact on both the time and the cost involved in design iterations. "We estimate that it costs about $10,000 to design, build and test a physical prototype," explains Doerksen. "Now that we have access to ANSYS software, we can better predict performance in the real world — which means we are building far fewer prototype boards. In addition, we can work a lot faster. Now that we've established the category, we expect lots of 'me too' competitors to show up — and we need to accelerate our launch of future designs to stay ahead."

"ANSYS software is helping us quickly make design changes, predict how they will impact real-world performance and achieve meaningful improvements," notes Doerksen. "That's a world of difference from when I was building boards in my garage on the weekend. The Future Motion design team is excited about the next-generation refinements we can make now that we have access to a world-class simulation tool. It's been a wild ride, and it just keeps getting better."

ANSYS Startup Program
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Lighten UP

Reducing cargo weight is important to increase aircraft fuel efficiency. Using engineering simulation, Carbon Freight has developed sturdy, lightweight cargo pallets that are 18 percent lighter than traditional pallets.

Lightweighting is one of the most important trends in the aerospace industry today, as jet manufacturers and their suppliers work to reduce the overall weight of planes and improve their fuel efficiency. But little attention has been paid to reducing the weight of the cargo carried by planes every day.

^ Carbon Freight's pallet

Carbon Freight — a startup based in Pittsburgh, U.S.A. — is attacking this issue with flexible, lightweight cargo pallets that are 18 percent lighter than traditional pallets. "There hasn't been much innovation in the air cargo industry, certainly not compared to the aerospace leaders' focus on new materials and production processes that reduce weight," notes CEO Glenn Philen. "Since cargo can represent a significant percentage of a fully loaded jet's weight, it only makes sense to look at historic cargo storage and transportation product designs — which have been in use for decades — and ask how we can adapt them for the challenges of today."

Measuring 8 feet by 10.5 feet, freight cargo pallets have typically been constructed of aluminum. By integrating composites into the materials mix, Carbon Freight has been able to achieve a significant reduction in overall weight. This weight reduction allows a typical cargo plane to carry up to 1,365 pounds in additional freight, and it enables passenger flights to carry more people by reducing cargo load.

> “Simulation has helped us model and understand our pallet structures to improve their overall strength and flexibility, while minimizing their potential for damage.”

While Carbon Freight’s innovative design decreases weight, at the same time it actually increases a pallet’s strength and durability significantly, compared with existing lightweight options. “Durability is a key characteristic for cargo pallets, because they need to fit together as closely as possible in the hold of an aircraft in order to optimize all available space,” explains Philen. “But they also take a lot of abuse, and they need to have some give. We’ve found that composite pallets initially present some durability challenges, but there are actually opportunities for increased durability over other options. They actually deliver a lot of positive performance characteristics that go beyond lower weight.”

The close proximity of pallets to one another, coupled with constant movement and handling, have created some engineering challenges for the Carbon Freight team. Says Philen, “We not only have to consider the loading stresses on our products created by the cargo, but also a wide range of contact stresses that occur as pallets are lifted, transported and packed together. There is a diverse set of complex forces that our design team needs to consider in order to deliver the best product durability over time.”

^ Structural simulation of a Carbon Freight pallet

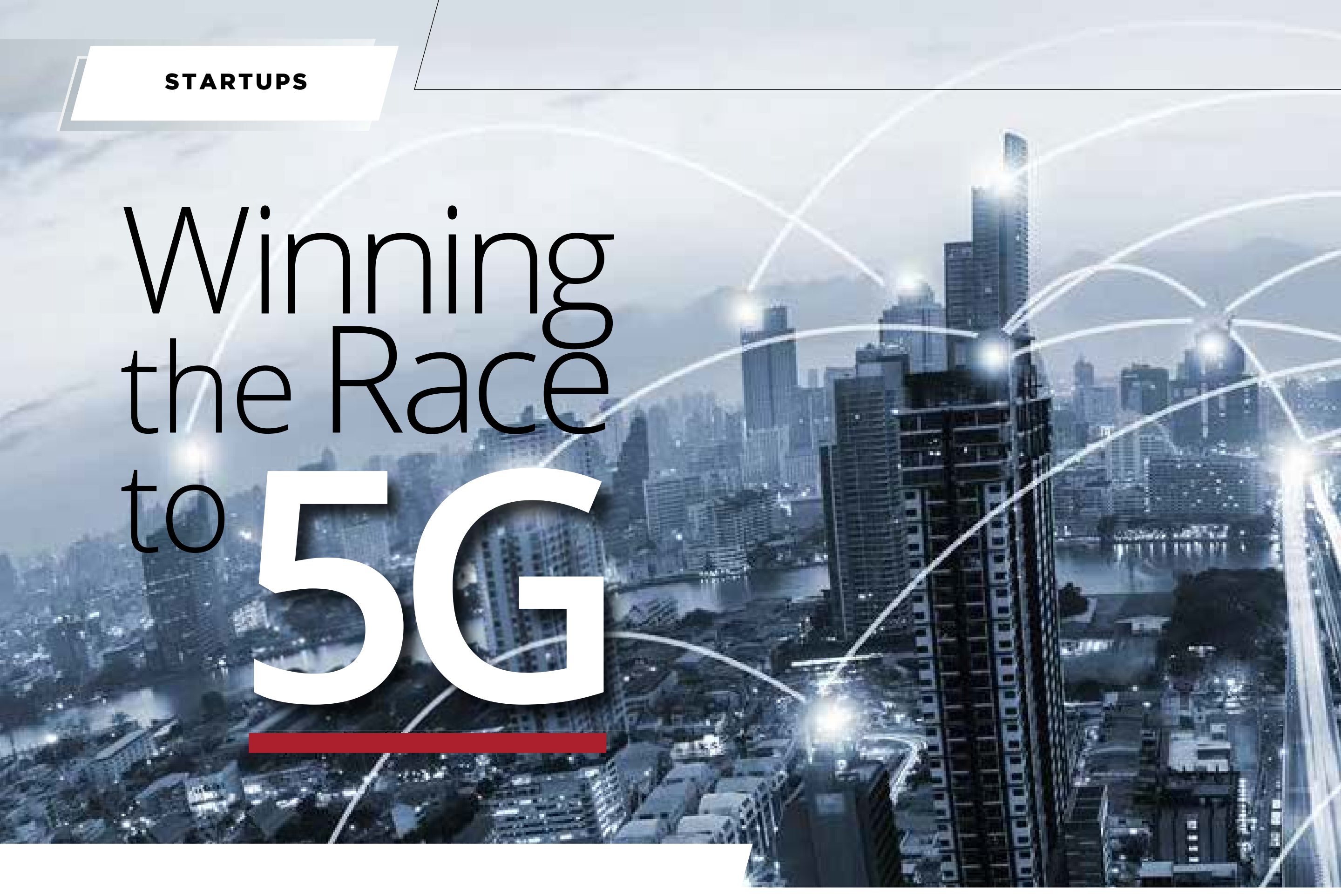
Carbon Freight’s product development team has relied heavily on engineering simulation to understand and manage these diverse physical stresses. “We’ve been able to test different material thicknesses and fiber orientations without the time and expense of creating physical prototypes. When we do get to the physical testing stage, we’re really happy with the accuracy of our simulations,” noted Philen. Simulation has also been able to help Carbon Freight manage one of its biggest business challenges: securing regulatory approvals from the Federal Aviation Administration and other organizations. “One of the reasons that traditional aluminum pallets are so entrenched is that it’s difficult to secure approvals for a new product design,” Philen points out. “Everything that goes into an aircraft must be stringently tested and proven to be safe. As passengers, we want and need that high degree of confidence. But the numerous approvals present challenges that a startup like Carbon Freight has to overcome to compete in the global aerospace industry. Established companies have an advantage in navigating the approval process.”

By visually demonstrating how its pallets will perform under everyday stresses — and verifying their safe performance over time — engineering simulation has helped Carbon Freight progress through the regulatory approvals process. According to Philen, “Simulation via ANSYS has saved 50 percent in development time and hundreds of thousands of dollars in physical testing.” The company is on track to launch its pallets to the global marketplace in early 2017.

Despite the fact that simulation has helped reduce product weight by 18 percent, Carbon Freight executives recognize that there will be challenges involved in breaking into the global market. “Composite materials are more expensive than aluminum, which means a higher price point for our pallets. However, the new lightweight design of our products has the potential to save significant fuel costs and add revenues over their lifetime. We’re offering passenger airlines and freight carriers a very attractive value proposition, and we believe Carbon Freight has a bright future ahead,” concludes Philen.

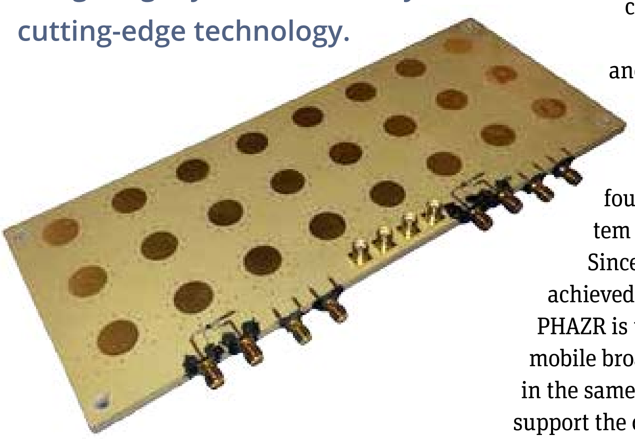
Simulation of 3-D Composites
ansys.com/composites

< The Carbon Freight team



Winning the Race to 5G

PHAZR was founded with the goal of developing a unique 5G millimeter wireless network that provides a 128 times faster experience and 1,024 times more capacity compared to 4G LTE for mobile and fixed-access applications. To get there first, this innovative startup leverages ANSYS software to not only speed up its analysis, but provide design agility and flexibility for this cutting-edge technology.



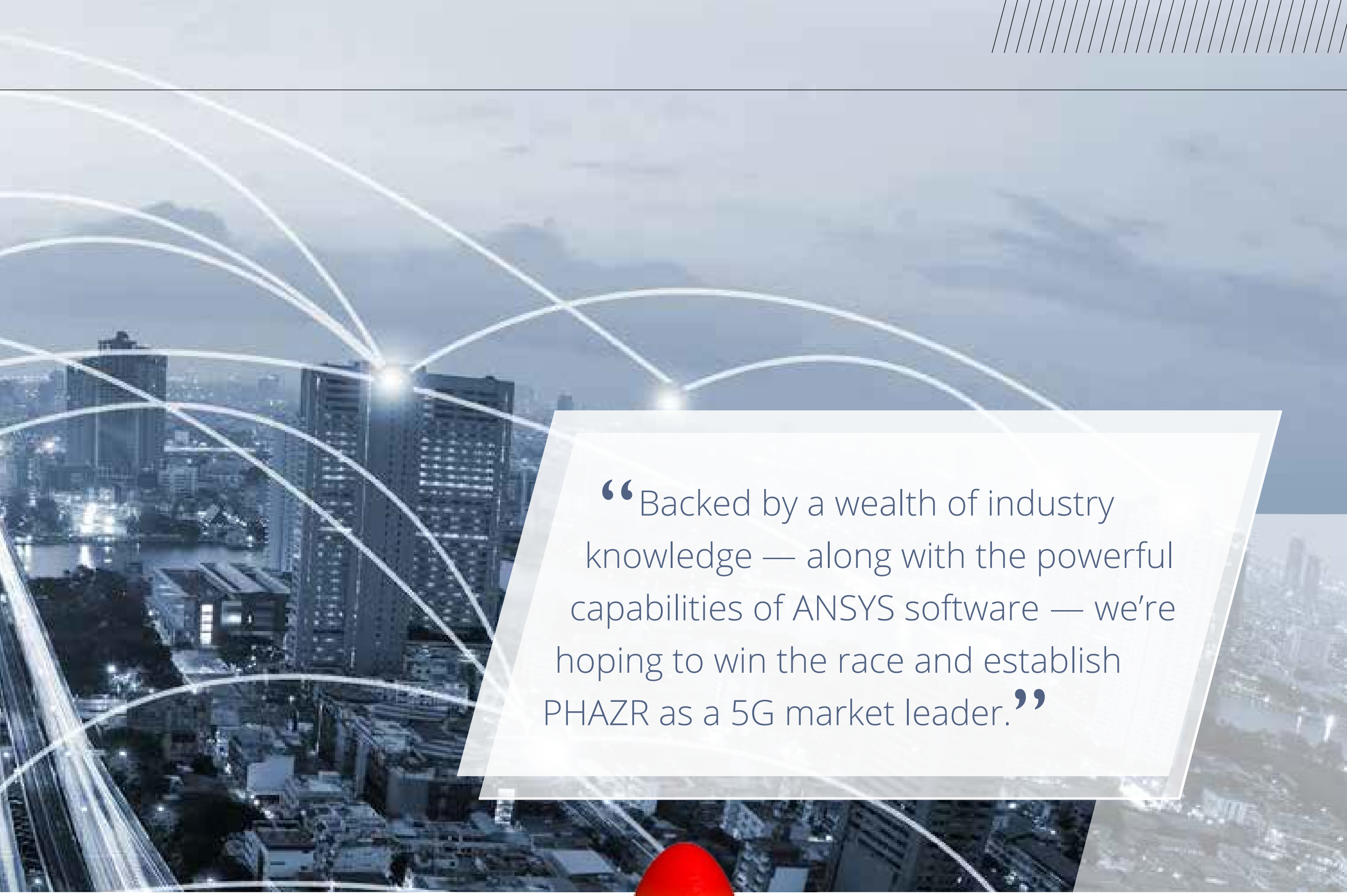
With fourth-generation (4G) mobile internet technology reaching its maturity, the world is bracing for the launch of a new fifth-generation solution starting in 2017, spurred by the U.S. Federal Communications Commission's (FCC) announcement in July 2016 that spectrum will be allocated to support a new standard for 5G.

"Carriers such as Verizon and AT&T have already publicly stated that they will be offering 5G service in 2017," says Paul Gilliland, head of business development for PHAZR, a startup company based in Allen, Texas, U.S.A. "Now the race is on to see which technology provider can step up to fill this need."

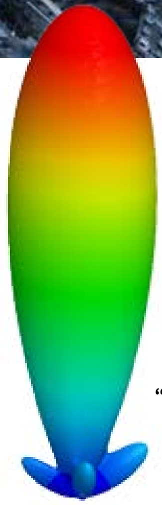
PHAZR was formed in 2016 by a group of executives and senior engineers from leading technology companies — including Samsung, Ericsson and Texas Instruments — who believed that they could quickly arrive at a commercial 5G solution better than the competition. They founded PHAZR to develop a unique 5G millimeter wave system that will address mobile and fixed-access applications.

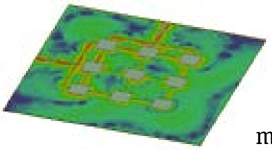
Since consistent, uninterrupted user access has not been achieved using 4G technology, the engineering challenge for PHAZR is to significantly increase capacity, allowing many more mobile broadband users to receive service with much higher speeds in the same service area. Fifth-generation technology should also support the consumption of significantly higher data quantities per user, creating a true streaming experience.

Engineers at PHAZR address this challenge by creating millimeter wave systems that can adjust beam width and power levels to



"Backed by a wealth of industry knowledge — along with the powerful capabilities of ANSYS software — we're hoping to win the race and establish PHAZR as a 5G market leader."





accommodate a variety of user needs. PHAZR's 5G millimeter wave systems operate in the 24 GHz to 40 GHz frequency range, which means that antenna elements can be much smaller than those supporting 4G systems, which operate below 6 GHz.

By packing as many of these high-frequency antennas as possible into very small arrays, PHAZR engineers are enabling radio energy to be "steered" to the specific users being serviced. Not only will the user experience be improved, but transmission sites can be much smaller, making them easier and less expensive to install.

"What we're doing at PHAZR is really revolutionary, because it represents a new way of looking at how beams are propagated and the frequency at which they operate," explains Gilliland. "This creates a number of engineering challenges, which we are addressing every day via simulation."

PHAZR's product development team leverages the power of ANSYS software for electromagnetic simulations to study the radio frequency propagation of various antenna and array designs at different frequencies across a variety of materials. As they analyze the results, engineers can make changes to the designs and move forward quickly until they arrive at an optimal solution. The simulations are extremely accurate, and they allow PHAZR to avoid building expensive and time-consuming evaluation parts — saving at least two weeks per design.

According to Gilliland, not only is ANSYS software helping the PHAZR team speed up its analysis, but it is providing all-important design agility and flexibility. "There are still some uncertainties in exactly what 5G service is going to look like, so we're making assumptions in our product design efforts today," Gilliland says. "As the standard and requirements become clearer, ANSYS software will allow us to make rapid changes to meet those requirements, without investing in physical testing or prototypes."

Gilliland notes that the ANSYS startup program has been critical in enabling PHAZR to compete with much larger companies. Gilliland points out, "It means so much to our team to have access to a world-class product development tool like ANSYS software without making a huge financial investment."

"Without the power and agility provided by engineering simulation, we would be challenged to be in the race to compete with feasible 5G solutions," he adds. "Backed by a wealth of industry knowledge — along with the powerful capabilities of ANSYS software — we're hoping to win that race and establish PHAZR as a 5G market leader."

High-Speed, High-Bandwidth Communication Systems Design
ansys.com/communications

Simulation in the News

ANSYS SPURS PERVASIVE ENGINEERING SIMULATION WITH ANSYS 18 RELEASE

MCADcafe, January 2016

ANSYS 18 builds upon decades of cutting-edge technology for the most complete and accurate digital prototypes across all major physics, electronics and embedded software areas. This feature-rich release expands the boundaries of simulation upfront in the development process to include digital exploration and extends simulation to the operations and maintenance of products through digital twins.

"We're doing things today that could only have been imagined just a few years ago, and simulation is playing a huge role. ANSYS simulation allows us to make better decisions earlier in the design process to get our design right the first time and produce the best products on time at the lowest cost for our customers."

— **Bob Tickel**, *director of structural and dynamic analysis, Cummins*

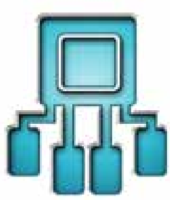
NASA GRANT TO SIMULATE SPACE IMPACT ON METAL PARTS

3ders.org, November 2016

Researchers in additive manufacturing at the University of Pittsburgh Swanson School of Engineering received a $500,000 award from NASA to develop a simulation tool based on ANSYS software to predict the integrity of 3-D printed metal parts used in space.

ANSYS ACQUIRES KPIT MEDINI TECHNOLOGIES

The Economic Times, November 2016



KPIT medini Technologies, a Berlin-based group that develops functional safety products, was acquired by ANSYS in November 2016. As products become smarter and more complex, the need to simulate the entire system to avoid failure becomes vital. A combined ANSYS–medini solution enables companies to have one system simulation solution for the entire product development cycle to make systems safer and more reliable.

ANSYS NAMES INDUSTRY VETERAN RICK MAHONEY TO LEAD WORLDWIDE SALES

AEC Newsroom, December 2016

ANSYS has strengthened its executive team and added best-in-class enterprise sales capabilities by appointing industry veteran Rick Mahoney as its vice president of worldwide sales and customer excellence.

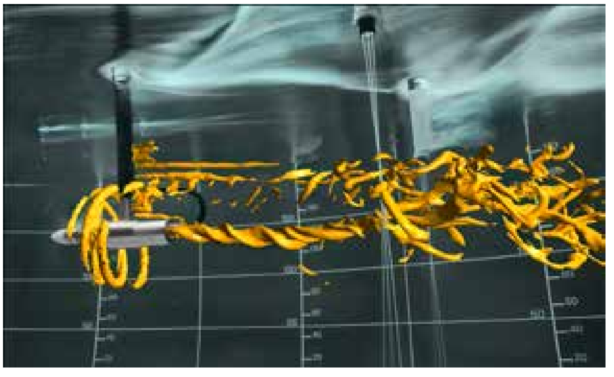
"ANSYS is perfectly positioned to help our customers take advantage of trends like IoT and Industry 4.0, which are reshaping product development, manufacturing and operations. Rick brings the right combination of industry knowledge and demonstrated success to help our customers innovate faster and more efficiently."

— **Ajei Gopal**
CEO, ANSYS

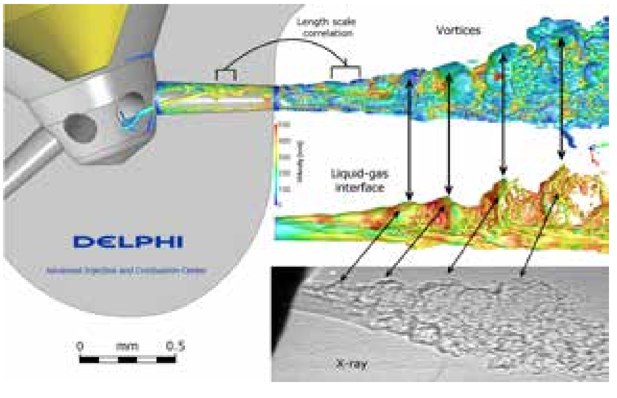
ANSYS 2017 HALL OF FAME WINNERS

IT Business Net, January 2017

From improving automotive fuel injection systems to capturing ocean energy to designing cutting-edge transportation systems, the winning entries of the annual ANSYS Hall of Fame competition highlight how engineers are solving complex, time-consuming and expensive challenges with engineering simulation software. View the winners and runners-up at ansys.com/hall-of-fame.



To capture energy from ocean tides to create renewable energy, researchers at Cardiff University used ANSYS simulation software to analyze wakes captured by tidal stream turbines to increase reliability and reduce costs of tidal energy.



Delphi Automotive Systems used ANSYS simulation to explore vortex-driven atomization in high-pressure diesel injection.

GE AND ANSYS TO PRESIDE OVER A DIGITAL TWIN AND INTERNET OF THINGS MARRIAGE

Engineering.com, November 2016

GE and ANSYS announced a collaboration to bring together simulation, model-based design (MBD) and the Industrial Internet of Things (IIoT). ANSYS will work with GE to expand and integrate ANSYS's leading physics-based engineering simulation and embedded software development platform with GE's Predix platform to power digital twin solutions across a wide range of industries.

INTEL CUSTOM FOUNDRY AWARDS ANSYS TEAM FOR EXCELLENCE

Intel Custom Foundry (ICF) customers are powering cutting-edge products by leveraging ICF-certified ANSYS solutions for electromigration, power and electrostatic discharge reference flows for its 10-nanometer (nm), third-generation trigate process technology. The close collaboration between ANSYS and Intel Custom Foundry teams have enabled mutual customers to minimize design costs and risks, and bring innovative and reliable products to market quickly. The Intel Custom Foundry team recognized three members of the ANSYS team for their efforts and commitment to the successful closure of the 10-nm certification program.

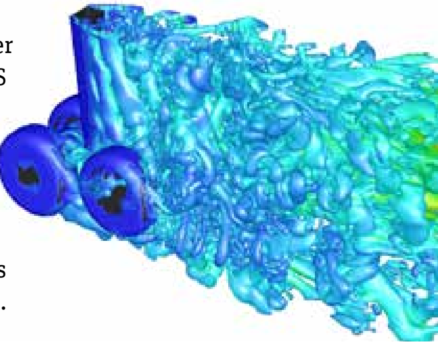
"The certification of ANSYS tools gives our mutual customers a competitive advantage when implementing robust, high-performance intellectual properties and SoCs on our 10-nm design platform."

— **Venkat Immaneni**
Senior director, foundry design kit enablement for Intel Custom Foundry

TURBULENCE — WHAT A DRAG IT IS WHEN YOU DRIVE

Engineering.com, December 2016

Understanding turbulence is difficult. To predict flow on the scale of molecules and apply it to cars, planes and entire buildings requires using physics models through simulation. Florian Menter explains a solution ANSYS has developed to more accurately and efficiently determine turbulence called stress-blended eddy simulation (SBES). This model blends RANS and LES techniques.



"The whole trick is to be able to convert between RANS areas and LES intelligently — and on the fly."

— **Florian Menter**
Senior Research Fellow, ANSYS

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