The turbo sector faces the pressing challenge of increasing the energy efficiency of not only the world’s more than 3 million major turbomachines— but all turbo-related equipment, whether it burns fuel directly (as in the case of gas turbines), whether energy is consumed in the process of driving the machines (as with industrial compressors), or whether it extracts energy from a flow stream (as for water turbines). It’s been proven that even fractional improvements in fuel performance yield substantial economic benefits. Experts estimate that just a 1 percent increase in fuel efficiency would deliver $30 billion in savings for the global commercial aviation industry over a 15-year horizon. The world’s gas-powered energy plants could realize a $66 billion financial benefit by achieving that same 1 percent improvement [1].

While efficiency is a huge concern, it is only one urgent priority on the agenda of the world’s turbomachinery engineers. Every day, they must balance concerns about operating efficiency or fuel economy with a range of other initiatives for cost and performance improvement. Energy efficiency initiatives are not only driven by cost, but also by environmental concerns, since reduced energy consumption generally relates to reduced carbon emissions (and it is one concrete way of measuring progress and compliance).

For example, according to the International Air Transport Association, in 2012 fuel costs accounted for approximately 33 percent of the overall expenses of the world’s airlines [2] — but the other 67 percent of costs relates to applications that could benefit from improvement as well. To succeed in an increasingly crowded global marketplace, airlines are driving costs out of every area of their operations, including aircraft maintenance. Every innovation that targets fuel efficiency — such as new composites materials that reduce weight — must meet a host of other performance criteria. They must be proven durable enough to also reduce lifetime maintenance and repair costs. And, of course, composites must demonstrate sufficient strength to ensure passenger safety under a full range of flight conditions.

Engineers of turbomachinery for automobiles, power plants and other applications face similar Catch-22 engineering challenges. While the universal mandate for increased efficiency receives an enormous amount of attention — as well as a large percentage of R&D dollars — the reality is that it is just one performance...
New features and capabilities in ANSYS software enable engineers to predict turbomachinery performance and solve product design challenges faster than ever, with a high degree of confidence.

Today, as product development teams in this segment face more-intense pressures than ever before, engineering simulation has risen to the top of the list as a critical competency. Computer-aided design tools help to elucidate performance trade-offs at an incredible level of detail. Engineers can readily learn how their specific energy-efficiency initiatives, such as increased combustion temperatures, affect related performance features like materials strength and durability. By providing insight into these trade-offs, engineering simulation has supported the development of many important technology advancements in turbomachinery.

Today, new features in ANSYS software — combined with robust design practices and powerful high-performance computing environments — enable engineers to predict turbomachinery performance and solve product design challenges faster than ever, with a high degree of confidence. Even the most complex design problems can be illuminated and addressed at an exacting level, as engineers strive to make ongoing improvements that balance efficiency gains with other critical design criteria. Following is a discussion of some of today’s most advanced turbomachinery design challenges — as well as strategies for answering them via engineering simulation.

BLADE ROWS: NEW TRANSIENT TECHNIQUES
The fluid flow through blade rows affects many aspects of turbomachine performance, including work input or output, efficiency and operating range. For practical reasons, traditional analysis of blade rows has focused on steady-state performance. As good as it is, steady-state analysis fails to capture all the real-world intricacies of the flow as one row of blades rotates past another.

Specialized transient blade row methods from ANSYS — called transformation methods — accurately predict blade row performance over time, as well as over a range of real-world operating conditions. Irrespective of pitch ratio, these methods require modeling only one or two blades per row — yet still yield a full-wheel transient solution. Not only are problem-solving time and data storage space reduced dramatically, but smaller output files mean much faster post-processing of simulation results.

ANSYS has partnered with Siemens and other turbomachinery customers to apply these new transformation methods to a range of product design challenges. The results include dramatic improvements in simulation time and cost, creating a significant competitive advantage — while also ensuring that product integrity is maintained.

Specialized transient blade row methods can accurately predict blade row performance over time and a range of real-world operating conditions.
ANSYS has developed new high-fidelity simulation techniques for aeromechanics studies. By coupling ANSYS Mechanical with ANSYS CFX transformation methods for transient blade row analysis, product development teams can simultaneously consider the aerodynamics and mechanics of the blade row. Software from ANSYS supports the close coupling of multiple physics required to study the nuanced interactions of the fluid flow and bladed components.

Software from ANSYS supports the close coupling of multiple physics required to study the nuanced interactions of fluid flows and bladed components.

Blade flutter can be accurately modeled via unsteady simulations for any range of nodal diameters using Fourier transformation methods. Forced response methods enable an assessment of stability that considers unsteady flows, predicted by modeling only one or two blades per row. High-speed, iterative solvers from ANSYS reduce processing time, while still ensuring the high fidelity and design robustness needed to deliver safe, reliable results in real-world product applications.

AEROMECHANICS: MINIMIZING VIBRATION AND FLUTTER

A catastrophic failure at the Sherburne County Generation Station in Minnesota in late 2011 caught the attention of the global turbomachinery industry. During an overspeed testing exercise, vibration was observed, then the blades broke; the 80-ton rotor was twisted, and metal components were thrown into an adjacent control room. While no one was harmed, this turbine failure is costing utility Xcel Energy more than $200 million and months of equipment downtime [3]. In public statements, Xcel noted that the vibration problem was a function of the original product design [4] — bringing new attention to the critical need to identify failure modes at the earliest possible design phase.

To help turbomachinery engineers meet vibration and flutter challenges, Siemens and ANSYS are collaborating on the application of steady and transient blade row methods to the Siemens Platform Compressor test rig, a half-scale multistage industrial axial compressor. One objective is improved prediction of compressor stall. Good comparison between experiment and simulation has been observed, as reported in recent ASME Turbo Expo papers. COURTESY SIEMENS.
COMPOSITES: ENSURING HIGH STRENGTH, RELIABILITY
While composites materials have garnered much attention for their inclusion in car bodies and aircraft fuselages, they also have important applications in turbomachinery. By fabricating turbine blades from these advanced materials, wind power companies in particular have combined light weight with outstanding aerodynamic performance.

ANSYS offers a specialized tool, ANSYS Composite PrepPost, for modeling layered composites — while ANSYS Mechanical APDL supports simulations of ceramic matrix composites. These materials show special promise because they can withstand the high temperatures associated with many turbomachinery applications. Earlier this year, ANSYS expanded its focus on composites modeling with its acquisition of EVEN — Evolutionary Engineering AG — a leading global provider of composites analysis and optimization technology.

This growing portfolio of composites modeling solutions allows turbomachinery engineers to define the optimal materials formula and layering strategy, then subject their designs to simple physical stresses. By computing progressive damage, delamination and cracking, engineers can confidently predict failure modes under demanding conditions. As the role of composites grows in the worldwide turbomachinery industry, the capabilities of ANSYS software will also expand to anticipate evolving user needs.

COMBUSTION MODELING: NEW ACCURACY AND FIDELITY
The global drive for greater energy efficiency has placed a new focus on the combustion processes that lie at the heart of many turbomachines. Higher firing temperatures can improve efficiency, yet they can degrade engine materials and shorten product life unless appropriate measures are taken.

As turbomachinery engineers explore combustion innovations, they can rely on ANSYS for new capabilities that model the complexities of combustion more accurately than ever. Advanced modeling techniques from ANSYS — including thickened flame, improved spray and fuel evaporation models — allow
engineers to better determine fuel–air mixing, flame position, temperature distribution and pollutant formation within combustors. High-fidelity meshing capabilities, combined with advanced turbulence modeling, give ANSYS users an edge by resolving the geometry and flow to the degree required for accurate simulation.

Turbulence can be modeled via a variety of methods, depending on the needs of the engineering team and the specific combustion issue under study. ANSYS offers scale-resolving simulation (SRS) methods such as large- and detached-eddy simulation (LES and DES) as well as efficient scale-adaptive simulation (SAS) tools.

**ROTORDYNAMICS: ENSURING STABILITY**

To combine light weight and a small profile with incredibly high strength, turbomachinery engineers make strategic trade-offs as they design rotor systems. Not only do they need to understand the dynamics of each individual component, but they need to optimize the frequencies and vibration modes of the system as a whole.

ANSYS software helps to illuminate these trade-offs by demonstrating how specific design choices — such as shaft size, bearing properties and spacing, and housing stiffness — will impact such performance characteristics as operating range and stability.

ANSYS has been steadily increasing its capabilities to support engineering teams in designing rotating machinery. Specialized functions in ANSYS Mechanical APDL help to streamline the import process for bearing properties, as well as for other component properties. Multi-spool simulation capabilities enable realistic simulation of modern aircraft engines. Engineers have the flexibility to create full 3-D models of rotor systems or reduce their designs to axisymmetric models for faster analysis.

**HEAT TRANSFER: OPTIMIZING THERMAL PERFORMANCE**

As pressures escalate to increase energy efficiency via higher temperatures, thermal management issues are coming to the forefront among turbomachinery teams around the world.

By coupling ANSYS Mechanical with ANSYS CFD products, engineers ensure that engine materials can withstand high temperatures — while also optimizing the effectiveness of their engine cooling strategies. Running these types of multiphysics studies is easier than ever due to improved capabilities in ANSYS Workbench to link fluid flows, conjugate heat transfer, thermal and mechanical stress, and deformation. Advanced turbulence models from ANSYS also support the study of complex heat transfer processes.

With the need to simulate multiple physics under a comprehensive range of real-world operating conditions, heat transfer simulations can be very large and numerous. The compatibility of ANSYS solutions with high-performance computing (HPC) environments — combined with the rapid solvers in ANSYS software — has taken heat transfer modeling to a new level of speed and flexibility.

**The compatibility of ANSYS solutions with high-performance computing environments — combined with the rapid solvers in ANSYS software — has taken heat transfer modeling to a new level of speed and flexibility.**

—New transient blade row analysis capabilities in ANSYS CFX can be coupled with ANSYS Mechanical to simulate only one or two blades per row in an unsteady state. Blade vibration and failure modes can be identified across the full wheel, at a fraction of the previous computational time, cost and computing resources.

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ANSYS: CONTINUING TO RAISE THE BAR

In this issue of ANSYS Advantage, you’ll find many examples of how ANSYS customers apply advanced technologies to emerge as global leaders in turbomachine efficiency — as well as other critical aspects of equipment performance.

Dresser-Rand employs engineering simulation to achieve a wider operating range for centrifugal compressors so these machines can operate reliably under the broad range of flow rates required by processing industries. Mirjam Sick, head of R&D engineering methods at ANDRITZ HYDRO, explains how her company has used ANSYS technology for about 25 years to arrive at innovative new designs that deliver dependable, robust performance for clients around the world. Turbomachinery experts from PCA Engineers describe how they optimize turbochargers for increased performance and efficiency.

Whatever your own turbomachinery engineering challenges, you’ll probably be inspired by these real-world testimonies to the power of engineering simulation.

Turbomachines may never be simple to optimize. But ANSYS will continue to make advancements in our ability to model and predict turbomachinery performance.

While few applications are as complex as turbomachinery, the good news is that turbomachinery engineers have always been among the first to embrace improved simulation capabilities to meet their advanced challenges.

Turbomachines may never be simple to optimize. But for more than 40 years, ANSYS has partnered with customers worldwide to make continuing advancements in the ability to model and predict turbomachinery performance. Today we are all focusing on improving efficiency, but who knows what the future may bring? Whatever challenges lie ahead, ANSYS is committed to meeting the needs of this complex and ever-changing industry.

References