Spotlight on Engineering Simulation for Rotating Machinery

As the **World Turns**

World conditions and increased competition challenge rotating machinery designers to deliver higher levels of performance, efficiency and reliability — faster than ever before.

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Turbomachinery, or more broadly speaking rotating machinery, spans almost all industry sectors and in many plays a vital role. Rotating machines change the state of working fluids (pumps or compressors), convey or transport fluids (fans and pumps), extract energy (turbines) and create propulsion (propellers). Performance, efficiency, reliability and rapid delivery have always been important, but today's world conditions intensify the pressures designers face.

Currently, the price of oil hovers near $100 per barrel. Concern for climate change is widespread, not only by the general public but also by legislators worldwide. Since rotating machines play a critical role in power generation and various forms of transportation — and, in some cases, are the limiting factor regarding cost, efficiency and emissions — it is natural that they are in the spotlight and the subject of intense analytical scrutiny.

In the energy industries, most of our power is produced by gas, steam and water turbines. Steam turbines extract power in nuclear and coal-fired power plants. Land-based gas turbines, similar to their aeroengine cousins, run on natural gas and, in some cases, oil. Although still relatively small in volume, wind turbine production has increased dramatically in recent years, with the largest machines being 6 megawatts (MW) in size and having rotors approaching 130 meters in diameter. The largest water turbines, such as those used in the Three Gorges Dam in China, have 10-meter diameter runners.

In the transportation industry, turbomachinery plays an equally important role. For air travel, the rotating machinery used on commercial aircraft is well known — the gas turbine aircraft engine. Its key rotating components include the fan, which can be seen when boarding the plane, as well as the compressor and the turbine. Since fuel is a major and often volatile cost for airlines (significantly impacting their profitability) and noise and emissions regulations are becoming increasingly stringent, there is a drive for cleaner, quieter and more fuel-efficient engines.

For transportation at sea and on the ground, diesel engines in ships, trucks and an increasing number of cars use turbochargers to improve their performance and efficiency. These engines also use electric-driven fans and pumps, which must be optimized, since available electrical power is limited. Efficiency of the automatic transmission torque converter — another rotating machinery component comprised of a pump, a stator and a turbine — is critical to vehicle fuel efficiency.

Turbomachinery plays an important role in other industries as well. Compressors and pumps are important to the chemical, process, and oil and gas industries, and are even key components in large industrial air conditioning systems. In the medical industry, heart pumps must be designed to be compact and to minimize blood damage.

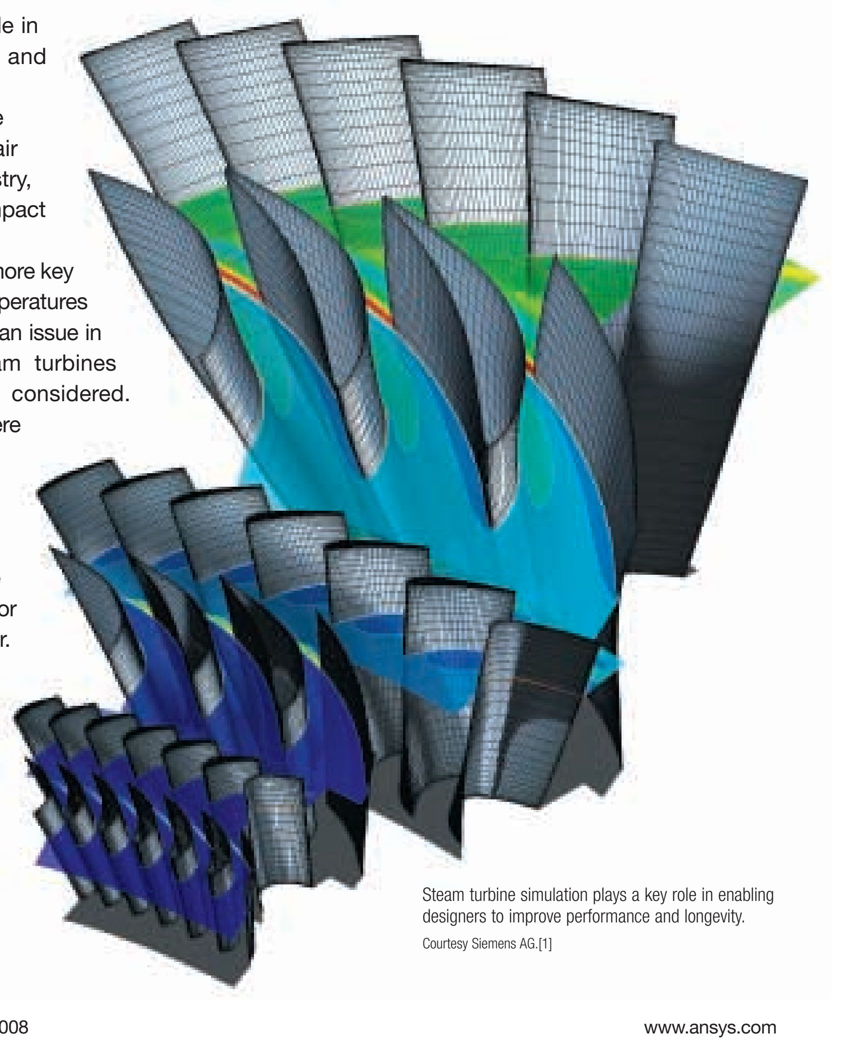
Each rotating machine type has one or more key design challenges. Cooling due to high temperatures is problematic in gas turbines. Cavitation is an issue in pumps. Non-ideal gas behavior in steam turbines and refrigerant compressors must be considered. In aeroengine fans, noise is a challenge. There are space limitations when designing automotive fans. For hydraulic turbines, large-scale transient instabilities — also known as vortex ropes — may occur at off-design conditions. These examples indicate the diverse physics requiring consideration for accurate simulation of real machine behavior. In reality, these physical processes interact, and multiphysics analysis increasingly is becoming a requirement for high-fidelity simulations.

Several design, performance or production factors are common among turbomachine types. Reliability and safety require accurate prediction of steady and transient thermal, aerodynamic and structural loads for stress and fatigue life predictions. However, excessive safety and strength features are likely to make the machine too expensive or too heavy; these features also can preclude other competing requirements such as efficiency.

Operational cost and emission issues have recently intensified the pressure to produce efficient machines. Time-to-market and cost pressures resulting from competition have underscored the need to "get it right the first time." These factors, in turn, demand that simulation software provides solutions of ever-increasing resolution and accuracy. Software, when employed in Simulation Driven Product Development (SDPD), helps designers resolve these and other challenges and is a key enabler for reduced-cost, first-to-market rotating machinery development. ■

References

[1] Gerber, A.G.; Sigg, R.; Völker, L.; Casey, M.V.; Sürken, N., "Prediction of Non-Equilibrium Phase Transition in a Model Low Pressure Steam Turbine," *Journal of Engineering for Power and Energy*, September 2007, Vol. 221, No. A6, pp. 735–744.



Steam turbine simulation plays a key role in enabling designers to improve performance and longevity.

Courtesy Siemens AG.[1]