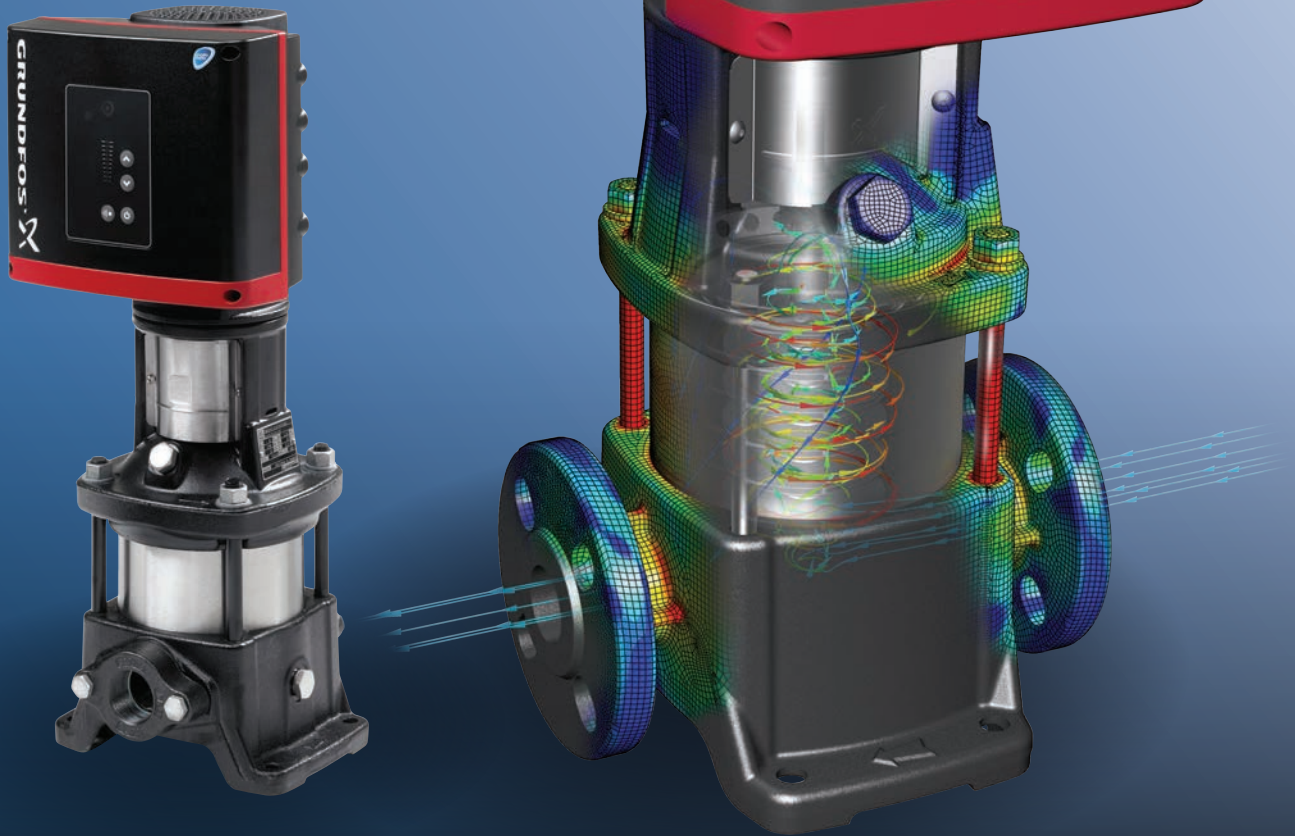# PUMPED

Simulation-driven development increases pump efficiency and reduces product development time at one of the world's leading pump manufacturers.


By **Jakob Vernersen**, Head of Mechanical Technology,
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Grundfos calculates that pumps currently account for 10 percent of the world's total electricity consumption. The company's engineers continually focus on optimizing pump efficiency to reduce energy consumption and operating expenses while having a positive impact on the environment.
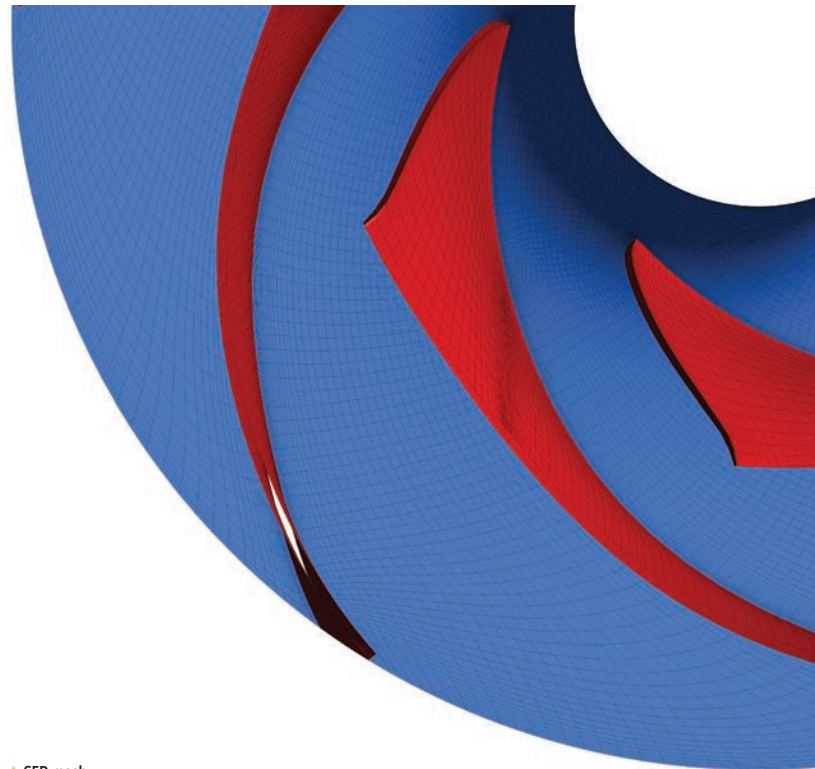
To design pumps, Grundfos has been using finite element analysis (FEA) since the 1980s and computational fluid dynamics (CFD) since the 1990s. Originally, FEA and CFD were

With simulation, Grundfos engineers significantly improved hydraulic efficiency of the new pump.

▲ Parametric model of the impeller used to define hydraulic geometry
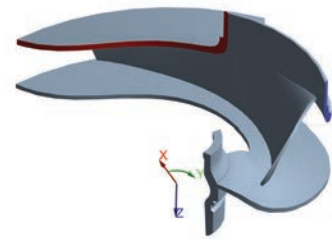
▲ To reduce the size of the problem and obtain acceptable mesh density, cyclic symmetry was used for the impeller.

▲ CFD mesh
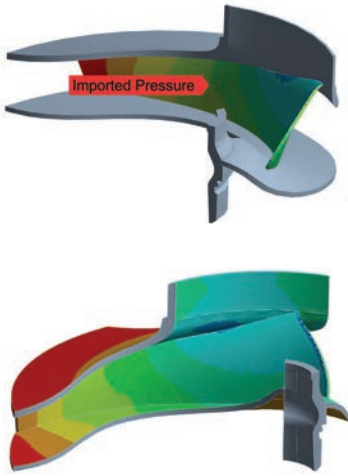
GRUNDFOS AND ANSYS
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a user interface that allows engineers to specify the type of component they want to design, such as an impeller, guide vane or volute. Then PumpIt initiates an automated design optimization loop that calls simulation tools, including ANSYS CFD software, to explore the design space.

In a recent example, Grundfos engineers used PumpIt to drive ANSYS CFX CFD simulation to optimize the hydraulic surfaces of a new pump design. They increased the hydraulic efficiency of the pump by 1 percent to 2 percent while extending the maximum efficiency level over a wider range of flow rates. The team used ANSYS Mechanical FEA software to optimize the pump from a structural standpoint, ensuring that it will meet fatigue life targets while minimizing weight and manufacturing cost.

PUMP DESIGN CHALLENGES

With an annual production of more than 16 million pumps, Grundfos is one of the world's leading pump manufacturers. The company is the leading producer of circulator pumps used for heating, ventilation and air conditioning in private houses, offices and hotels, with a market share of approximately 50 percent. Grundfos also produces centrifugal

used for research and troubleshooting. Some of the information from these simulations was helpful in new product design. Then, more than 15 years ago, Grundfos chose to use simulation for product design to develop reliable and efficient products. Most recently, the company linked together a chain of simulation tools into an automated design loop, called PumpIt, that enables engineers to investigate hundreds of designs without manual intervention. An optimization routine explores the entire design space and identifies optimal designs based on criteria set by Grundfos engineers. PumpIt provides

The multiple physics simulation process reduced overall design time for the new pump design by 30 percent and saved approximately $400,000 in physical prototyping.
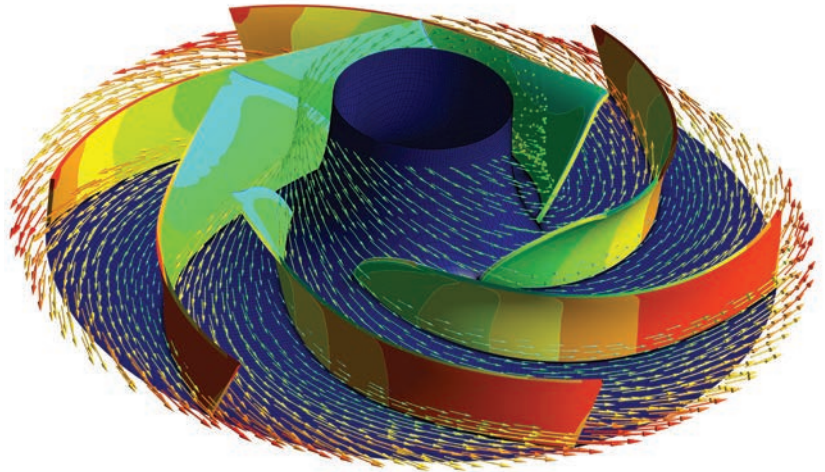
CFD pressure results were mapped onto structural simulation as loads.

CFD results demonstrated using pressure contours and velocity vectors.

Deformation of the hydraulic impeller

Global stress simulation

pumps for water supply, sewage, boiler, pressure boosting and other industrial applications, as well as pumps that are integrated into other original-equipment manufacturers' products.
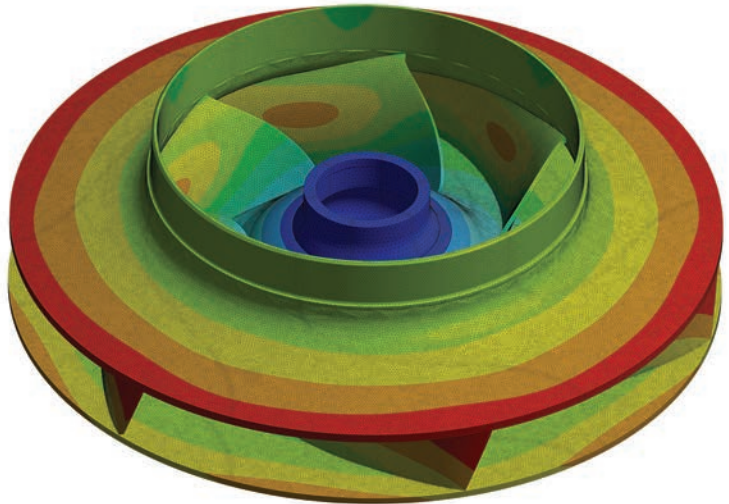
To optimize Grundfos equipment, engineers must improve the peak efficiency of the pump. Delivering a relatively flat performance curve with high efficiency levels over as wide a range of flow rates as possible is another goal. The flow rate of the pump depends on the installation; a relatively flat performance curve can deliver high levels of efficiency for many applications. A flat performance curve also reduces cavitation, thereby increasing longevity. Another important goal in pump design is to meet component structural requirements with the minimum amount of material. Minimizing material usage reduces manufacturing costs and decreases component weight. Lighter pump components make it possible to use less-expensive bearings while reducing noise and vibration.
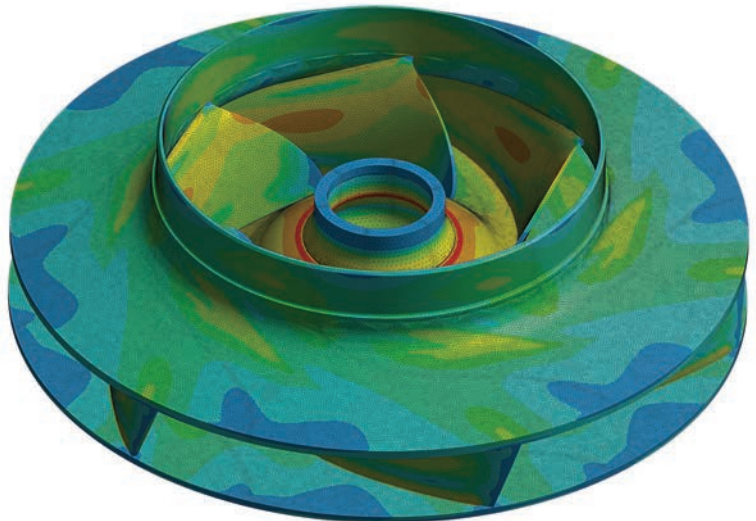
FLOW SIMULATION

Recently, Grundfos engineers used PumpIt to design multi-stage hydraulics for a new pump. The team developed parametric models of all pump components to define hydraulic geometries of the surfaces in contact with the fluid being pumped. The design objectives were to maximize hydraulic efficiency and deliver maximum efficiency over the widest possible range of flow rates. The
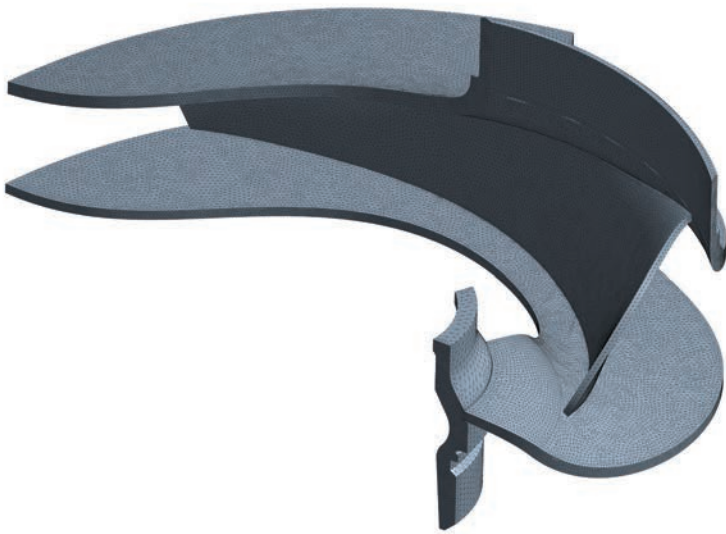
▲ Structural mesh

▲ Grundfos engineers used submodeling to evaluate critical areas of the component with a high level of detail without greatly increasing simulation time. Image on right reveals stress results.

PumpIt tool used design of experiments (DOE) to create a series of iterations that explored the design space for each component. PumpIt then generated the geometry for each design iteration and issued a call to the CFD software to simulate each iteration.

The initial DOE included about 40 designs. It determined which parameters played the most important roles in the simulation, and it delineated broad ranges of the most promising values for these parameters. The parameters and values were then used as the starting point for a Kriging-based optimization algorithm that automatically generated additional design iterations for CFD evaluation. The optimization routine evaluated the results of each design iteration and then performed additional iterations based on these results. Each iteration moved the design closer to the efficiency objectives.

The initial analyses were performed with a coarse-density mesh and standard turbulence model to reduce the time required to obtain promising parameter values. As the design converged on optimal values, the CFD model was refined by applying a finer mesh and a more-advanced turbulence model. To obtain high-fidelity results for an optimized design, engineers used up to 48 cores to perform analyses on a high-performance computing cluster. The cluster had more than 1,000 cores using more than 8 terabytes of random access memory and 50 terabytes of high-speed storage running on the Lustre® parallel file system. Engineers simulated hundreds of design iterations overnight.

The next step was to evaluate the manufacturability of the most promising designs. Grundfos engineers considered how easily each design could be produced with several alternative production technologies. To do this, they evaluated the geometric parameters that are required for each production method. In this case, they decided to stamp the components from stainless steel sheet metal. The performance statistics for the best designs were displayed in the PumpIt multidimensional solution visualizer that can be configured to display any outcome variable.

STRUCTURAL ANALYSIS

After optimizing the hydraulic design with CFD, Grundfos engineers performed structural analysis with ANSYS Mechanical to ensure that each component would meet fatigue life requirements while keeping cost and weight as low as possible. They mapped the hydraulic pressure determined by CFD simulation onto the finite element analysis to specify loading conditions that accurately match the complex hydraulic pressure distribution. To minimize computational cost and accommodate an acceptable mesh density, cyclic symmetry was applied.

The welding operation on the sheet metal components was modeled according to the recommendations of the International Institute of Welding publication's "Recommendations for the Fatigue Assessment of Welded Structures by Notch Stress Analysis." Fatigue life was evaluated using the notch stress method. The team also used submodeling to evaluate critical areas of the component with a high level of detail without greatly increasing simulation time.

# Grundfos was able to simulate hundreds of design iterations overnight.

Engineers configured the automated workflow to vary the welding parameters so they could determine how to optimize the welding process. The team also used structural simulation to predict the potential for failure in any given lifespan. The only other way to obtain this information would have been with an expensive and lengthy physical testing program. Grundfos engineers performed several sensitivity studies on input variables, including welding thickness, air gap and flow points, to determine the robustness of the design with respect to fatigue life of components. By providing a statistical distribution of fatigue life for each input variable, simulation made it possible to improve component quality and reliability.

On other structural components, topology optimization was used at the concept level of the design process to arrive at a design proposal that was then fine-tuned. This replaced time-consuming and costly design iterations, thus reducing development time and overall cost while improving design performance. Dassault Systèmes' Tosca topology optimization software was coupled with the ANSYS Workbench interface and the ANSYS structural solver.

PERFORMANCE AND TIME TO MARKET IMPROVED

The result was a substantial improvement in product performance with reduced design cost and lead time. With simulation, Grundfos engineers significantly improved the hydraulic efficiency of the new pump. Compared to a traditional prototype-based design process, the multiple physics simulation process reduced overall design time for the new pump design by 30 percent and saved approximately $400,000 in physical prototyping.

Recently, Grundfos made the decision to take another step forward and migrate its simulation process to the ANSYS Workbench environment. Workbench was selected as the integration framework because of its ability to seamlessly integrate the broad portfolio of ANSYS applications as well as third-party applications. ANSYS Workbench can be used to develop state-of-the-art user interfaces, workflow and applications. Workbench's common tools and services, including parameter management, units and expressions,
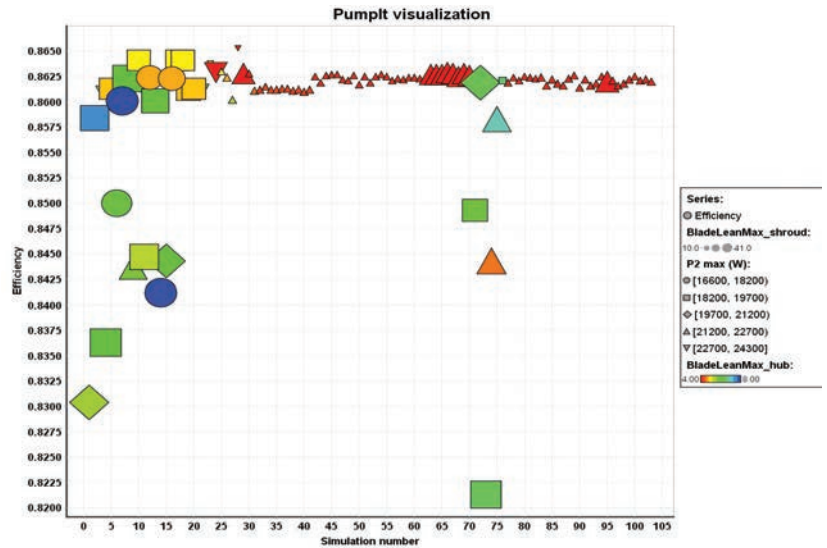
▲ The ability of each iteration to meet design objectives is graphically displayed in the PumpIt solution visualizer.
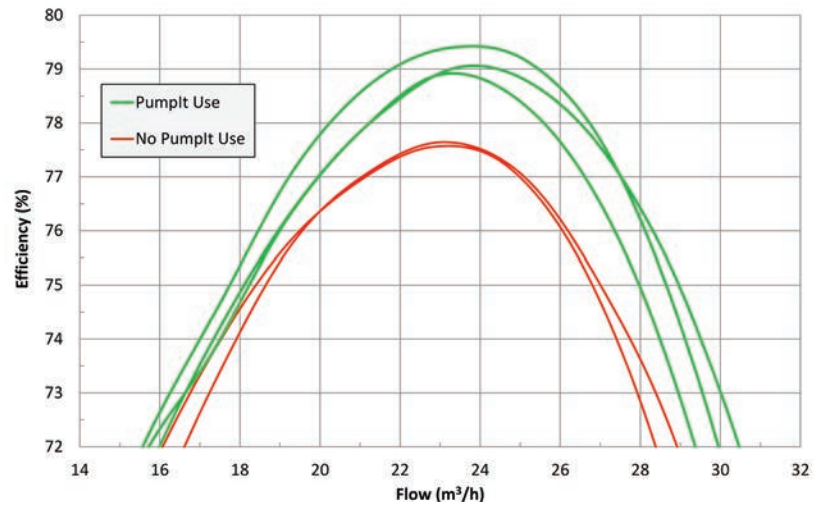
▲ Grundfos engineers made a substantial improvement in pump hydraulic performance.

Simulation made it possible to improve component quality and reliability. ▼

application development tools, and solver coupling capabilities, can deliver considerable time savings. ANSYS HPC Parametric Pack licenses make it cost-effective for Grundfos to simulate large-scale parametric design variations. Using Workbench workflows, engineers are creating a simulation-driven development process for multiple physics to design hydraulic components such as impellers, guide vanes and volutes. This tool could allow Grundfos to raise pump performance to an even higher level while providing further reductions in design cost and lead time. ∧

Grundfos is supported by ANSYS channel partner EDR Medeso, which has supported Grundfos during creation and implementation of a simulation-driven development strategy.