White Paper

Cutting Design Costs: How Industry leaders Benefit from Fast and Reliable CFD

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With engineering managers increasingly sensitive to the cost of product design, it is no longer enough to justify engineering software based on gut feelings about its value. Managers want to see cold, hard return-on-investment numbers before they buy into any technology. Computational fluid dynamics (CFD) software is no exception.

Simulation Softens the Financial Blow of Product Development

Any engineer who has used CFD software will likely have a strong sense of its worth as a problem-solving tool. This engineering simulation software can provide solutions to complex fluid flow, heat and mass transfer, chemical reaction and related physical phenomena that would be difficult or even impossible to tackle in any other way. Even when engineers have deeply ingrained product knowledge, they find, more and more, that fluid flow problems have become too complex to solve without CFD software.

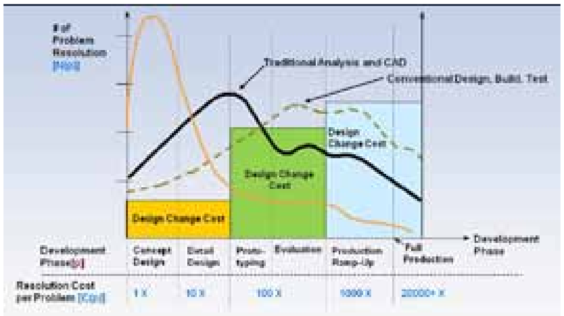
CFD saves time and money not just by increasing analysis throughput but also by improving the engineer's insight into fluid flow problems. Insight can reduce the number of design variants under consideration in the first place, by helping engineers filter out bad designs when there are few (if any) cost consequences. Because design variants build upon one another, improved insight also can prevent engineers from heading down the wrong design path and building upon a faulty design foundation.

Yet, capturing CFD's worth in formal return-on-investment terms can be difficult. The reason why is that one side of the cost–benefit balance sheet is much more obvious than the other. Upfront costs for licenses, high-performance computing and training are as obvious as a price tag.

The economic benefits of CFD, while readily apparent to engineering users, can be much more subtle and hard to quantify in an accounting ledger. Yet those benefits do exist, and they can be quantified if users pay attention to CFD's ability to reduce costs that are embedded in every step of the product development process. This paper presents a closer look at these embedded costs and how engineering organizations have used CFD to reduce these costs in real-world applications.

Time-to-Market Costs

New product designs start to incur costs from the very beginning of the development process and, if all goes as planned, generate revenue only when they make it to market. This fundamental aspect of product development economics is painfully obvious to any company whose products languish on the "drawing board" for too long — racking up development costs instead of recouping expenditures in the marketplace. One way to get products out the door faster, often while improving their performance and quality, is to make use of simulation software. The time-to-market savings from CFD will vary with the application, but it is not uncommon for companies whose products involve complex fluid flows to compress their product development cycle by months or even years.

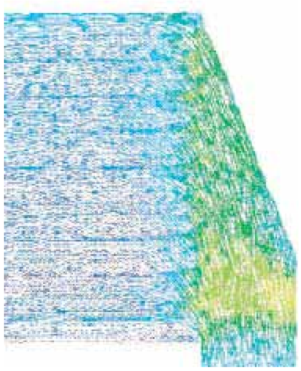


Simulate Early and Often

Best-in-class companies are three times more likely to take a systematic approach simulation. They use it regularly throughout the design process, especially in the concept stage when it is easiest and most cost effective to make changes. Such companies spring back from tough times faster than competitors by optimizing their development process and implementing a get-it-right-the-first-time strategy by predicting and analyzing product behavior earlier in the design process. They also evaluate more design iterations in the concept/design stage.

Source: Aberdeen Group: The Impact of Strategic Simulation on Product Profitability

Consider the experience of U.S.-based Weil-McLain, a leader of space conditioning and water heating systems. When developing an advanced three-pass, horizontal-flue boiler, the company's engineers used CFD software to analyze fluid flow patterns and heat transfer of different boiler designs. By helping them to speed up the usually tedious process of evaluating design iterations, CFD software cut more than six months from the company's typical time to market using conventional build-and-test methods — but not at the expense of reaching the product's key performance and quality targets. The new Weil-McLain boiler featured design improvements that boosted efficiency to more than 86 percent, making it one of the most efficient units of its kind.

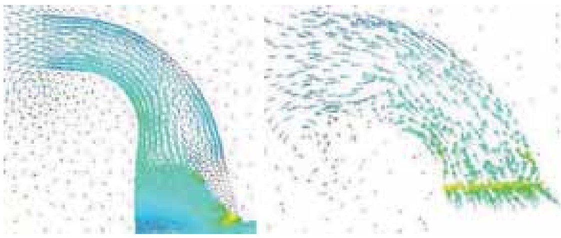


Simulation at Work

Saved 6+ months over build-and-test method

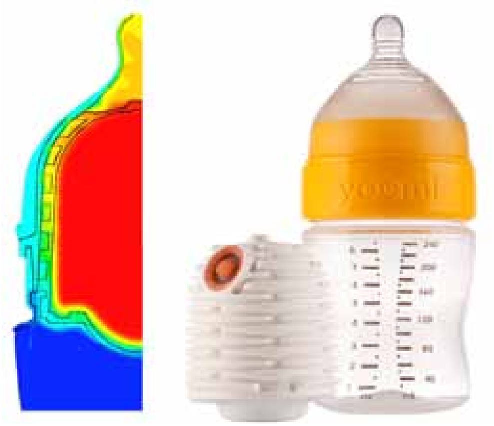
Weil-McLain needed to highlight the performance of various boiler designs, specifically the effects on fluid flow patterns and heat transfer. In one design, a large area of stagnant, recirculating gas promoted little additional heat transfer potential; in another design, a much higher average velocity was in contact with the back wall (right), promoting better heat transfer effectiveness. The company applied ANSYS® simulation software to guide its selection of a final set of prototypes, arriving at one that was the most efficient and economical design.

A similar time-to-market savings took place at AcoustiFLO, LLC, a specialist in custom fan engineering in the U.S. For an efficient new centrifugal fan module that could drop into packaged air handlers, the company's engineers used CFD software to evaluate the interaction between the fan's diffuser and impeller in many different design variants. By helping the investigating team find an optimal design quickly, CFD pared more than six months from the company's usual development cycle.

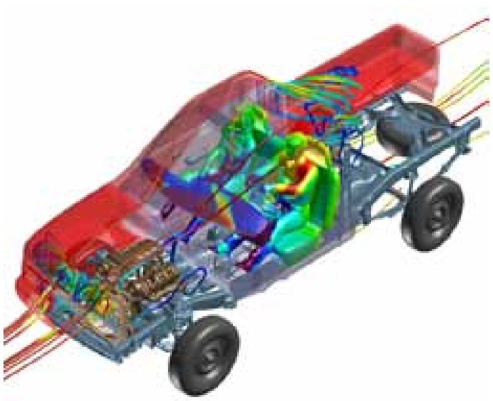


Simulation at Work
Cut 6 months from development cycle
AcoustiFLO's original fan impeller housing (left) shows significant areas of flow recirculation; the improved housing design (right) shows no evidence of recirculation and much higher efficiency that the original design. Using ANSYS FLUENT to perform CFD simulation, the engineering team discovered unexpected interactions between the diffuser and impeller, which would have been difficult to access with physical testing only.

Even greater time-to-market savings are not uncommon. Take the case of yoomi Ltd., a U.K. company that recently developed a self-warming baby bottle. To heat the bottle, the company's engineering consultants employed a chemical heater based on sodium acetate, which generates heat when it undergoes a phase change. In yoomi's initial prototype, the sodium acetate heater produced only enough heat to warm milk halfway to the required temperature of 34 degrees C. By simulating the multiphase fluid dynamics of the heating compound in different bottle designs, engineers managed to double the performance of the initial prototype while building just four physical models. The resulting time-to-market was two years faster than a traditional build-and-test development process.



Simulation at Work
Cut 2 years over build-and-test method, saved $55,000
Intelligent Fluid Solutions in the U.K. used ANSYS® CFX® software to design the yoomi bottle warmer's channels, curving, widening and deepening them to increase the amount of surface area in contact with the fluid. Engineers also modeled the complex thermal system in which sodium acetate trihydrate goes through a phase change to better understand how the liquid progresses through the warmer channels, how it pushes air in the opposite direction, and how it picks up heat from the phase change material. The final step crunched through thousands of possible geometric alternatives to find the best design.



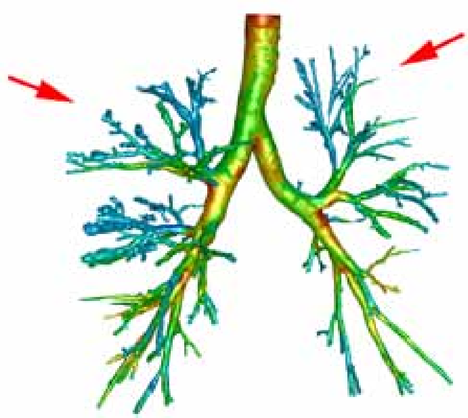
Underhood and cabin thermal management of a truck

Physical Modeling and Testing Costs

Now that engineering organizations have gained experience and confidence in CFD and related simulation technologies, they increasingly rely on virtual prototyping strategies that drastically reduce the need for physical models and testing. In some applications, CFD and coupled simulations have replaced nearly all of the physical testing. In others, simulation acts as a gatekeeper to allow fewer design concepts to pass through to the physical testing stage.

Either way, any reduction in physical prototyping and testing will remove cost from the design and development process. How much cost? It depends on the application, but tests on even lab-scale mixing equipment can cost hundreds of dollars per hour. Testing full-scale automotive or aerospace models in wind tunnels can run thousands per hour. And neither of these examples includes the cost of producing the physical prototype or analyzing test data.

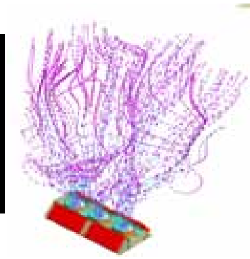
For example, computer modeling and simulation are helping researchers develop innovative respiratory drugs in a shorter amount of time. The cost of developing a respiratory therapy drug for asthma is estimated at more than $1 billion; the process can take up to 14 years and involve thousands of patients in clinical studies. At Belgium-based FluidDA, in silico respiratory studies employ fluid dynamics simulation to generate accurate images of pulmonary functions, such as airway volume and resistance for individual patients. The impact on development costs and time could be stunning.



Simulation at Work
Cut 6 months from development cycle

The high cost of drug development often discourages pharmaceutical companies from risking considerable resources for an uncertain ROI. In developing a new respiratory drug, FluidDA used ANSYS FLUENT to access changes in airway volume and resistance through functional imaging. Patient-specific functional-imaging data is an important component of this emerging field, called translational medicine. Researchers continually search for parameters that can facilitate the transition of drugs from preclinical to clinical stages, making drugs available faster for patient use.

In Germany, Voith Turbo used CFD to develop quieter fans by simulating a complete railcar cooling system. Increasingly stricter exhaust regulations and growing output requirements call for higher and higher cooling performance, which could lead to greater noise pollution. The company developed a plan to address these competing parameters in the rail industry. Currently, depending on the stage of product development, Voith is able to reduce its prototype costs by two-thirds.



Simulation at Work
Reduced costs up to two-thirds
Developing quieter fans for use in both railcars and locomotives is a challenge. Voith Turbo engineers used ANSYS CFX software to determine the volume flow rate of each fan and distribution of flow from the heat exchangers to the fans. The team established fan design data such as torque, rated input, pressure increase and efficiently for the complete cooling system — information that is not easy to obtain on a fan test under idealized conditions.

Testing also has a multiplier effect on total development costs. Because it adds time to the design process and extends time to market, testing can impact the product cycle well beyond the direct costs of prototype production, running test equipment and analyzing test data. Whenever CFD is used to break the cycle of endless physical testing, time to market tends to improve too.

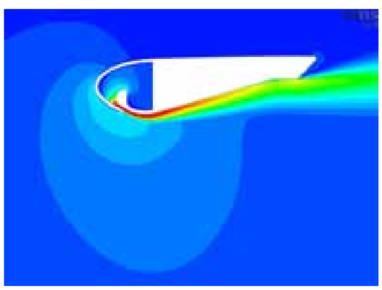
That's exactly what happened with Weil-McLain's high-tech boiler. The company saved $300,000 on prototyping expenses while reducing its time to market by more than six months. AcoustiFLO similarly saved $150,000 while bringing a new fan concept to market more than six months faster than it would have without CFD. And yoomi saved $55,000 by avoiding prototype costs in addition to its saving two years of time.

The Cost of Design Optimization
One of CFD's overlooked cost benefits is its ability to improve speed and quality of the design optimization process. Even when designing the simplest products, today's engineers must optimize a multitude of geometry, material and other design attributes. A seemingly straightforward flap valve design, for example, might involve dozens of subtle changes to the geometry of the valve body or flap. A more challenging fluid flow application, such as optimizing the aerodynamics of a Formula One car, might require many hundreds of changes.

The most advanced CFD simulation products increasingly contain features that eliminate the time-consuming, error-prone process of manually evaluating incremental design variations. Key among these features is the automated generation of parametric design variations, which dramatically speeds up the user's ability to evaluate multiple what-if scenarios without the need for manual rework.

Other tools allow users to evaluate the effects of variations within a given design tolerance or determine which design parameters require the tightest control. Still other features automate statistical optimization methods, including design of experiments (DOE) and Six Sigma analysis. A CFD suite with integrated tools can help users to understand which parameters the design is most sensitive to as well as determine which design parameters require the tightest control. For the most innovative and fastest results, all optimization techniques should take place within a single-user environment.

As an example of design optimization at its best, Dyson in the U.K. set about developing a revolutionary bladeless fan without benefit of previous experience with this type of design. Historically, the company relied on physical prototyping, but engineers faced evaluating hundreds of design candidates to optimize this new product. After testing a concept prototype, the goal was to increase the amplification ratio to move the maximum amount of air possible for a given size and power consumption. Using simulation, Dyson's engineers steadily improved the amplification ratio performance to 15 to one, a 2.5-fold improvement over the six-to-one ratio of the original concept design.



Simulation at Work
200 design interations, 250% quality improvement
For the Dyson bladeless fan, air is drawn into the base of the unit by an impeller. The image shows contours of velocity magnitude simulated with ANSYS FLUENT. Slower-moving air (dark blue and light blue contours) inside the ring accelerated by passing over a ramp and out through a narrow opening (green, yellow and red contours). The Dyson team investigated 200 different interations, which was 10 times the number that would have been possible if physical prototyping had been the primary design tool. As a result, engineers were able to establish relationships between air velocity and delivered flow rate for various designs — a key performance metric.

The Cost of Inaccuracy

CFD saves time and money not just by increasing analysis throughput but also by improving the engineer's insight into fluid flow problems. Insight can reduce the number of design variants under consideration in the first place, by helping engineers filter out bad designs when there are few (if any) cost consequences. Because design variants build upon one another, improved insight also can prevent engineers from heading down the wrong design path and building upon a faulty design foundation.

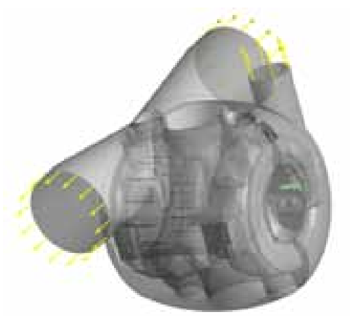
For example, in the oil and gas industry, CFD can be of great value to refining operations in minimizing the use of empirical assumptions that may not apply. It can allow trial-and-error processes to take place in the virtual realm, without any physical prototypes. In motorsports, accuracy can be the difference between winning and losing.

Some aspects of design insight come from software features, such as how robust multiphysics capabilities provide insight into interactions between fluid flows and structural elements.

Features aside, the foundation that underlies true design insight is accuracy. It determines the software's ability to reveal tiny design problems that can snowball into large problems during the iteration process.

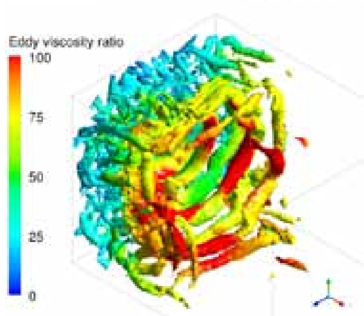
Accuracy also helps prevent over-engineering along with its embedded costs. With high-fidelity CFD results in hand, engineers can design with smaller safety factors — which can ultimately reduce the cost of a product's materials, components and manufacturing methods. Conversely, poor simulation accuracy tends to push engineers to take a more conservative, costly approach to product design.

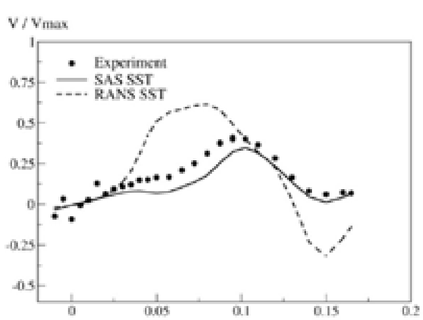
Consider turbomachinery design, which is highly complex and demanding. Bharat Heavy Electricals Limited (BHEL), a large energy-sector organization in India, needed to improve performance of one of its utility steam turbines. Engineers there used CFD to analyze similar turbine designs to acquire insight into the flow parameters for each stage and into loss coefficients for the inlet and outlet passage sections — a task that would have been impossible without simulation tools.



Simulation at Work
Understanding flow parameters

Experiment and testing can show improved performance but often cannot detect exactly why the improvement has occurred, BHEL used ANSYS CFX to analyze the flow path for a turbine, computing steam parameters such as pressure, temperature, enthalphy, power per stage, stage isentropic efficiency and leakage flow for stage.

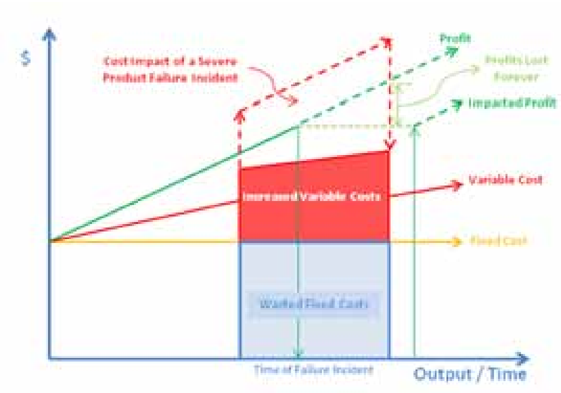




Simulation at Work
Turbulence and accuracy

Simulation of turbulence structures in a single swirl burner (top) and reacting flow velocity profiles (bottom). Note the significant influence of selecting the right turbulence model (in this case SAS). A CFD code user must think in terms of tick-boxes of which model is available in which code; he also must also consider implementation integrity and the CFD supplier's underlying know-how behind the technology.

Unfortunately, not all CFD products are created equal when it comes to accuracy. Modern CFD software, for instance, now contains a turbulence model, but differences in how those models have been implemented in software can have a dramatic effect on accuracy. Because the factors that drive accuracy can be somewhat opaque to users and difficult for non-specialists to grasp, the best advice is to work with established CFD vendors whose software has been thoroughly validated in the widest variety of real-world applications.

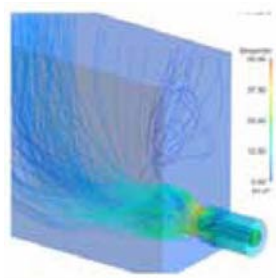


The Cost of Product Failure and Downtime

When a product failure incident occurs, the consequences can mount up: loss of profits, repair costs, fixed and variable operating costs wasted during downtime, and a myriad of other costs that reverberate throughout the business. The damage can be measured in dollars — millions in lost profit per year — as well as in reputation, enough to send a company to bankruptcy.

For example, in chemical process equipment, flow fields can be very complex and difficult to measure. Troubleshooting or improving efficiency requires multiple data points, which are often unavailable. To reduce downtime and loss of revenue, CFD can be invaluable at virtually analyzing equipment at full scale. Fluid dynamics analysis provides an inside look into the function and operation, offering valuable information to equipment manufacturers, plant managers, production managers, process engineers, and research and development staff.

Consider the case of Brazilian power generation company Tractebel, which needed to decrease maintenance downtime by identifying the cause of wall erosion in a coal boiler. Addressing this problem was quite costly because of the materials involved; in addition, the boiler needed to be shut down while repairs were made. Tractebel engineers used CFD to make informed and cost-effective decisions regarding the operation of the burner and, consequently, the plant.



Simulation at Work

Reduced down time

A common problem in coal-fired boilers is erosion of the boiler walls, which can lead to down time. Tractebel simulated a coal burner with ANSYS CFX to identify contributing erosion factors such as wall shear stress. The fluid fl ow results enabled engineers to identify modifications that might be made to minimize wall erosion in the boiler, reducing associated costs.

On the warranty front, India-based Control Components Inc. (CCI) faced accelerating warranty costs related to its turbine bypass valves. Power plants today operate at supercritical conditions to meet fluctuating power demands, which places added strain on the valves. CFD simulation made it possible to quickly upgrade the turbine bypass valve in a few weeks, compared to the six to 12 months that would have been required using conventional methods.

Cutting Design Costs: How Industry leaders Benefit from Fast and Reliable CFD

Simulation at Work
Reduced warranty costs

Power plant valves undergo much more thermal and mechanical loading than originally designed for. CCI used ANSYS CFX to simulate valve flow parameters, such as pressure (shown), at harsh operating conditions. This information was used to design structurally stronger components that can be installed in a simple field retrofit to existing valves.

Adding up the Savings

For all its proven utility as an engineering tool, CFD simulation software sometimes gets knocked for its cost of implementation. This criticism, however, does not hold up to scrutiny when all the embedded costs associated with the product development process are taken into account.

The actual cost benefit of CFD depends on the application, but the total savings from bringing better products to market in the shortest possible time clearly outweigh licensing, hardware, training and support costs.

In trying to reduce design cost and lead time, bypassing the use of CFD simulation is a liability to companies that face fierce competition. Organizations in all sectors, from aerospace, automotive and chemical processing to energy and healthcare, are utilizing CFD simulation software to identify optimum design solutions and maximize their overall bottom line. Are you?

Simulation at Work
Winning products

Red Bull Racing won the 2010 Drivers' and Construction' championships with the help of CFD simulation to optimize aerodynamics. " ANSYS FLUENT" helps with the quality of the final product, because we have such confidence in the accuracy of the results. We can design parts and get them to the car, confident that those parts will work on the track," said Steve Nevey of Red Bull Racing. "We don't have to spend as much time correlating with wind tunnel results nor trying to work out why things don't tie up with track results. Removing that interation from the loop makes a big improvement on the quality of our results."

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