Avoiding Small Mistakes — and Huge Costs

Robust design practices using engineering simulation help the world's most innovative companies to protect product integrity and identify errors early — saving warranty costs, reputation damage and lost customers later.

By Wim Slagter, Lead Product Manager, ANSYS, Inc.

Faster and more frequent product introductions may compromise the ultimate quality and reliability of product designs.

Despite the many incredible advances we've seen in the practice of engineering, no product or process is guaranteed to always perform as intended. Regardless of how carefully we engineer, there are still natural material variations that affect product outcomes down the road. Although manufacturing has become highly automated and standardized, tolerances and variations are unavoidable in sourcing, production, distribution, delivery, installation and degradation over a product's life. Perhaps the greatest source of variation and risk lies in the physical world in which a product must perform — with its wide range of user behaviors, temperature extremes, and range of structural, fluidic and electromagnetic forces occurring over time.

Amid all the uncertainties of the end-to-end product lifecycle, it is challenging to ensure the kind of consistent, reliable performance that supports product integrity and protects brand reputations. Yet today, there are few tasks more critical to ensuring long-term profitability.

Product failures deliver an enormous financial setback in a number of ways. First, there are the obvious immediate bottom-line impacts of recalls and warranty payouts. Despite all our engineering sophistication, today's warranty costs alone can account for up to 10 percent of total sales. According to *Warranty Week*, U.S.-based manufacturers spent $24.7 billion on claims in 2011, up from $23.6 billion in 2010. Those same manufacturers held $36.6 billion in their warranty reserve funds at the end of 2011, up from $33.8 billion at the end of 2010.

But as manufacturers increasingly apply robust design tools and processes, these numbers are improving. Warranty claims in 2012 dropped 3 percent to just under $24 billion, while sales of products with warranties increased that year — and *Warranty Week* reported that companies are using technology to work smarter and reduce these costs.

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Even so, warranty costs are still significant — and they represent only the short-term effect of product failure. Over the longer term, the cost of lost customers, negative publicity and bad product reviews can be even more devastating. The internet brings our entire world into close proximity, so unhappy customers can always find a product alternative — as well as share their dissatisfaction instantly with the world via social media. In this extremely competitive, ultra-connected and highly scrutinized environment, one fact is clear: Manufacturers need to avoid even the smallest design mistake, because of the risk of devastating short- and long-term costs.

ROBUST DESIGN: AN ENGINEER'S MOST VALUABLE TOOL

If variability and uncertainty represent undeniable realities, how can engineers hope to manage these risks? The answer lies in considering, from the earliest design stage, the widest possible range of material properties, manufacturing processes, real-world operating conditions, and end-user behaviors. By bringing many sources of variation and uncertainty into the product development process, engineers can produce the most robust design.

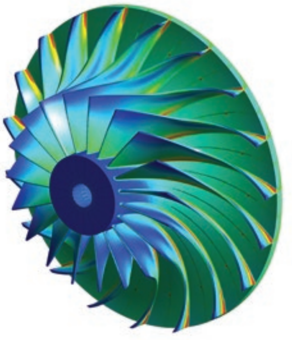
When engineers use conventional simulation practices, they assume that all inputs are known — and they compute the product's response, optimizing their designs to maximize desired performance characteristics at a single design point. Conversely, robust design assumes that no one fully understands every possible input. Simulation is applied in a parametric way to identify the best possible overall product design by considering many sources of uncertainty and variation that otherwise would not be taken into account.

Robust design empowers engineers to predict and control performance outcomes in the face of dozens, hundreds or even thousands of multiphysics inputs that products are subjected to every day. Whatever their industry or specific product development challenge, to ensure ultimate product integrity, engineering teams must progress from examining a single design point to exploring hundreds, thousands or tens of thousands of design points.

Today, businesses in every industry feel increasing pressure to launch new product models that keep pace with both competitors and changing market needs. However, faster and more frequent product introductions may compromise the ultimate quality and reliability of product designs.

In a recent ANSYS survey, when almost 3,000 respondents were asked to name the biggest pressures on their design activities, 52 percent cited "reducing the time required to complete design cycles." At the same time, 28 percent of respondents named "producing more reliable products that result in lower warranty-related costs" as a chief concern.

Comparing results from this survey to a study ANSYS commissioned in 2011, there is nearly a threefold increase in the number of respondents who feel pressure to design products that incur lower costs from warranty claims, recalls and other consequences of product failure. In 2013, respondents also reported much greater pressure to find new ways to differentiate their products from competitors' offerings, particularly in terms of higher quality.



▲ Because of turbomachinery design complexities, this engineering field is fairly advanced in applying robust design. An academic team at the Dortmund University of Applied Sciences and Arts in Germany combined ANSYS Workbench with optiSLang — an efficient software tool for sensitivity analysis — to optimize a radial compressor. The goal was to retain efficient fluid flows while strengthening the blades to withstand greater stresses. Traditional simulations would have focused on a single, rotationally symmetrical sector of the compressor; in this case, the team used multiphysics structural–CFD parametric analysis to simulate stresses and flows for a complete 360-degree geometry. By quickly identifying the critical stress points at the outlet of the impeller, the team optimized the compressor geometry. Stress was reduced by an impressive 40 percent, while efficiency was maintained. Original design (top), optimized design (bottom)

Engineering simulation addresses this complex challenge by providing a systematic way to quickly validate, modify or discard new product ideas based on their likely performance. While it would be impossible to physically test for every source of variation, engineering simulation makes stringent, reliability-focused product testing accessible and cost-effective via robust design technology.

DEMOCRATIZING ROBUST DESIGN VIA TECHNOLOGY

As more R&D teams discover the central role that engineering simulation plays in ensuring ultimate design robustness, the good news is that a perfect storm of technology improvements has helped to make simulation faster, more streamlined and more accessible than ever. The incredible growth in high-performance computing (HPC) capabilities has enabled even the most computationally large problems to be solved rapidly via parallel processing, distributed solving, automation and other capabilities.

HPC is essential to the growing "democratization" of robust design practices because this reliability-focused product development method relies on broad systems-level analyses that study multiple forces acting on multiple components. Automated, parametric studies make it easy for engineers to understand the impacts of the smallest design changes on systems-level performance and isolate the most critical design points — yet these multiphysics, multirun simulations consume enormous amounts of computing power, making HPC a key enabler.

Continuing enhancements to ANSYS software have helped to create this perfect storm, placing robust design tools in the hands of more and more engineers every day. In matching the speed and power of HPC with smarter, more targeted ways to manage and solve large multiphysics problems, ANSYS has emerged as a leader in the growth of robust design.

TOOLS ENABLE ROBUST DESIGN

While the benefits of simulation-driven, reliability-focused design processes are evident, many engineering teams seem hesitant to leverage today's sophisticated robust design tools. The survey conducted by ANSYS found that 22 percent of respondents have not engaged in parametric simulation because they perceive it as too labor-intensive, with turnaround times that are prohibitively long. There is also a mistaken belief that the costs of simulation-driven robust design are prohibitively high, especially related to software licensing.

However, improvements in the ANSYS Workbench platform help to democratize robust design practices by supporting more persistent parametric simulations with an increasing degree of automation. At the same time, a parametric HPC licensing model makes robust design more scalable and cost-effective than ever.

Reaping the benefits of robust design requires a full array of software solutions, support and licensing agreements that address customer needs at every stage of the robust design journey. ANSYS assists customers throughout this journey, from parametric simulation and design exploration — including techniques such as response surface and design of experiments (DOE) — to goal-driven optimization and probabilistic optimization.

Typically, as customers recognize the impact of parametric studies on ultimate product integrity — as well as on design process time and cost-effectiveness — they are eager to take simulation usage to the next level. A number of key capabilities in ANSYS software make it easier for users to adopt robust design best practices that can reduce design process time and related costs.

Automated Execution of Multiphysics Simulations

To increase workflow throughput, ANSYS software allows users to automatically investigate multiple, parametric design variations — all without programming. The Workbench project window provides a guide throughout the simulation process by working through the system from top to bottom. The entire process is also persistent: Engineering teams can streamline workflows by automatically propagating changes in geometry, meshing and physics without manual rework. Because a single physics is often not enough to understand the full design space, Workbench makes it easy to tie together multiple physics and create virtual prototypes with drag-and-drop simplicity, connecting physics with no scripting, file transfer or file conversion.

Accurate, Reliable and Customizable Solver Technology

ANSYS software contains sophisticated numerics and robust solvers to ensure fast, accurate results for a nearly limitless range of engineering applications. Solvers are highly optimized to deliver outstanding parallel scaling on today's multicore processors. To meet an organization's present and future simulation and workflow process requirements, ANSYS software is readily customizable and extensible; users can implement their own specialty physics models, and the user environment can be readily customized and scripted for establishing best practices and further workflow automation.

Integrated Parameter Management

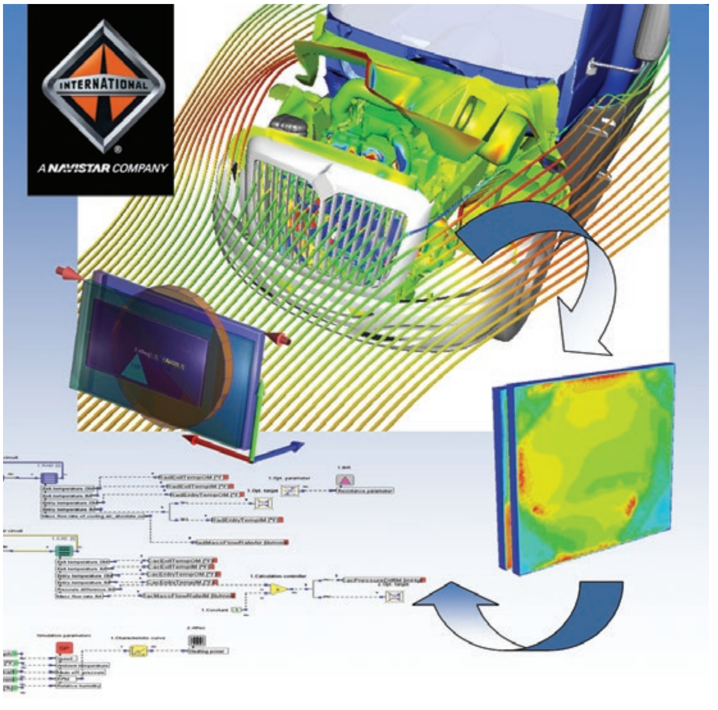
Workbench hosted applications support numerous variations that reflect a range of design and operating parameters — including CAD parameters, mesh settings, material properties, boundary conditions and derived result parameters. Parameters defined within the applications are managed from the project window, making it easy to investigate multiple variations of the analysis. From within the project window, a series of design points can be built up in tabular form and executed to complete a what-if study with a single operation.

Integrated Design Exploration Capabilities

ANSYS DesignXplorer features a variety of DOE types that sample the design space, allowing engineers to efficiently explore via a relatively small number of simulations. A response surface can be fitted to the results, making it possible to predict the value of every other design point within the design space. The DOE table of design points can be solved in batch mode on a local machine or remotely distributed for a simultaneous solve. ANSYS simulation software can be used in concert with many optimization partner solutions.

Simultaneous Design-Point Analysis

Software from ANSYS supports robust design simulation practices with a more complete, more robust set of tools that enable simultaneous submission of multiple parametrically linked simulation jobs. The HPC Parametric Pack license amplifies the available licenses for individual applications (such as pre-processing, meshing, solving and post-processing), enabling simultaneous execution of multiple design points — while consuming just one set of application licenses. The Remote Solve Manager (RSM) in Workbench allows users to submit multiple design-point jobs, with each job executing on multiple parallel processing cores and — if needed — via third-party job schedulers.



▲ Navistar has utilized ANSYS Fluent and KULI to develop a vehicle thermal optimization solution. This coupling methodology has improved thermal predictions and increased design turnaround time. Employing this process has given Navistar a competitive advantage in developing thermal solutions to meet increasingly stringent emission regulations. COURTESY NAVISTAR, INC.

Shape Optimization Accelerated by Morphing Capabilities

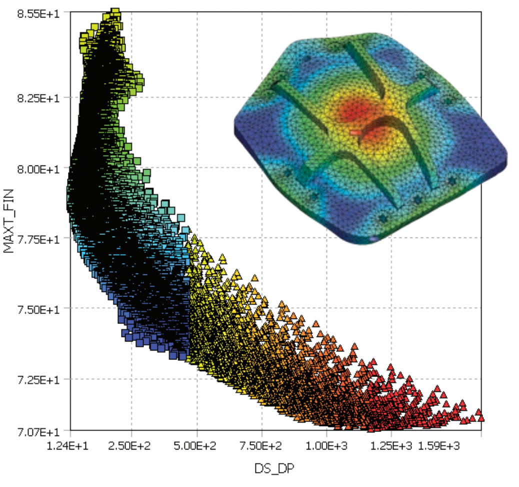
ANSYS software integrates morphing technology within the computational fluid dynamics (CFD) solver to solve a series of design points without manual creation of a new geometry and mesh. Developed with software partner RBF Morph, this groundbreaking technology allows the entire setup to be accomplished within ANSYS Fluent. Engineers define a series of shape parameters that form the basis of the design space, then the computational mesh is automatically morphed for each design point. The clear advantage of this approach is that geometry updates are not needed until after the final design is selected.

LEARN FROM THE LEADERS IN ROBUST DESIGN

This issue of *ANSYS Advantage* highlights the many benefits of taking a robust design approach. These real-world stories show the wide range of ways that leading engineering teams are applying robust design to address an equally diverse spectrum of pressing design challenges.

Technip, a leading supplier to the global energy industry, recently used DesignXplorer to automate 20,000 simulations aimed at modeling performance complexities of an undersea piping system. In an industry in which the cost of mistakes can be devastating, Technip now tells its customers, with confidence, that this equipment has been tested against every possible stress load.

Electronics leader JVC KENWOOD has employed robust design practices to develop innovative automotive speaker technologies. The company has reduced its overall product development cycle by 10 percent, increased product performance by 5 percent, and reduced the amount of materials in the typical speaker by up to 40 percent — a significant cost savings.



◀ **Structural analysis and shape optimization of fuel cell end plates were performed to optimize stiffness within space limitations. After generating 10,000 virtual experiments using simulation, engineers created a scatter plot of performance requirements showing maximum temperature versus pressure drop. Dark blue squares represent data points that meet all design requirements and have minimal temperature.**

COURTESY ADVANCED ENGINEERING SOLUTIONS.

This edition's thought leader is Al Brockett, who recently retired following a 35-year career leading the engineering team at Pratt & Whitney. The company has used a robust design methodology — which it calls design for variation — to achieve a 64 percent to 88 percent return on investment by reducing design iterations, improving manufacturability, increasing reliability, improving on-time deliveries and realizing other performance benefits. Brockett offers practical advice for other engineering teams interested in adopting robust design as a guiding principle.

RENEW YOUR COMMITMENT TO PRODUCT INTEGRITY

Robust design delivers a variety of business benefits that can be customized to your organization's top-level strategic challenges — whether your pressing need is improving speed to market, launching a game-changing product innovation, or driving materials or manufacturing costs out of your processes. At its heart, however, robust design is focused on a much more critical deliverable: protecting product integrity. Unless your products perform as expected, under unpredictable real-world conditions, every single time, the other business benefits simply won't matter.

While ANSYS has invested significantly in robust design capabilities, such as parametric setup, persistent updates, and

Robust Design and Smart Products: A Special Challenge

One of the biggest trends in engineering is the increased incorporation of smart electronic features that enable products to monitor and improve their own performance. From everyday devices like mobile phones to unexpected applications like wind turbines, the inclusion of smart technologies makes design robustness even more critical — but also more challenging to achieve.

Integrating electrical, mechanical, digital control and embedded software components into a single design can create an environment of technological chaos, in which it is difficult to isolate and address factors that truly impact systems-level performance. There may be thousands of requirements for a system, and these may be at odds with requirements at the component level. Typically, each engineering discipline works independently, functioning in isolation from each other and passing project information from one group to another in serial fashion. In many cases, mechanical engineering groups complete work and then forward tasks to electronic/electrical design engineering, which then forwards tasks to software engineering.

Each discipline works in silos, with individual design processes and nonintegrated design tools. As a result, engineers downstream in development have little opportunity to provide valuable input early in the cycle, and design deficiencies often are not uncovered until late in the process — when changes are costly and time consuming.

Simulating the complete system requires combining these engineering disciplines along with their models of varying orders of fidelity (3-D, 1-D and 0-D) and embedded software systems. ANSYS Simplorer — historically used for modeling power electronics and other electrical systems — is being adapted to address these complex multidomain, multitechnology problems. Simplorer supports design robustness by allowing engineers to incorporate ANSYS mechanical, fluid and electromagnetic software with circuit and system capability, as well as Esterel embedded software technology, to identify early-stage design issues that other simulation tools (or build-and-test methods) cannot detect.

DOE and HPC technologies, many engineering teams still are not leveraging engineering simulation to support design robustness. As you review this edition of *ANSYS Advantage*, perhaps you'll be inspired to renew your own commitment to product integrity by advancing robust design efforts via simulation.

Whether you are a beginner or an advanced user of robust design practices, ANSYS can assist you with building in product integrity from the start. Based on our experience in supporting robust design initiatives with some of the world's leading engineering teams, we're confident that high-impact engineering simulation can help you make, and keep, the kinds of meaningful performance promises that establish your company as a true leader in product integrity.

Pratt & Whitney's robust design methodology has achieved a 64 percent to 88 percent ROI.

How to Evolve Your Simulation Practices Toward Robust Design

Establishing a robust design process is not a one-time event, but an evolution that occurs over time as simulation practices become increasingly sophisticated. As shown below, most organizations begin this journey by looking at a one-off design, single-physics analysis for validation purposes. As engineering teams begin to apply ANSYS solutions in a parametric manner, using techniques to visualize and interrogate the design space, simultaneously executing multiple designs through multi-goal analyses, and looking at statistical variation of design input parameters, their design process drives towards optimization in a world of design input uncertainty — and they become ever more confident that their products will perform as expected in the real world.