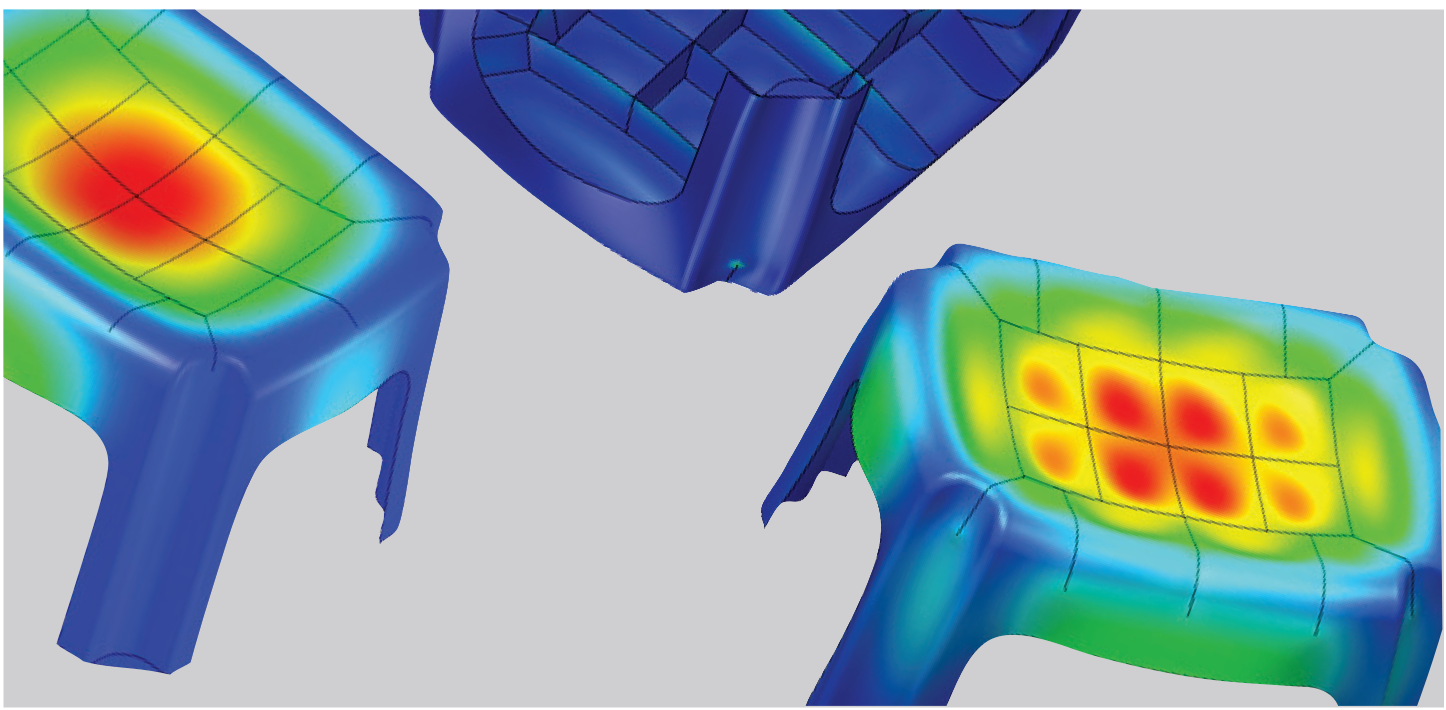
DRIVING BETTER PRODUCT DESIGN WITH SOLIDWORKS SIMULATION

Overview

The SolidWorks® Simulation suite provides the advanced capabilities you need to get to market faster—designers can catch mistakes sooner, change course quickly, and create better-performing products at a lower cost.



Introduction

How does simulation technology improve the design process?

For companies that want to be the best in the industry, simulation software is an invaluable tool, even in the early stages of product development. Simulation technology provides design engineers with the right tools, the right hardware—at the right time—to make better decisions. The end results? Better products, lower costs, and faster time-to-market.

When managers and design team leaders become involved early in the process, they gain insights as well. With a better understanding of simulation based on finite element analysis (FEA), they can contribute to improving the product development process. This paper shows the value of simulation as a design driver for both product and process, and offers suggestions for its successful implementation.

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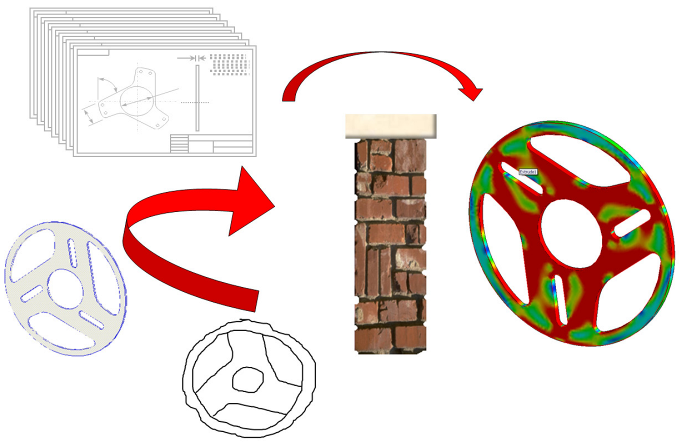

Figure 1: The traditional product development process

How SolidWorks Simulation streamlines product development

Over the past eight years, the CAD/CAE (computer-aided design/computer-aided engineering) industry has done a great job at making traditional analysis tools easier to use and more accessible to design engineers. Yet, the workflow has always been, "Here's the design—now here's the analysis," with the emphasis on the sequential nature of the tasks (Figure 1).

However, explicitly separating design from analysis, or simulation, ignores the benefits to be gained by making the two tasks shared and iterative. The fact of the matter is, it's all design. By empowering your product teams to make better design decisions, your company can develop products faster, make fewer mistakes, and become more profitable. To accomplish this, designers must make decisions on form, fit, and function, and confirm them in small steps throughout the design process.

Figure 2 illustrates how decision making plays a vital role in a realistic process workflow for a new virtual 3D pair of goggles.

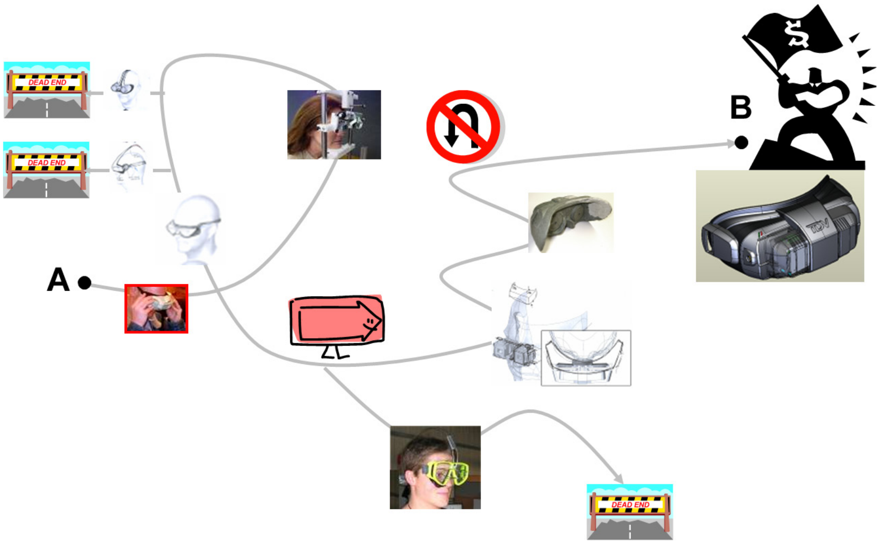

Figure 2: A realistic product development map.

Getting from point A to point B as efficiently as possible involves meeting such targets as minimal performance, market timing, and manufacturing costs. Unfortunately, as designers test ideas, adjust, start over, explore, and verify, many of the answers generate more questions.

The design process is clearly not a linear process, but rather a sequence of decisions and adjustments. Therefore, the danger, or the risk, in product development stems from making too many decisions without knowing if they are the best ones. If problems are discovered late in the design process, you will have a tough time recovering quickly or inexpensively. With periodic confirmation that the design is headed on the right (best) track, however, you can minimize the risk.

What if there were a technology, a tool, or a process that could offer more immediate feedback? Consider a type of GPS (global positioning system) for product development that says, "That probably wasn't a good idea" immediately after a designer makes a decision. This would reduce the risk of that particular "wrong turn" generating further errors down the design. Instead of making a series of decisions that later requires one huge course correction, you would be able to make small continuous corrections, straightening out the process development line. Figure 3 shows the results of such small corrections (the solid line) in the design of a printer-cartridge latch—a much more efficient path than the errant, dotted design line.

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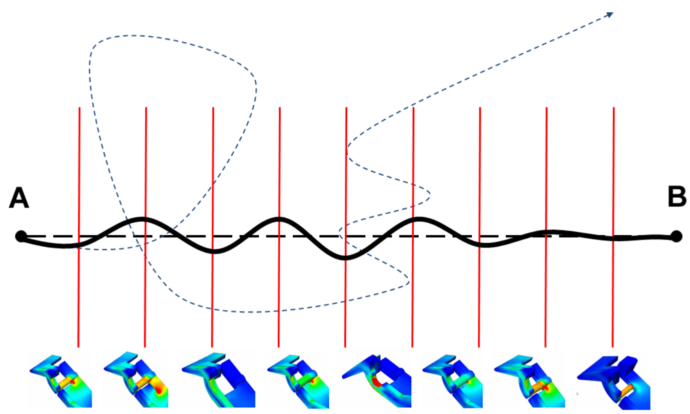

Figure 3: Linearizing product development for greater efficiency

The more linear the process, the more efficient it will be. With less cost going into your design, the greater chance you have of creating an optimal product, rather than one that is just "good enough."

Experts say the important thing to manage during product development is how quickly those mistakes are caught, since this knowledge corresponds directly to efficiency. Most decisions build and branch from one another. The faster a mistake is trapped, backed up to where it started, and corrected, the smaller the chance of pumping good money into a fundamentally bad (final) idea. This is a natural by-product of the more "linear" process shown above.

Influences on design decisions

Making "course corrections" as quickly as possible after a decision is made is critical. It comes down to effectively answering the question, "How can the designer know that was the right decision?"

Here is an example of actual design-decision workflow. Figure 4 shows an existing plastic stool. The goal is to develop a new stool with two primary design requirements: it must (1) handle a 200-pound person standing on it, and (2) be as inexpensive as possible.

Figure 4: Proposed stool design

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Three potential approaches are shown in Figure 5. It is possible that building an unstiffened, uniform wall design with the minimum thickness allowed by the molding process will work. This "first pass" only uses 24 in^3 of plastic. Adding stiffening ribs not only will increase the product cost, but also will improve the structural performance. The SolidWorks Simulation model shows that adding "some ribs" adds 10 percent to the cost, while a final, more conservative option—using the deepest ribs possible without changing the overall styling—will add 30 percent to the cost.

Simulation shows that the shallow rib option actually does meet the structural requirements, such that adding additional material to deepen the ribs contributes nothing but cost to the design.

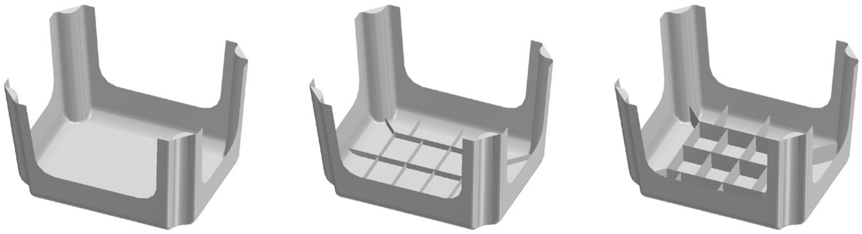

Figure 5: Proposed ribbing options for strength

Considering these three options, the "no ribs" version seems to be the highest-risk decision, and the most likely to not work. At the same time, the deeper rib design is most likely to be the sturdiest. This thought process brackets both the high-risk and the low-risk options. Without any further knowledge, most design engineers would opt for the deeper rib option to be conservative.

The company has just committed to expensive and time-consuming tooling on gut feel, and this particular rib design may still not be sufficient. At the same time, the product might be overdesigned, thus violating the project's costing goals.
Now consider making this decision with actual data on the performance of each concept, which would reduce the risk to an acceptable level. Figure 6 shows the results for each option calculated by SolidWorks Simulation.

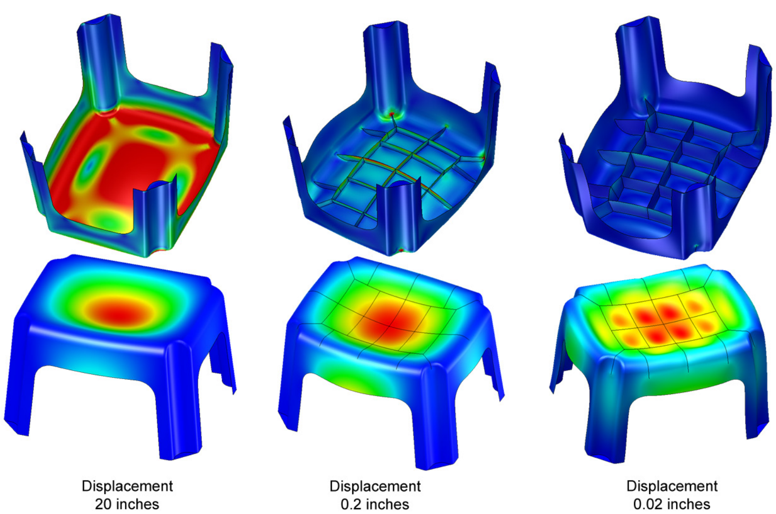

Figure 6: Simulation results for three options

Even an inexperienced designer can see that the concerns about the unstiffened design were justified. However, the results for the two ribbed designs contradict "gut feel" for the best option. Simulation shows that the shallow rib option actually does meet the structural requirements, such that adding additional material to deepen the ribs contributes nothing but cost to the design.

What does this say about gut-feel design? Although most designers get it right more often than wrong, just what "right" means deserves some clarification. After the conservative approach was selected, testing would have indicated it could indeed support a 200-pound adult and everyone would move on. It was apparently "good enough." However, one would never know, with that workflow, that it was overdesigned by 20 percent of the material cost. Can any company afford to operate this way?

Questions in the product development process

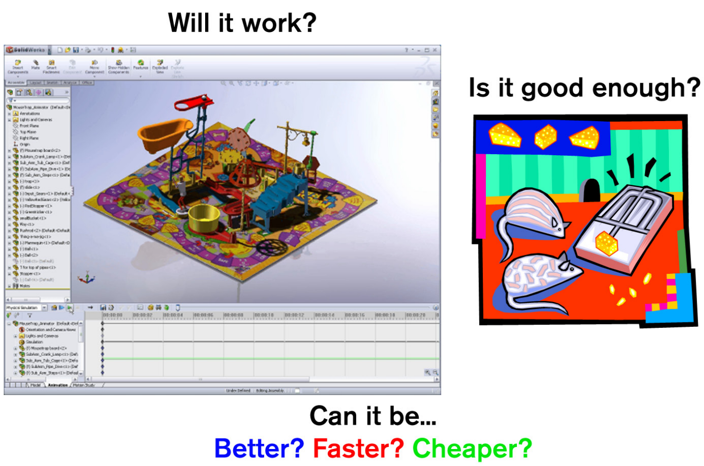

Figure 7: Three categories of design questions.

In the prior example and in most product development efforts, the questions that lead to tangible design decisions can be grouped into three categories (Figure 7):

1. Will it work?
2. Is it good enough?
3. Can it be Better? Faster? Cheaper?

Most designs pass through the first two steps sequentially. As soon as the answer to number 1 is "yes," the design details are compared to specifications and cost goals to evaluate number 2. Most designs are then handed off to manufacturing after "good enough" is confirmed through traditional prototyping methods.

However, building "Better, Faster, Cheaper" into the decision process is important in making your company more efficient and in making the design process more robust. Yet, with greater pressure to reduce time-to-market, how can designers get more value out of traditional tasks without adding time or cost to development? The answer lies in the old adage, "Work smarter, not harder." Simulation is uniquely positioned to provide that competitive edge in pursuit of "Better, Faster, Cheaper."

What defines simulation?

Simulation is a technology that is accessible and usable today by generalist design engineers, the people on the front line who are asking the most questions and making the most decisions. In addition, simulation has become a business imperative for companies striving to be competitive in their industries.

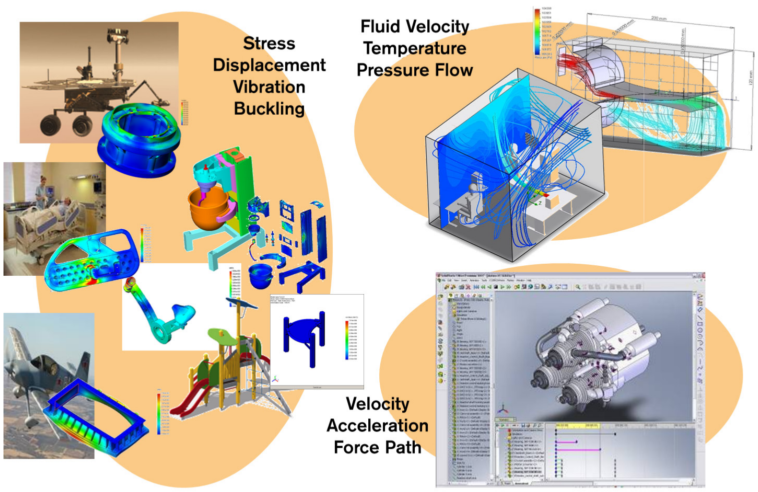

Figure 8: Three types of simulation

When used as an integral part of your day-to-day decision making, simulation is one of the few tools that can effectively linearize the design process. Simulation provides answers to questions precisely when they can best guide subsequent decisions.

For mechanical product design, simulation typically falls into three areas (Figure 8):

- Structural simulation predicts if a part or system is going to break, bend too much (like the stool), shake, buckle, or collapse.
- Fluid-flow software shows how a system responds to conditions such as internal or external air- or water-flow, identifying fluid velocities, pressures, and temperatures.
- Mechanism or dynamic analysis synthesizes linkages and finds forces, velocities, and accelerations.

In the simulation software industry, these functions typically are divided among separate products. The SolidWorks Simulation suite is specifically packaged that way: SolidWorks Simulation answers structural questions, SolidWorks Flow Simulation deals with fluid questions, and SolidWorks Motion addresses mechanism concerns.

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How do engineers currently get answers?

Product designers and managers worldwide describe a fairly consistent approach to their standard design process when simulation is not employed.

"We looked at something that worked in the past and made it bigger/smaller."
Although many successful design decisions are indeed based on previous product versions and experience, this approach generally does not explain how to do something better. It just offers guidance for achieving more of the same. The new product may indeed be "good enough," but may not begin to address "Better, Faster, Cheaper."

"We use spreadsheets or hand calculations."
Hand calculations are the traditional approach backed by centuries of results. Most engineers are comfortable with hand calculations, feeling they are more reliable and accurate than unfamiliar simulation tools. However, the reality is that hand calculations require significant assumptions and simplifications in the geometry, dimensional tolerancing, loading, and material properties. In fact, the level of abstraction required by hand calculations often limits their value to extremely rough estimates at preselected areas of concern.

In the same vein, the richness of the output from an FEA-based simulation often highlights limitations with certain simplifications that are not readily apparent from the numerical or XY chart output of a hand calculation. Yet, the validity of the simulation is challenged, while the "tried and true" calculation is accepted.

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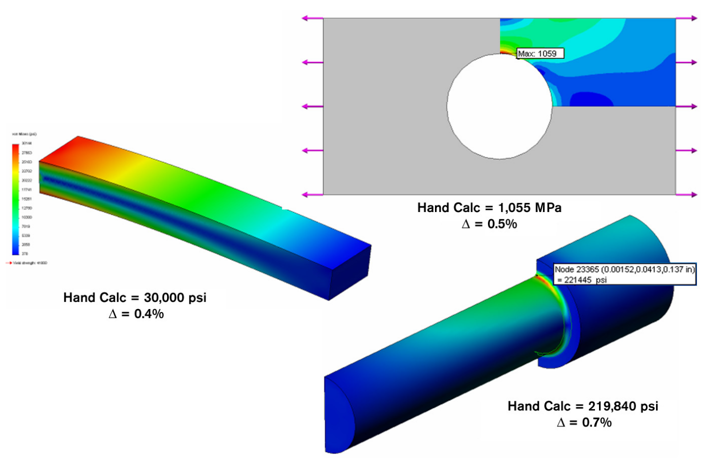

Figure 9: Comparing hand calculations to simulation.

A simple test confirms that with the same simplifications and abstractions, simulation generates exactly the same local results as a hand calculation, as shown in Figure 9. What also can be seen from that figure, though, is that designers begin to understand the flow of load or stress throughout a part and gain additional insight, even in these highly abstract, yet common, cases.

The value of simulation over equivalent hand calculations is readily apparent when more real-world, manufacturable geometry is put to the test, as in the spherical pressure vessel shown in Figure 10.

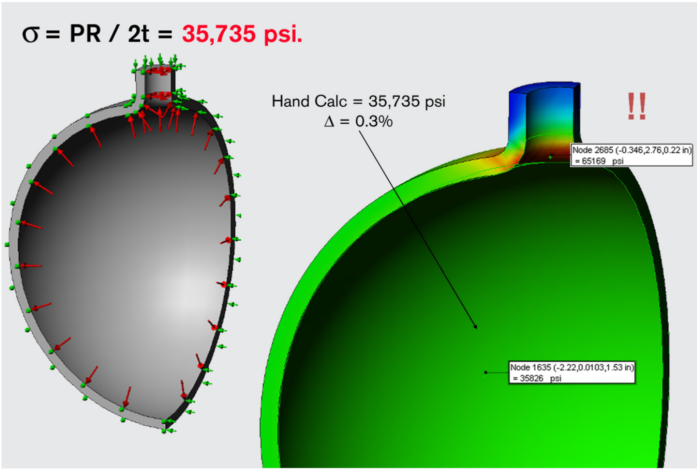

Figure 10: Stress results on a spherical pressure vessel

Closed-form equations can predict the tangential stress in the vessel, assuming an unbroken sphere. However, the hand calculation neglects to highlight an extremely important piece of information: the nozzle is going to fail first. The focus is just too narrow and presupposes that failure will only occur where it is convenient to calculate. The value of simulation is the ability to look at the whole system and see problems that may not have been anticipated.

So is simulation riskier than a hand calculation? No, because anyone who is comfortable with hand calculations will get the same answers with simulation plus more insight. The simulation also can be orders of magnitude faster than stepping through the calculations, even for simple problems.

“We test prototypes.”

Is testing more reliable than simulation? Many design engineers believe, just as with the hand calculations, that simulation is abstract but testing is “real.” However, failure testing typically provides only one data point as well, confirming that a part will pass or fail under a single set of conditions. The test does not tell where the part will break next or if failure would have been imminent had the test loading been slightly higher. Likewise, the test cannot predict if the part will even break at the same place given another sample built with material properties or dimensions at a different place in the tolerance range.

Even with the limitations of a single prototype, running multiple iterations to cover manufacturability can be cost-prohibitive. With simulation, however, the cost per iteration is reduced nearly exponentially. Once a parametric solid model has been built in SolidWorks Simulation, changing the environmental conditions or feature size is nearly immediate and essentially free to rerun. The software can even step through a spreadsheet of parameter values to run a series of simulations automatically.

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In a matter of minutes, designers can look at many more combinations of all the variables that comprise the chaos of product development and manufacturing than could ever be evaluated in physical tests. Leveraging this capability enables a design team to ask all those questions that could never have been asked in the past. As a result, they gain a much broader picture for making better decisions.

With simulation at the front of the design process, risk is designed out—not built in—so there is time to move beyond “good enough.”

We don't need design simulation…

So why isn't everyone taking this approach? Engineers and even managers give these reasons:

- **"Our parts never break."** The company that believes this statement either does not have enough information or is not pushing the envelope; the parts may be quite overdesigned. Most companies whose parts always work on the first try have probably left money on the table.

- **"We always get the best design on the first try."** While possible to achieve, it is impossible to know the design is "the best" on the first try. This can only be validated by a series of design iterations where variations are shown to make no improvement.

- **"Simulation takes too long."** This perception stems from the traditional practice of waiting until the end of the design process to validate all the decisions at once. The more complex the model, the longer it takes to mesh, solve, debug, and interpret. This generally is not an issue when simulation is used interactively to drive the design early in the process.

- **"We don't know how to use it," or "It requires a specialist."** Those obstacles used to be very real. However, one of the reasons SolidWorks Simulation has been so successful in delivering simulation tools to design engineers is that it does not require a specialist when used as outlined in this paper. If it did, it could only serve as a final validation tool, not as a driver of quality and innovation.

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Despite the fact that upfront simulation offers the benefits of ongoing course corrections before making expensive decisions, many analysis specialists argue that mainstream design simulation is a dangerous proposition. Their concern is that engineers will build "bad" structural analysis models and make "bad" decisions from them. However, this concern is not supported when put in the context of the actual design process at most companies.

Without simulation, an engineer will design a product with decisions based on applicable hand calculations, historical data, or instinct. The product will be built and tested, and it may or may not work. This is accepted practice. But, if simulation is performed, it will be on the very same "gut-feel" design. While a design flaw may be missed or the need for unnecessary corrections assumed, it is unlikely that a good designer will make a radical or counterintuitive change based solely on simulation data.

Regardless of the quality of simulation or results interpretation, the physical test will still bear out the validity of the design. But, with early analysis, the opportunity for insight—perhaps to see stress where no stress was expected or counterintuitive bending—can be invaluable. Exposing an anomaly or poorly understood feature can easily justify the effort.

There is another, more subtle benefit to this process. When design engineers check their individual decisions as they go, they learn why these decisions make sense. They learn why an engineer with 20 years of company experience always puts a rib here or always uses a locking feature. Once engineers know why a decision works, they do not need to question it again.

What business factors ensure successful design simulation?

Once the case has been made for iterative and interactive simulation in the design process, the focus shifts to implementation and process concerns. How can a manager maximize the value of this technology?

Management must support simulation proactively

This means supporting simulation, not merely buying it. Many seats of "shelfware" are being wasted at companies because the directive, whether explicitly stated or implied, is that simulation is a fire-fighting tool, not a mainstream design tool. If a company finds that a simulation product has not worked as expected, management needs to rethink the bigger picture of how it is being used.

Supporting simulation also means working at integrating it into the workflow. Organizations respond to cues from management—most design engineers will not go out of their way to push a technology if they do not believe it has appropriate weight and visibility at upper levels.

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Have realistic expectations and determine measurables

One of the fastest ways to kill a simulation initiative is to place unrealistic expectations on its success. Determine, perhaps with outside expertise, what is expected from simulation and how to measure its progress.

For an initial project, choose an existing product with a solid history for comparing simulated performance to current data. Focus on trend behavior and relative gains from different design options.

Validate all "checkable" decisions

Any given product may have operational data that is difficult to acquire or consumer use that is too unpredictable. There may be system responses that cannot be measured or easily correlated. Such uncertain product aspects may still be best validated through testing. Parameters that are checkable, understandable, and well defined, however, are well suited to simulation. Successful companies identify these factors and make sure that they track them as the design is developed.

Fitting specialists into this business model

There is a difference between design-level simulation and analysis used as an end-stage digital prototyping tool. When all checkable decisions have been verified and a design is ready for prototyping, it may be complex enough to warrant a handoff to a specialist. This person should be able to sift through the volumes of information being generated and make better decisions on what the data is saying, from a pass-fail standpoint.

Specialists also are extremely important as teachers and mentors. The most successful design simulation organizations regularly update the skills of their design teams by using either an internal or external specialist.

Testing remains the final decision-maker for design validity

All companies have a traditional "gate" that serves as the final arbiter of acceptability—this can be testing, specialist review, or design code compliance. Few companies invest heavily enough in simulation technology to replace those gates with a virtual equivalent, as this is truly the domain of specialists. But, with upfront design simulation, the expensive prototype that is either physically or virtually tested will be the most likely to succeed at that point.

Design simulation is more than a glorified "spell-checker"

Finally, do not use simulation as a "spell-checker." Do not settle for a simple "thumbs up" or "thumbs down" response from the simulation, indicating "good enough." The value of the simulation tool is its ability to let designers explore and experiment. Instead of asking whether a decision is good or bad, ask how it can be better or how it can be the best. Insight and innovation are valuable by-products of the simulation process.

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Conclusion

Adding design simulation to the workflow enables companies to get to market faster by helping designers catch mistakes faster, change course, find the right way to approach the problem, and then come up with less expensive products that perform better.

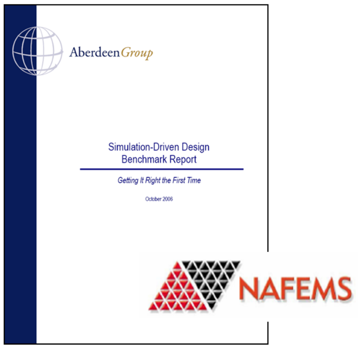
While simulation is traditionally focused on validating the "planned use" of a product, it also adds value in checking for "predictable misuse," such as learning what will happen if a part is twisted or loaded off-center. The decreasing cost for checking more aspects of a model in simulation supports checking more cases of predictable misuse than was ever possible with traditional prototyping methods.

When managers and design team leaders become involved, they gain insight as well. By understanding the basics of simulation technology, they can ask intelligent questions on why the designers set up a problem a certain way or made a particular approximation or assumption.

For companies concerned with being the best in the industry, simulation software is a valuable tool even in the earliest of product development stages. The greatest benefit to simulation technology is the opportunity that it provides to ask questions—lots of them—related to the behavior expected from the products and the environments in which they operate. Simulation software gives design engineers the right tools and the right hardware, at the right time, to make "what if" ideas part of the design process. The result is "Better, Faster, Cheaper."

When your design team is empowered to make better decisions, the end result will be better products—and design simulation is the best tool to make that happen.

The Aberdeen Group conducted an independent study, cosponsored by NAFEMS, an international nonprofit organization that supports simulation quality and education, of companies that use design simulation tools directly integrated into design engineering as a process driver. Consultants concluded that all best-in-class manufacturers use simulation in the design phase, compared to only 75 percent of companies deemed trailing in their industries. Their data showed that using simulation in the design process had an extremely positive impact on the overall profitability of these companies, measured in time-to-market as well as cost.


AberdeenGroup

Simulation-Driven Design
Benchmark Report

Getting It Right the First Time

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