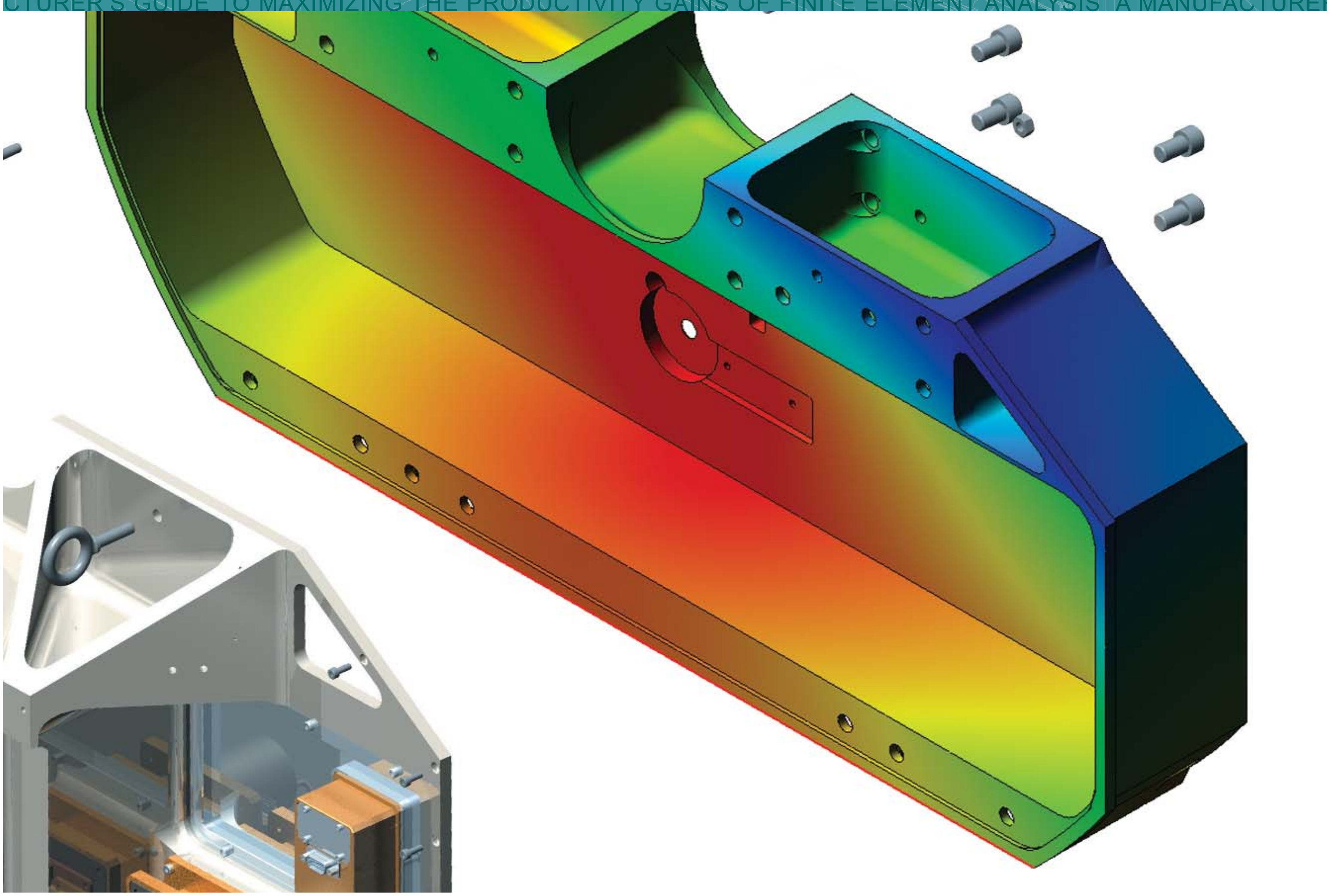
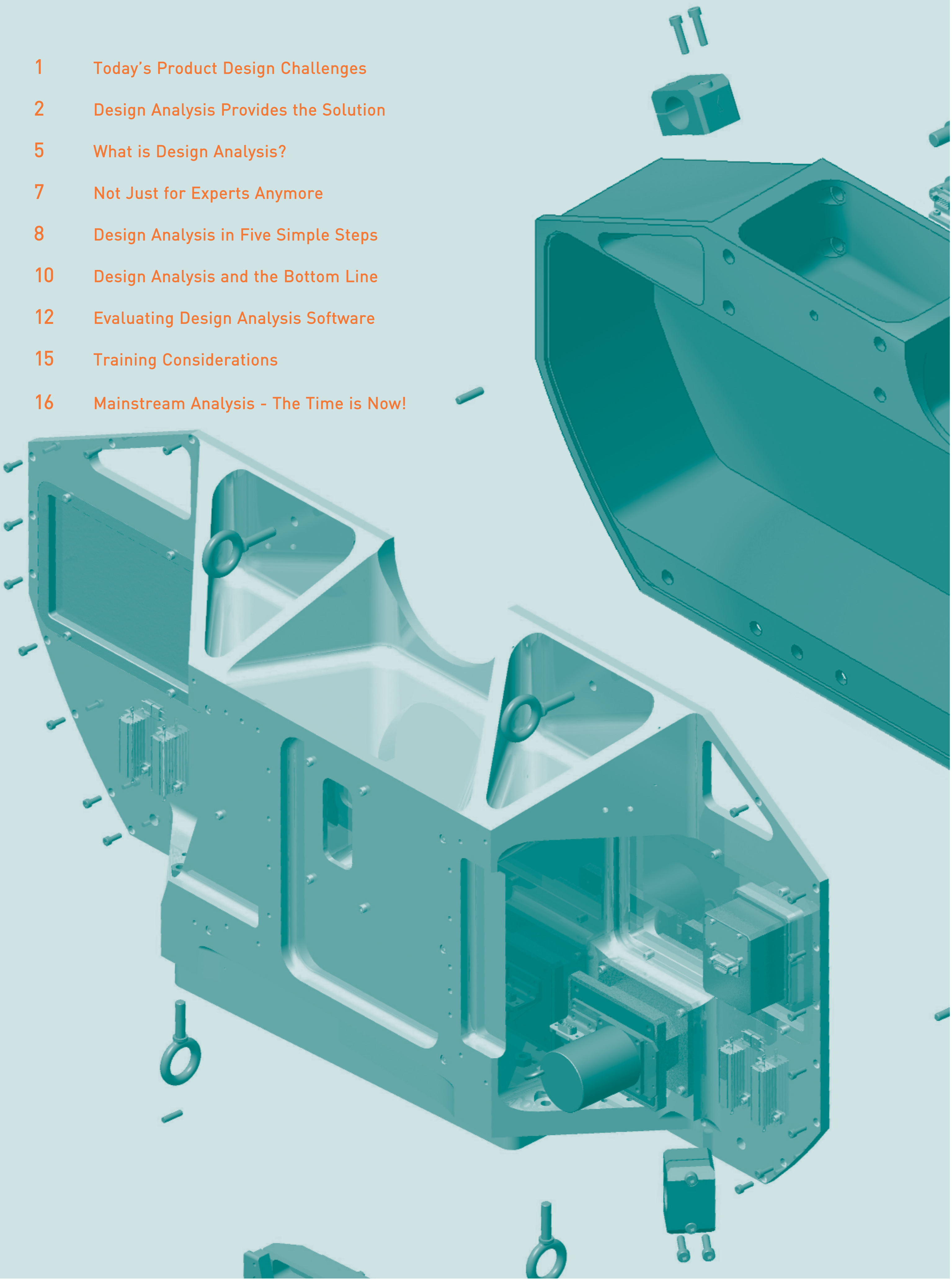
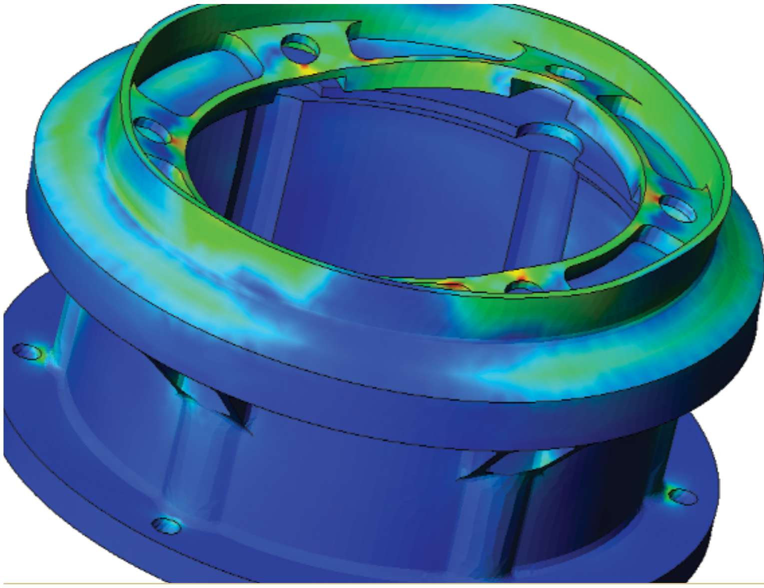
A Manufacturer's Guide to Maximizing the Productivity Gains of Finite Element Analysis (FEA)

going Mainstream Analysis

CTURER'S GUIDE TO MAXIMIZING THE PRODUCTIVITY GAINS OF FINITE ELEMENT ANALYSIS A MANUFACTURER







"Using some of the optimization features, we can typically take 15-20% additional mass out. COSMOS™ is the tool that makes it possible."

Jim Staats, Vice President,
Alliance Spacesystems Inc.

Today's Product Design Challenges

Prototyping Bottlenecks

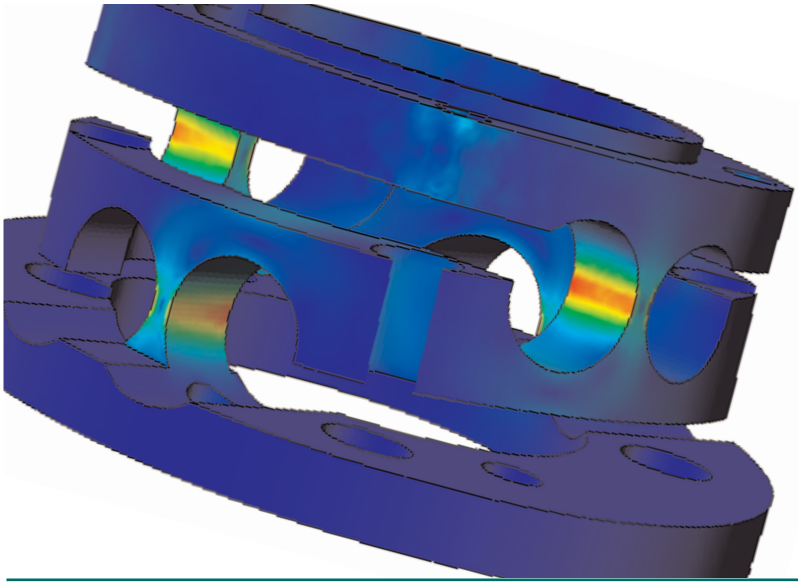
Before a new product goes into production, prototype testing takes place to ensure that the product's performance meets customer expectations. Some tests require only simple physical mockups, while other tests, such as structural integrity tests, may require the production of fully functional physical prototypes.

Fully functional prototypes are expensive, take time to manufacture, and extend product development cycles, especially when numerous prototypes are required. Prototype testing often reveals problems that require design modifications, resulting in the need for additional prototyping and testing to examine the modified design. Typically, several costly design-prototype iterations are necessary before arriving at the final product design.

In the real manufacturing world, the delay and expense related to prototyping and testing often reduce the number of design-prototype-test iterations, which has an adverse impact on product quality. Companies simply cannot afford to build and test the number of prototypes needed to arrive at an optimized design and are willing to accept a design that is "good enough" rather than continuing to optimize the design. Physical prototyping and testing have become major obstacles to successful product development, creating bottlenecks that add costs and extend design cycles, frequently without producing the best possible product design.

Faced with competitive pressures for more innovative, streamlined designs and safer, more reliable products, many manufacturers leverage computer-aided engineering (CAE) technology to simulate prototype-test iterations and optimize designs based on a thorough understanding of the physical behavior of a design. By using mainstream design analysis technology to predict design behavior, engineers can optimize product designs on the computer without building a single prototype.

This guide is designed to help engineers and product developers understand the value of 3D design analysis and to describe how to evaluate and select a design analysis system that provides maximum benefits to the product development process.



"The biggest advantage was time saving over our previous methods. COSMOS is so fast and easy to use that we were able to make the 20 analysis runs that were required to understand the problem and solve it."

Don Bartlett, Senior Staff Engineer,
Fanuc Robotics NA

Design Analysis Provides the Solution

Background

During the early 1990s, the product development process began evolving from the prototype-test approach to a new product development paradigm that is driven by computer-aided design (CAD) technology. Rather than incurring the costs and time delays related to building and testing prototypes, engineers began to analyze computer models of the intended design using the finite element method, better known as finite element analysis (FEA).

Design analysis with FEA is a software technology that engineers use to simulate the physical behavior of a design under specific operating conditions. FEA breaks a solid model down into geometric "elements," which are mathematically represented on the computer as a 3D mesh overlaying and permeating the solid model, to solve differential equations that govern physical phenomena as they apply to simulated geometries. Using FEA, engineers simulate responses of designs to operating forces and use these results to improve design performance, minimizing the need for physical prototypes.

Early design analysis software packages were separate, highly specialized applications that were used for unique and specific simulations that could not be tested effectively with prototypes. Nuclear reactor containment buildings are an example of the early use of design analysis, simulating a testing scenario that was extremely hazardous to duplicate with an actual prototype.

While the benefits of design analysis for all types of product development are obvious, the mainstream, industry-wide shift away from physical prototypes and towards 3D design analysis which began in the mid-1990s continues because of the following important developments:

- 3D solid modeling software became powerful, affordable, and easy to use;
- Design analysis software became powerful, affordable, and accessible to nonspecialists;
- The Microsoft® Windows® operating system enabled the use of CAD and analysis applications on PCs;
- Computer hardware became powerful, affordable, and reliable.

Notice the common themes here: more powerful, easier to use, and less expensive. The computing power of the mainframe computers of the 1980s

Bucyrus International, Inc.

is a global leader in the manufacture of shovels, drills, and draglines for the surface mining industry. By using COSMOS software, Bucyrus® reduced their analysis time by 20% and shortened the design cycle by 25%.

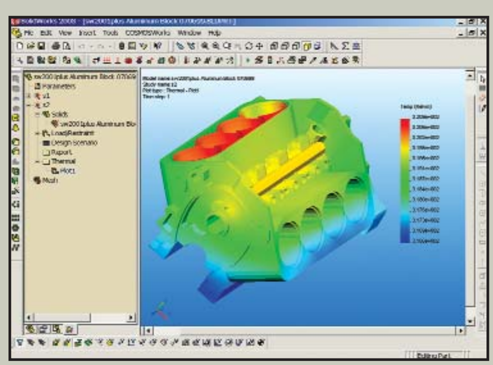
is now available on the desktop at a fraction of the original price. The development of advanced design analysis tools enables manufacturers to take advantage of the availability of affordable computing power and reap the benefits of mainstream design analysis.

Powerful Combination

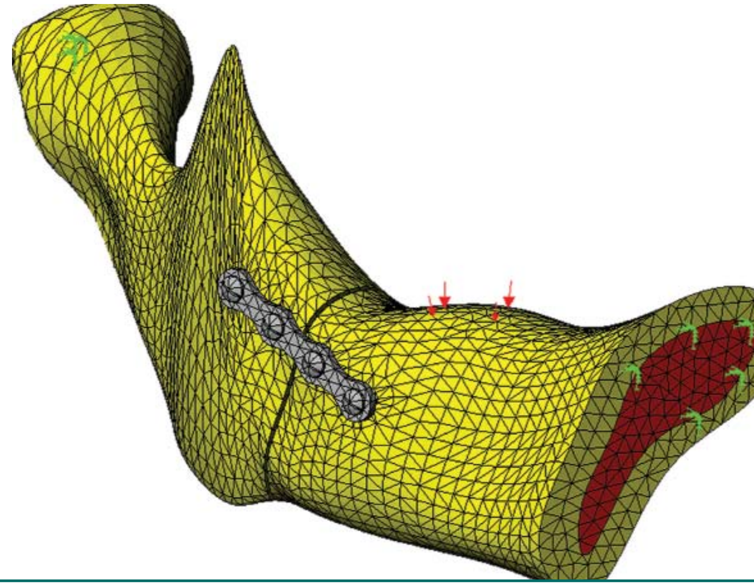
Leveraging the combined powers of 3D solid modeling and design analysis software, engineers can now test a design on the computer instead of using prototype-test iterations for design. CAD models have become virtual prototypes, and design analysis has supplanted physical testing, enabling faster, less costly, and more optimized product development. In addition, computer-based design analysis allows for more in-depth examination of product performance than would ever be possible using even the most detailed prototypes, resulting in more innovative, reliable, and marketable products.

Prototypes vs. Design Analysis

Studies have shown that 80% of a product's manufacturing costs are locked into the approved design, which is why the ability to perform quick and inexpensive design iterations prior to releasing the design has become a critical competitive advantage. Design analysis makes it possible to perform design iterations quickly and inexpensively on computer models instead of on costly physical prototypes. Even if prototyping costs were not important considerations, design analysis provides significant product quality benefits, enabling engineers to detect design problems far sooner than a prototype could be built. Design analysis also facilitates studies of more than one design option and aids in developing optimized designs. Quick and inexpensive analysis often reveals nonintuitive solutions and benefits engineers by providing them with a better understanding of product characteristics.



Single-window integration between CAD and analysis



"To develop a new artificial jaw joint, different model variations were created using different plate/screw materials, and static analysis was performed in COSMOSWorks™ to see how using different materials would affect the stress. "

Tomoaki Kawamoto and Toshio Sugahara, Researchers,
Okayama University, Faculty of Dentistry

If it isn't broken, it still might need fixing

Numerous misconceptions surround the use of design analysis software. Many engineers believe that FEA-based design analysis is esoteric, expensive, and hard to use. Some engineers believe design analysis software requires a Ph.D. to operate, is only used by really big companies, and is unnecessary for the type of work they do. Studies have shown that seven out of ten design engineers using 3D CAD have these impressions.

As a result, many engineers take untested designs straight to prototype or even directly into production, thereby jeopardizing product quality and valuable customer relationships. In other cases, designers simply stay the course by reproducing outdated products, preferring to continue with concepts that have worked in the past instead of striving for innovation and breaking new ground. Their premise is: "If it isn't broken, don't try to fix it." Staying with the status quo can cost a company a lot of money in lost opportunities for introducing higher-quality, more aesthetically pleasing, modern products that more consumers want to buy. Not optimizing product design can increase expenses, for example, the use of excessive amounts of materials, that could be trimmed by implementing design analysis and optimizing designs. Saving just one-tenth of a penny per unit can add up to a sizable sum when a manufacturer produces thousands of units. In other words, even "if it isn't broken, it still might need fixing."

Now that design analysis is fully automated and very affordable - some analysis capabilities are included free as part of some 3D CAD packages - the misconceptions regarding design analysis are fading away as more and more engineers evaluate design analysis tools.

A connecting arm before and after optimization

KryoTech, Inc.,

a manufacturer of innovative cooling systems for personal computers, shortened its design cycle from one year to three months, in part by using COSMOS integrated design analysis inside SolidWorks software.

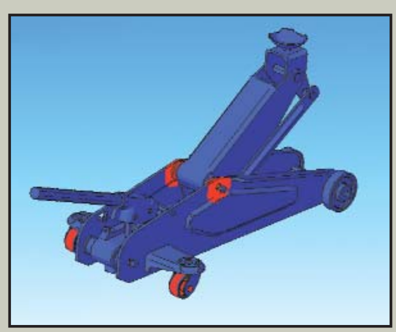
What is Design Analysis?

In its simplest terms, design analysis is a powerful software technology for simulating physical behavior on the computer. Will it break? Will it deform? Will it get too hot? These are the types of questions for which design analysis provides accurate answers. Instead of building a prototype and developing elaborate testing regimens to analyze the physical behavior of a product, engineers can elicit this information quickly and accurately on the computer. Because design analysis can minimize or even eliminate the need for physical prototyping and testing, the technology has gone mainstream in the manufacturing world over the past decade as a valuable product development tool and has become omnipresent in almost all fields of engineering.

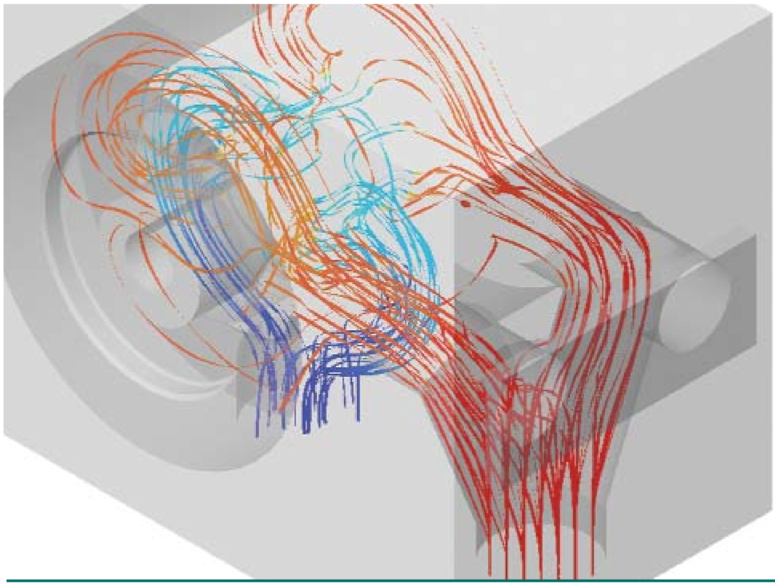
Design Analysis employs the finite element analysis (FEA) method to simulate physical behavior of a product design. The FEA process consists of subdividing all systems into individual components or "elements" whose behavior is easily understood and then reconstructing the original system from these components. This is a natural way of performing analysis in engineering and even in other analytical fields, such as economics. For example, a control arm on a car suspension is one continuous shape.

An analysis application will test the control arm by dividing the geometry into 'elements,' analyzing them, then simulating what happens between the elements. The application displays the results as color-coded 3D images, red usually denoting an area of failure, and blue denoting areas that maintain their integrity under the load applied.

Engineers use design analysis for just about every type of product development and research effort imaginable. Analyzing machine designs, injection-molded plastics, cooling systems, products that emit electromagnetic fields, and systems that are influenced by fluid dynamics are just some examples of how companies leverage design analysis.



In this picture red zones indicate potential failure



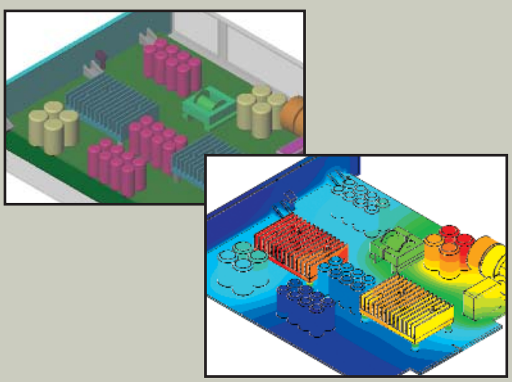
"With some software programs, you just know that you are benefiting. I would say that COSMOS has definitely paid for itself ten times over."

Steve Massey, Mechanical Engineer,
Sturman Industries

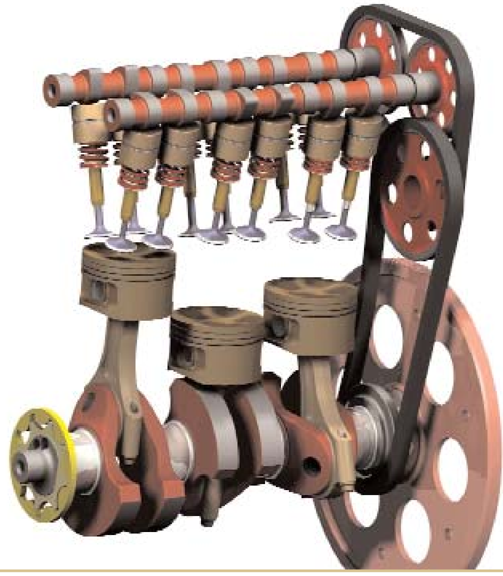
In the field of mechanical engineering, design analysis can solve a wide range of product development problems. Engineers can use design analysis to predict the physical behavior of just about any part or assembly under any loading conditions: from a simple beam under a bending load to car crash simulations and vibration analysi's of aircraft. The true power of design analysis is the ability to perform any of these types of studies accurately without building a single thing. All that is needed is a CAD model.

The most common design analysis application in the field of mechanical engineering is stress analysis. Engineers study the stresses (both structural and thermal) on a part to determine whether it will fail or not and whether design modifications are necessary to overcome potential problems. Design analysis is also used to determine the potential for deformation of parts, resonant frequencies and modes of vibration of parts and assemblies, dynamic and seismic responses, contact stresses, and temperature distribution, to list a few. Design analysis is also used to analyze fluid flow, whether it be a gas or liquid in a pipeline, the mixture of air and fuel in an engine intake manifold, or molten plastic filling up a mold.

Besides working very closly with CAD packages, commercial design analysis applications also interface with increasingly popular programs for motion analysis to create complete virtual analysis and test systems. In other engineering disciplines, design analysis is used successfully to study electromagnetic fields, soil mechanics, groundwater flow, bone growth, etc.



COSMOSFloWorks™ was used to model air flow through this circuit board environment



Steve Prentice Design Limited

is an automotive consulting firm using COSMOS software for first pass analysis. In 18 months, we have completed more concept projects than ever before, taking them to a greater level of definition in less time than customers believed possible.

Not Just for Experts Anymore

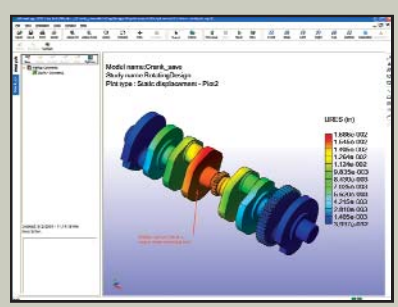
Design analysis provides the greatest benefits when implemented very early in the design cycle because that's when it is easiest and most cost-effective to make design changes. When analysis is performed in conjunction with solid modeling, design engineers can leverage analysis results to fix, improve, or optimize designs.

For many years, design analysis was the exclusive domain of highly specialized analysts, who would analyze models after a design engineer had finished his or her work. This approach resulted in a lot of wasted time related to the back-and-forth interaction between designers and analysts, especially when solid models had to be recreated in a separate analysis package.

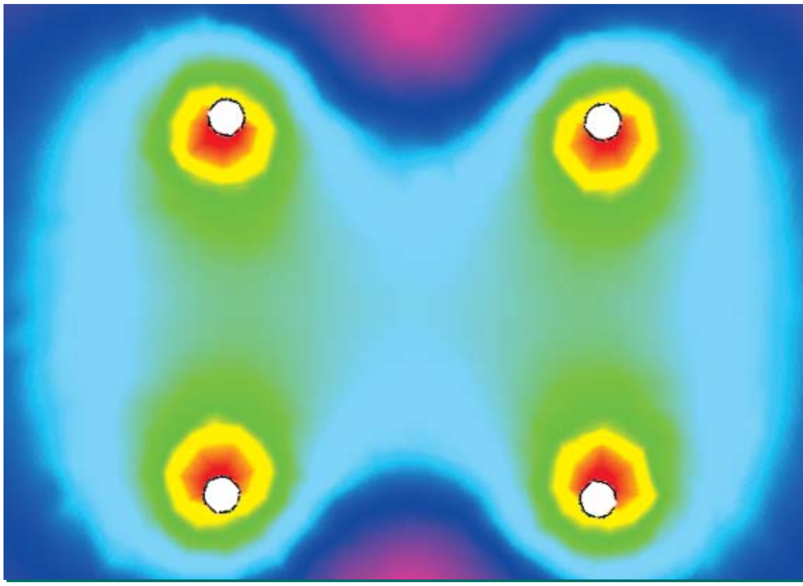
But in recent years, the benefits of using design analysis as part of conceptual design have become apparent. When properly trained to use today's modern, integrated analysis systems, design engineers are better positioned than analysts to leverage analysis results to modify solid models as design iterations progress. The direct involvement of design engineers in analyzing their own designs allows for quick turnaround times and ensures that design modifications indicated by analysis results are promptly implemented in the design progress.

In many ways, design analysis technology is helping to blur the lines of demarcation among traditional engineering organizations. While drafting, designing, and analyzing product designs were traditionally separate tasks executed by different people, the availability of powerful, easy-to-use, and affordable CAD and design analysis software has fostered a greater sense of collaboration among all engineering functions.

Analysts continue to play an important role by conducting the more advanced and time-consuming types of analysis.



Users can communicate analysis results with other members of the design teams with tools such as SolidWorks eDrawings



“With COSMOS the time-savings are so dramatic they are, in a sense, unquantifiable. We can change geometry and complete the analysis within a half hour. If we had to do these three-dimensional calculations by hand, it would take days.”

Chris Andre, Mechanical Engineer,
Genetronics

Design Analysis in Five Simple Steps

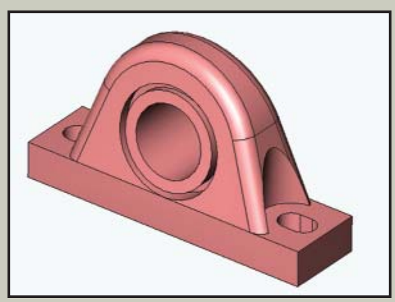
This bracket provides a simple example of how design analysis is used. The design of this bracket has just been completed, and we are ready to make production drawings based on the CAD model.

However, we are not sure if the bracket is going to be strong enough to withstand service loads without excessive deformations and stresses. Production deadlines are approaching and we are almost over budget, so we need answers quickly and inexpensively. Design analysis can give us these answers using nothing more than our original CAD model and an analysis package.

With an integrated design analysis system, we can conduct the analysis directly on our solid model without ever leaving our CAD package. Once we have our geometry, we can set up the model, run the analysis, and analyze the results in a few easy steps.

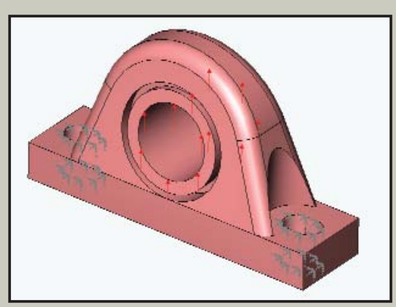
Step 1

First, we define and assign material properties to the model.



Step 2

Next, we apply the proper loads and supports that represent real-life loading conditions.

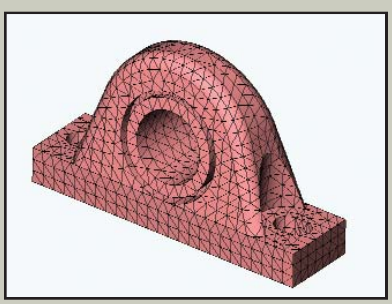


True Technologies

is an audio engineering consulting firm. Faced with a part that was failing after only 20 minutes of use, they turned to analysis for help. Once the part was optimized in COS-MOS, it operated for more than 1,000 hours without failure, even when the power was increased 50%.

Step 3

Now, we mesh the geometry. Meshing is basically splitting the geometry into small, simply shaped pieces called finite elements. Design analysis uses finite elements to calculate our model's response to our indicated loading conditions. Meshing is done automatically with little, if any, need for user intervention.

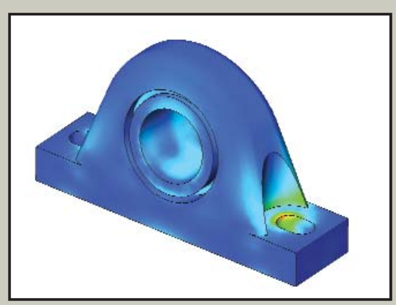


Step 4

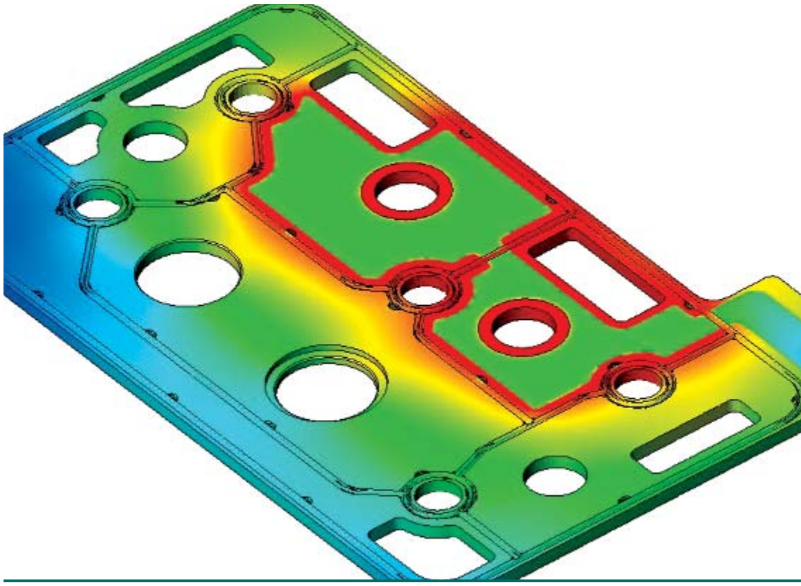
After the model is meshed, the analysis solution proceeds. This step is entirely automated with no user intervention necessary.

Step 5

Once our solution is complete, we can analyze the results. Of course, the results depend on the type of analysis performed. In our case, we were interested in structural properties like deflections and stresses. We can also use design analysis to evaluate resonant frequencies, temperature distribution, or structural response to dynamic loads.



Our analysis results will either verify the function of our design or show us where we have problems that require design modifications to achieve the required quality, stress level, natural frequency, etc. With integrated analysis packages, design modifications can easily be performed on the same CAD model that we used for the initial analysis.



"Using COSMOSWorks means that we can run calculations on the various design approaches during the design stage easily and quickly. We can then compare them against one another."

Karsten Hoffman, Project Leader,
Dräger Medical

Design Analysis and the Bottom Line

Using analysis as a design tool produces higher quality products faster and at lower cost. Obtaining these benefits, of course, requires an investment in purchasing design analysis software and in training users. New hardware is typically unnecessary because existing CAD workstations are generally adequate for running analysis software.

The actual return on investment (ROI) that a company realizes from implementing design analysis software depends on the company's analysis needs, the specific analysis package selected, how the analysis software is implemented, and the amount of training conducted.

In many cases, the cost of the analysis software and training is recovered during the first year of implementation.

Return on Investment (ROI)

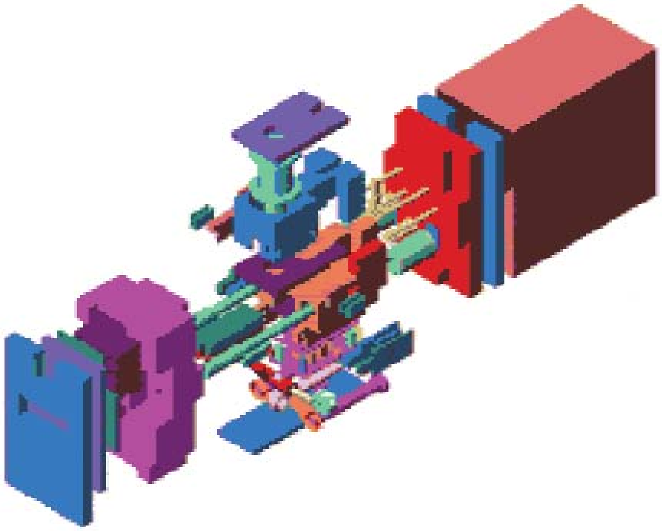
Although a comprehensive ROI assessment prior to implementing 3D design analysis is useful for planning purposes, simple calculations based on easily quantified metrics also provide useful insights. Here's one example from the field of automotive engineering.

The cost of prototyping and testing simple parts such as an engine bracket, pulley, or door hardware can easily run from $10,000 to $20,000 and these steps take several weeks to complete. Compare that expense to the cost of a single license of integrated design analysis software and user training, and it's plain to see how design analysis software can benefit a company.

Analysis results can be produced in a matter of hours in most instances, an important competitive advantage for all manufacturing companies. Cost reduction benefits from using design analysis instead of traditional prototyping/testing are even greater when complex parts and products are involved.

For complex parts, prototyping/testing costs can easily run into hundreds of thousands of dollars and can take several months to complete. While an ROI calculation can capture easily quantifiable cost-savings, there are additional benefits that are more difficult to quantify, such as the ability to analyze multiple design configurations, the potential for reducing warranty costs, and the impact of improved product quality overall.

ROI will differ in each individual case, and companies should also consider the penalty costs associated with not using design analysis for product development. Clearly, the cost and product quality benefits associated with using design analysis as part of product development can result in substantial returns on a company's investment in design analysis software.

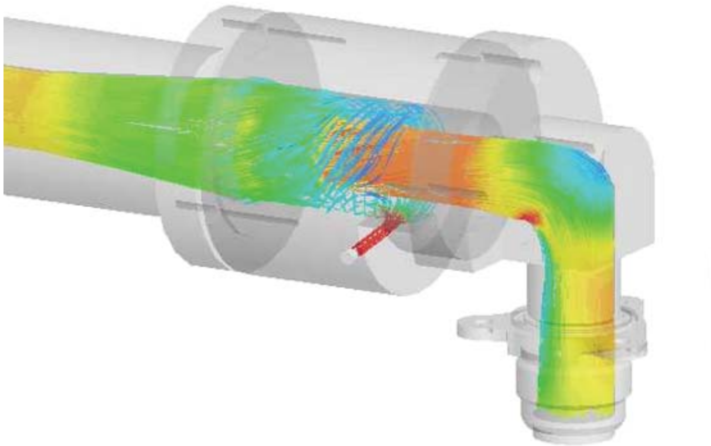


SANDIA National Laboratories

spent five months of effort and only achieved 90% completion with a competitive analysis product. After switching to COSMOS, SANDIA National Laboratories was able to analyze a very detailed solid model consisting of 306 parts in just one week.

Cost Savings from Faster Time-to-Market	
Size of engineering and design team	5
Average fully loaded salary (includes variable overhead)	$65,000
Time-to-market improvement using COSMOS analysis	30%
Annual time savings from increased productivity (in man-hours)	3000
Annual cost savings from improved time-to-market	$97,500
Cost Savings from Improved Product Quality	
Annual cost of field failures	$100,000
Reduction in field failures from using COSMOS analysis	20%
Annual cost savings from reducing field failures	$20,000
Annual cost of product recalls	$10,000
Reduction in recalls from using COSMOS analysis	15%
Annual cost savings from reducing recalls	$1,500
Total cost savings from improved product quality	$21,500
Cost Savings from Reducing Prototypes and Physical Tests	
Annual cost of prototypes	$150,000
Reduction in prototypes from using COSMOS analysis	32%
Annual cost savings from reducing prototypes	$48,000
Annual cost of physical tests	$175,000
Reduction in physical tests from using COSMOS analysis	23%
Annual cost savings from reducing physical tests	$40,250
Total cost savings from improved product quality	$88,250
Increased Profit from Faster Time-to-Market and Increased Quality	
Annual revenue	$20,000,000
Average profit margin	8%
Increased sales from higher quality products	3%
Annual profit increase from higher quality products	$48,000
Increased sales from faster time-to-market	5%
Annual profit increase from higher quality products	$80,000
Total profit increase from faster time-to-market and increased quality	$128,000

Summary of Savings and Increased Profit	
Annual cost savings from faster time-to-market	$97,500
Annual cost savings from improved product quality	$21,500
Annual cost savings from reducing prototypes and physical tests	$88,250
Annual increased profit from faster time-to-market and Increased quality	$128,000
Discount rate	15%
Annual financial benefit from COSMOS analysis software	$335,250
Three year financial benefit from COSMOS, net present value	$880,269
Total Cost of Ownership (TCO)	
Assumed first year total cost (including license, hardware, training, support, installation, management, etc.) per seat	($10,000)
Assumed annual cost after first year (including upgrades, support, additional training, etc.) per seat	($3,000)
Number of seats purchased	5
TCO for first year for all seats	($50,000)
TCO over three year period for all seats, net present value	($74,386)
Return on Investment (ROI)	
Total ROI for first year	$285,250
ROI for first three years, net present value	$805,883



> "There is no doubt that COSMOS helped us to reduce our project design time. When we began the project, we had estimated that it would take a total of eight months. By using COSMOS, we saved two full months of development work."
>
> David Rachels, Engineer,
> Purolator-Facet

Evaluating Design Analysis Software

There are many different design analysis programs on the market. How should manufacturing companies go about evaluating and selecting the analysis package that is best suited for use as a design tool? Which design analysis package will produce the highest return on investment when implemented in the design process?

There are several important issues to consider when evaluating and choosing design analysis software:

Design analysis packages should be integrated with CAD systems. While it is possible to exchange information between CAD and analysis packages through neutral files like GES or STEP, this method is time consuming, unpredictable, prone to error, and offers no bidirectional associativity between CAD and analysis models. A direct interface between the two is the best option.

An integrated design analysis package functions well only if the CAD software is a feature-based, parametric, fully associative solid modeler. These types of CAD systems enable design engineers to temporarily suppress unimportant geometric features without permanently deleting them and to easily examine different design configurations by taking advantage of the parametric nature of the CAD model.

In a truly integrated system, the CAD software becomes the host for the analysis application. This not only allows for quick design analysis iterations, but substantially reduces training time because all geometry functions (generally, the most time-consuming part of design analysis) are performed in the already familiar CAD package.

Design analysis software should be easy to use, but should also include capabilities for user intervention. Integrated design analysis software should provide user control over meshing, type and order of elements, idealization scheme and the desired solution method. While the default choices offered by advanced design analysis software are acceptable in most cases, the user should be able to control specific analysis tasks if intervention becomes necessary or desired.

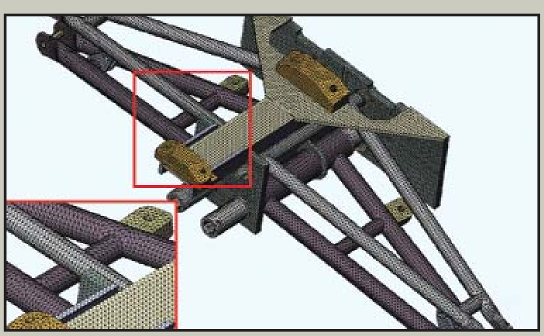
Design analysis software should have a good automesher and a fast solver. The quality of the finite element mesh is essential for producing accurate analysis results and a fast solver is important for producing analysis results in a timely fashion. Having both a good mesher and a fast solver reduces or eliminates the need for geometry preparation prior to meshing. Even large CAD models mesh and solve quickly with fast automeshers and fast solvers.

Xportation Safety Concepts,

a developer of innovative safety systems, uses COSMOS to analyze the design of its new airbag-safe infant seat for use in the front seat of automobiles, allowing it to exceed the stringent safety seat impact standards.

Design analysis software should handle most of the common types of analysis. How powerful should the analysis system be in terms of capabilities? Engineers are sometimes tempted to select an analysis package that can handle all possible types of analysis, just in case the need arises one day.

High-end analysis packages perform well in the hands of a highly trained analyst, but perform poorly when used concurrently with CAD during the product development process. Rather than selecting the most powerful analysis software available, manufacturers should look for the package that addresses the majority of their needs in the best possible manner.



Mesh of front suspension of snowmobile.

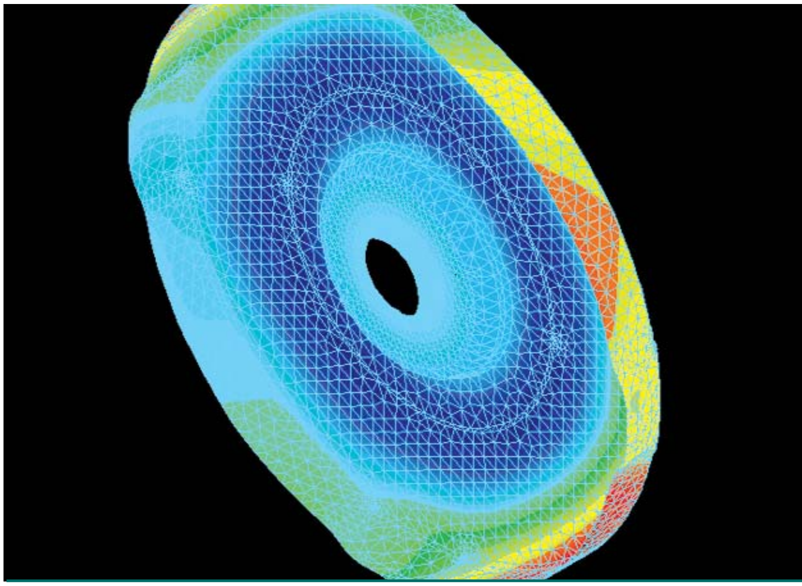
The analysis types performed in most concurrent design analysis processes include:

- Linear stress analysis
- Contact stress analysis
- Frequency model analysis
- Steady-state thermal analysis
- Buckling analysis

Integrated design analysis systems should support these types of analysis with the option to add more advanced analysis capabilities later. Chances are that even if an occasional project may require more advanced types of analysis, such as nonlinear or dynamic analysis, the analysis will be too complex for a design engineer to implement the design process.

It is wise to place complex analysis into the hands of a trained analyst. When more advanced analysis becomes necessary, integrated design analysis packages facilitate data exchange between design engineers and analysts without the need for model reconstruction or translation. Thus, an integrated design analysis package should ideally be a subset of a larger analysis program.

Design analysis software should also incorporate tools for communicating design intent to the rest of the product development organization. Analysis packages should have effective tools for presenting results in a clear and concise manner. Automatic



“COSMOS helped me see that there were two viable solutions: doubling the thickness or designing a ring dent. It was less costly to double the thickness of the material, so that was the solution I chose.”

Tao You, Engineer,
Fleetguard, Inc.

generation of reports and results should make analysis findings accessible to anybody with standard office environment software without having to use the analysis software itself. Result files should be created in standard graphic formats, such as .html for Internet graphics and .avi for animated plots.

Analysis expertise and resources should be available and accessible to users. Does the design analysis package provide access to online help systems, telephone technical support, and users groups and consultants independent from the software vendor?

The final consideration when evaluating and selecting a design analysis system is the cost. Design analysis software should not be overly expensive, either in terms of licensing costs, the cost of implementation, or training costs. However, the price tag alone should not be the only consideration. Many times, the cost of buying inappropriate software far outweighs the savings realized on the purchase price.

There's also projected ROI to consider. A package that's a little more expensive just might produce higher cost-savings that make up for the higher cost many times over.

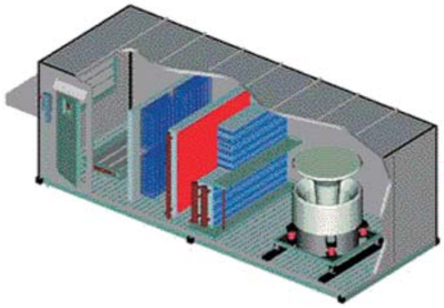
In summary, when evaluating and selecting a design analysis system, consider the following:

The CAD system should be:

- A feature-based, parametric, fully associative solid modeler
- Able to create all geometry for CAD and analysis functions
- Able to move between design and analysis models while keeping geometries linked

The design analysis package should be:

- Integrated with a feature-based, parametric, fully associative solid modeler
- Designed to minimize the need for user involvement with specific analysis tasks but offer tools to control analysis tasks when necessary
- Packaged with an advanced mesher and a choice of fast solvers
- Able to handle all common types of analysis, such as static, frequency, buckling contact, and thermal
- Scalable to high-end analysis packages for analysts
- Packaged with tools for communicating with the rest of the product development organization
- Capable of providing good user support
- Reasonably priced



Cambridgeport Air Systems

replaced three physical prototypes by using analysis, saving an estimated $5,000-$6,000. "COSMOS not only proves that designs will work, but it also helps our engineers reveal errors in designs and fix them before they would ever show up during manufacturing or testing."

Training Considerations

Preparing and training design engineers to reap the benefits of design analysis is just as important as selecting the right package for a manufacturer's needs. Design engineers generally need to conduct only simple types of analysis and today's integrated design analysis packages make FEA theory completely transparent to the user. Most design engineers possess the requisite knowledge to use design analysis from their engineering background.

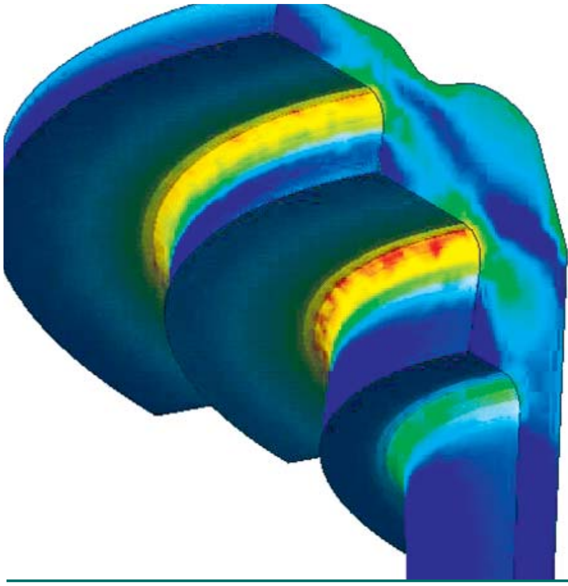
The amount of analysis training required for a design engineer to begin productive work should be a matter of days, not weeks or months. The key element in effective analysis training is providing users with a solid conceptual understanding of analysis fundamentals, such as major assumptions, limitations, and inherent errors as well as common mistakes, traps, and misconceptions.

The analysis training course should employ a hands-on computer approach so participants can benefit from the synergy produced by acquiring software skills while becoming familiar with analysis theory. Too much of an emphasis on "how to run the software" may overshadow more important issues related to analysis fundamentals and give the impression that familiarity with the software equals analysis expertise. Industry experience indicates that users who know the fundamentals of analysis can easily figure out how to operate software, but acquiring software operational skills does not necessarily lead to a full understanding of analysis.

In summary, design analysis training should:

- Focus on a conceptual understanding of analysis
- Avoid too much software-specific content at the expense of analysis basics
- Use hands-on analysis examples with a progressing level of complexity
- Employ examples that utilize CAD models
- Combine theory with hands-on examples
- Use integrated design analysis software while stressing the differences between the two technologies
- Follow up later with software-specific training

While focused training on the proper use of analysis can make a good design engineer even better, the opposite can actually make them dangerous. Effective training makes all the difference.



> "By looking at the parts using COSMOS, we were able to hit our target weight, strength, and safety factors. We've improved our engine reliability substantially using FEA software on our components."
>
> John Calhoun, Engineer,
> Robert Yates Racing

Mainstream Analysis - The Time is Now!

Mainstream Analysis

Integrating mainstream analysis into the design cycle is an important step for manufacturers. Many companies, including the COSMOS customers referenced throughout this guide, have already made this transition, reaping business, engineering, and productivity benefits in the process.

Today's rapid advances in computer hardware and software technology create an ideal opportunity for manufacturers to incorporate analysis into their design process. As discussed throughout this guide, the basic steps for adding analysis involve:

- Understanding how analysis provides the solution for many product design challenges
- Recognizing that analysis tools have evolved, becoming more streamlined and easy for non specialists to use
- Evaluating analysis tools thoroughly based on capability and need

By following these steps, manufacturing organizations can maximize the benefits of using mainstream analysis in mechanical design. In the process, most manufacturers realize increased sales and revenue and improved product quality and reliability.

To find out more about how COSMOS customers have benefited from "Going Mainstream Analysis," see the customer case studies published on the COSMOS web site (www.cosmosm.com).

Firms that Benefit from COSMOS Analysis Products

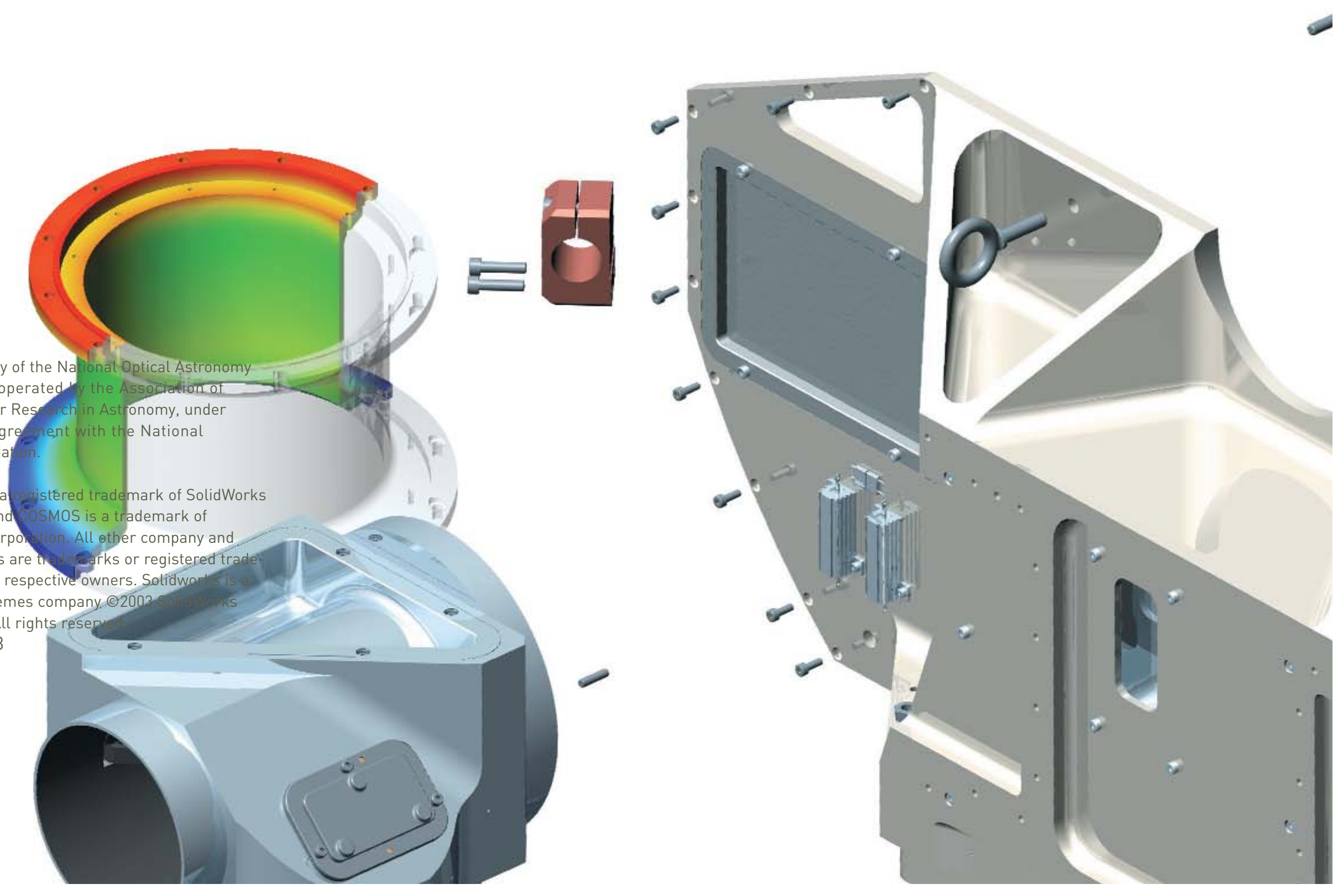
Acme Electric Aerospace Division | Adams Rite Aerospace | Aerocontrolex Group | Aerojet GE Corp. | Aerospace Corporation | Aerospace Industrial Development Corporation | ArmorWorks, Inc. | Avionics Specialties | Axsys Technology | BAE Systems | BF Goodrich Aerospace | Ceradyne Inc. | Dreesecode Software | Eagle Picher Technologies | Eaton Aeroquip | Electroimpact | Fairchild Fasteners | Fluid Components International | Fluid Regulators Corporation | Foster-Miller | Frontier Systems | Hartwell Corp. | Honeywell International Inc. | Huck International | Inbis Technology Ltd. | Industria | Innovative Engineering | Kaiser Electronics | Lawrence Livermore National Lab | Leigh Aerosystems Corp. | Lifeport Inc. | Litton Guidance & Control Systems | Lockheed Martin | Maestranza Aerea De Madrid | Mason Electric Co. | MHD Instruments | Michigan Aerospace | Mide Technology Corp | NASA Ames Research Center | NASA Dryden Flight Research Center | NASA Glen Research Center | National Aerospace Laboratories | Pacific Design Technologies, Inc. | Parker Hannifin Corp. | Pratt & Whitney | Reynolds, Smith & Hills Inc. | Sandia National Laboratories | Scaled Composites | Smiths Aerospace | Stage III Technologies | Technology Research Institute | Tecstar, Inc. | TRW Space & Electronics Group | Unison Industries | Universal Aerospace | Woodward FST | Wyle Laboratories | Advanced Integrated Manufacturing | American Expedition Vehicles | AP Racing | Autoliv North America | Automation Tooling Systems | Automotive Systems Laboratory Inc | Balcrank Products | Branick Industries, Inc. | Breed Technologies, Inc. | Casco Products Corp. | Castrol North America | Champion Laboratories, Inc. | Composite Group | D&R Technology Dechellis Machine | Delphi Packard Electric Systems | DSM Engineering | Epilog | Fey | Automotive | Ford Rvt Visteon | General Motors | Gentex Corp | GM Powertrain | Grove Design | GRP Connecting Rods | Hartwell Corp. | Honda R&D | Honeywell Co., Ltd. | Immersion Corp. | Impco Technologies, CA | International Rectifier, Ca | Johnson Controls Laser-tronics | Lear Corporation | Litens Automotive Group | Lund Industries | Maxon Lift | MSX International | Nordson Corporation | Norgren Automotive, Inc. | Olin Brass | Performance Accessories | Power Trax | Raetech Corp. | Roush Technologies | Solakian Plastics | Spectra Premium Industries | Teleflex I Turbodyne Systems Inc. | Tuthill Transport Technologies | Ultra Dyne | Visteon Automotive Steering | Volkswagen de Mexico | Wetherill Assoc., Inc. | Wynn Oil Co. | Yakima Products, Inc. | Yazaki Europe Ltd. | Adaptive Micro Systems | Amerock | B. Braun Medical | Bainbridge Networks | Berliner Wasserbetriebe | Brill Manitoba | Bristol Babcock | Columbus-McKinnon Corporation | Cybex International, Inc. | Datastrip Products, Inc. | Delta Hudson Engineering, Ltd. | Diamondback Fitness | Dorma Door Controls, Inc. | Easton Sports Composites | Eldon Design Associates, Inc. | Electronic Sensor Technology | Enersys Inc. | Eveready Battery | First Alert | Flex Products, Inc. | GE Lighting | Glad Manufacturing Company | GT Bicycles | Hewlett Packard | Hitachi Corp. | Icon Health and Fitness Inc. | Interlink Technologies | JBL Professional | Johnson Outdoor | Kimberly Clark Corporation | Klein Bicycle | Klipsch Inc | Konica Corporation | Life Fitness Products | Lockheed Martin | Lucent Technologies | Masonite International | Matsushita Air Conditioning | McKee Foods Corp. | Medeco Security Locks | Milwaukee Electric Tool Corp. | Motorola Incorporated | Nautilus Schwinn Fitness | NEC Machinery | Philips Medical Systems | Polaris | Polaroid Corporation | Procter & Gamble | Raytech Corporation | Rockford Corp | Smith & Wesson | Sony Wega GmbH | Spectra Logic | Stairmaster | Tality Inc. | Waterpik Technologies | Waupaca Elevator | Western Digital | ABB Switchgear | Aerovironment Inc. | Alden Products | American Power Conversion | American Water Heater Co. | Andis Company | Andrew Corp. | Anvik Corp | AVO International | Basler Electric | Battelle Memorial Institute | Chattanooga Group | Chromalox | Crouse-Hinds Div. Of Cooper | Daka Development Ltd. | Dynetics | Everbrite | Excellon Automation | Frazer-Nash Research LTD. | Greene, Tweed & Company, Inc. | Hansen Corporation | Heatrex Wescon Ind. | Hendry Telephone Products | IAP Research, Inc. | Interconnect Devices Inc. | Intermatic Inc. | Inventas AS | Jakel Inc. | Johnson Electric Industrial Manufactory Ltd. | JST Corporation | Kaman Aerospace Corp. | Kubota Corporation | LG Industrial Systems | MacLean Power Systems | MAEC Cahors | Marathon Electric | Marlow Industries | MBM Technology | Microvision | Milwaukee Electric Tool | Motile | Nxtphase | Pacific Scientific Co. | Petron Industries | Philips Oral Heathcare (Optiva) | Samtec, Inc. | Senco Products | Silicon Bandwidth, Inc. | SL Montevideo Technology | Southwire Co. (Wire And Cable Div.) | Star Trac By Unisen | Stratagene Cloning Systems | Subsea Mudlift Drilling Company, LLC | Toshiba Intl Corp. | Trinton PLC | Universal Power Track | XiDEM Corporation | Alum-A-Lift | American Meter Co. | Amtech | Applied Materials | Ashbrook Corporation | Australian Submarine Corp. | Automatic Systems, Inc. | Baker Oil

SolidWorks Corporation
COSMOS Analysis Products
12121 Wilshire Blvd. Suite 700
Los Angeles, CA 90025 USA
Phone: +1-800-469-7287
Outside the U.S.: +1-310-207-2800
Fax: +1-310-207-7805
Email: cosmosinfo@solidworks.com
www.cosmosm.com

SolidWorks Europe
Phone: +33 4 42 15 03 85
Fax: +33 4 42 75 31 94
Email: info@solidworks-europe.com

SolidWorks Asia/Pacific
Phone: +65 6866 3885
Fax: +65 6866 3838
Email: info@solidworks-ap.com

ANUFACTURER'S GUIDE TO MAXIMIZING THE PRODUCTIVITY GAINS OF FINITE ELEMENT ANALYSIS A MANUFAC



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