SIEMENS

Siemens PLM Software

FEA for all engineers

White Paper

Siemens PLM Software delivers advanced CAE technologies for engineers at SMB-level companies.

www.siemens.com/plm

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Executive summary

SMB manufacturers (small- to medium-sized businesses with revenues between $7 and $700M) are seizing the opportunity to improve their product design and development processes through investments in CAE (computer-aided engineering) or FEA (finite element analysis) applications, according to AMR Research. Introducing CAE in this way effectively brings product design and engineering closer together and reduces the number of required physical prototypes, which can drastically shorten cycle times and reduce costs. This allows manufacturers to bring their products to market more quickly and better meet their customers' requirements.

Engineers and engineering analysts can now work more closely together, sharing the same design model data and bringing higher-quality products to market sooner. Siemens PLM Software delivers an integrated engineering environment of world-class product lifecycle management (PLM) capabilities that include CAD (computer-aided design), CAM (computer-aided manufacturing), PDM (product data management) as well as CAE.

SMBs are being challenged, like large corporations, to grow a product from design to manufacturing as quickly as possible, without compromising quality, at a profit. There are several factors that manufacturers need to take into consideration including design for easiest manufacturability, material selection, size, shape, weight, stress, operational performance, durability and cost. Optimizing these constraints while allowing manufacturers to continue to be competitive is now possible. Siemens provides scalable simulation capabilities including Solid Edge® Simulation, a CAD embedded solution for design engineers and Femap™ with NX™ Nastran, a standalone solution for engineering analysts who require more advanced analysis techniques.

Twenty years ago, draftsmen and CAD users did not have the knowledge, training or tools to be able analyze how the parts they were designing would perform in their operating environment. Since then digital simulation and the integration of CAD and CAE have come a long way. CAD-embedded CAE tools allow simulation to be performed much earlier in the design cycle when design ideas are still being tried out. The ability of design engineers to experiment digitally with the design by performing what-if studies quickly and easily fosters innovation. At a later stage in the design process, it's often necessary to conduct more specialized analyses to ensure that the design will perform as expected in its operating environment, and this may require access to different types of solutions. Manufacturers that employ both approaches during the design process are more likely to arrive at a viable design the first time, which can often reduce the physical testing down to just one prototype.

The solution is to bring design and analysis closer together using the same design model data, allowing both early simulation by the design engineer when the design is still in flux, as well as more in-depth studies by the engineering analyst to ensure the design will not fail. Both approaches are key to shortening the design-analysis cycle and bringing higher-quality products to market sooner with less overall cost.

Introduction – FEA for all engineers

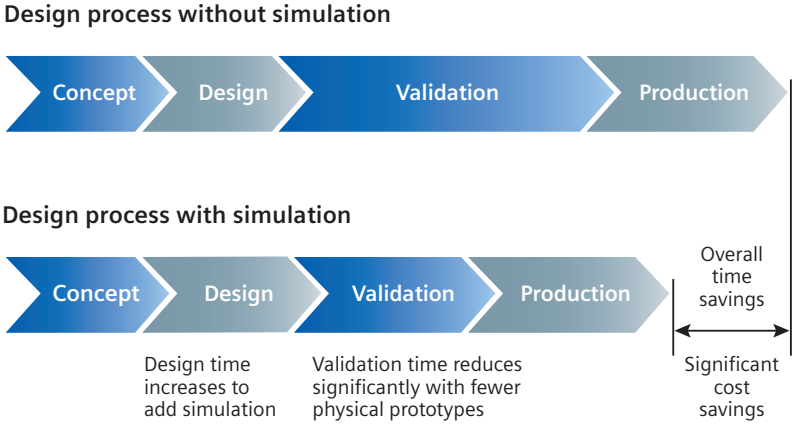
Over the past two decades, advancements in computing hardware and software have made the notion of product life-cycle management possible through effective integration of CAD and CAE. Mergers and acquisitions of large engineering companies plus the growth of mid-sized manufacturing businesses and worldwide outsourcing have significantly increased the competitive climate, creating the need for SMBs to invest in digital simulation tools. Engineering analysis tools, which once were only available to large engineering enterprises, are now accessible by mid-sized manufacturing businesses – but they can no longer afford not to utilize them.

SMBs, mid-sized companies with revenue between $7 and $700M, can now effectively compete with larger companies that command superior resources. In the past, CAD and CAE systems were used only by large engineering firms that could afford the hefty price tag associated with owning or leasing the software. Today, PLM software and the hardware required to run it are more affordable to SMBs, and the return on investment can be significant. Previously in large engineering firms, CAD was performed by full-time design engineers and CAE by full-time engineering analysts, who were gurus of their respective disparate realms. At the same time, small- to mid-size companies had to rely on drawing boards, hand calculations, and physical prototyping and testing. Today's engineers have more exposure to CAD and CAE technologies and are highly capable of performing stress, natural frequency, and other basic engineering analyses, particularly important early in the design process. Engineers with specialized analysis skills are still required for in-depth studies, but all engineers, in any size company, can have cost-effective access to easy-to-use engineering tools that are either embedded or associated with the CAD system. They also now have the added capability of complete product data management.

With the integration of CAE, finite element analysis can be performed during the design process, closing the design-analysis gap, minimizing design iterations, and almost eliminating the need for physical prototyping and testing. FEA allows engineers to effectively simulate the operating characteristics of their designs digitally, well in advance of prototype tooling. Countless dollars can be saved by identifying design problems before entering into the manufacturing process.

> "The mechanical applications market has finally entered a healthy growth phase in all application areas. Product data management tools will continue to lead the way, with computer-aided design and computer-aided engineering tools also experiencing solid growth during the next five years."

Laurie Balch, Gartner Group
"Market Trends: Me



Speeding up time-to-market by using virtual testing instead of physical prototypes for design validation.

The business challenges facing SMBs today

SMBs must efficiently utilize their resources not only to be profitable, but to be able to fight off competitive pressures and grow. Time is money. Inefficiency results in lower profits or missed opportunities. Inefficient use of time and resources results in waste, whether it stems from missed schedules, not meeting customer requirements, or quality issues relating to rework, warranty or legal concerns.

"Hedging against uncertainties about their financial prospects, manufacturers are aligning IT investments across three business scenarios. These include cost management, incremental growth and innovation."

Geraldine Cruz, Gartner Group
"Market Trends: Manufacturing, United States, 2004-2005"
19 November 2004

SMBs, like larger corporations, face the same business drivers such as development time compression, reduced product cost/price expectations, overhead cost reductions and demands for improved product quality and longer service life. These drivers can have a great effect on profitability.

"Small- and mid-size businesses (SMBs) have to deal with many of the same issues as their larger counterparts when designing and launching new products. In fact, small rarely implies less complexity. In many cases, these manufacturers are in specialty businesses that tackle complex designs that larger customers are not capable of handling."

Michael Burkett, David O'Brien, AMR Research
UGS Thinks Big About Midmarket PLM
September 2005

The effect of global competition and outsourcing is also putting pressure on SMBs, forcing them to review how they do business.

SMBs involved in a supply chain are seeing the effects of changing working relationships with larger businesses, with OEMs passing design and warranty responsibilities down to tier suppliers. This is forcing suppliers to come up with their own designs and analyzing those designs themselves, and in essence, having to do more in less time for the same or lower cost.

In 2004, AMR Research reported that the SMB (mid-market) is the fastest growing segment in the PLM marketplace with an expected growth rate in CAE of 12 to 16 percent annually. Not only is the number of SMBs growing worldwide, they are aggressively investing in PLM (including FEA) to become more competitive.

> "The real value of simulation in aerospace is that you could not do what we're currently doing without it. Typical program schedules that used to take 5 years are now done in 2 years or 1 year. In our opinion, Femap is one of the best solutions on the market, and it's very easy to use."

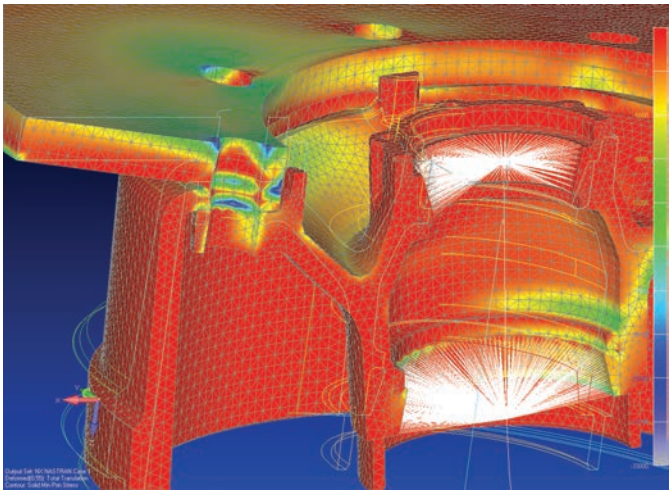
Chris Flanigan, Quartus Engineering
www.quartus.com

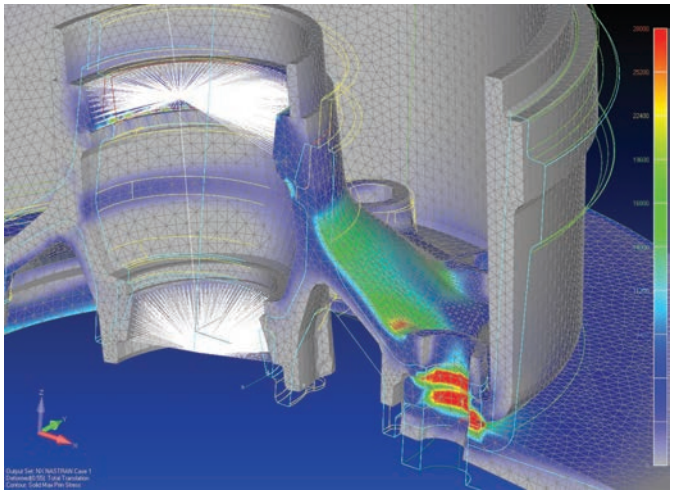
The solution is to invest in fully integrated PLM systems where both designers and engineers can easily use FEA to eliminate poor designs digitally, early in the design-analysis process.

Analysis model of SpaceShipOne.

Why FEA?

CAD has been accepted by SMBs for several years as a key to competitive product design. As SMBs increasingly become responsible for the design, analysis, manufacture and warranty of the products they develop, their need to utilize FEA to be cost-efficient also increases. The design-analysis phase of product development is key in determining whether or not the product design will perform as required, meet customer expectations and reduce warranty claims. In addition, customers are expecting shortened product delivery times. Therefore, SMBs need to add simulation to their product development processes in order to meet their product quality and delivery commitments. Performing simulation early in the design phase will help SMBs innovate more, reach feasible designs earlier and also reduce design and analysis rework. Developing more feasible designs early and validating them virtually will also reduce the number of physical prototypes that have to be built and tested, yielding significant time and cost savings. FEA allows SMBs to experiment with designs digitally, leading to greater innovation, better designs and reduced risk.





Finite element model of a brake drum assembly.

"For the cost of two individual brake drum tests, I can buy Femap with NX Nastran and do countless computer studies. These studies give insight into the behavior of the parts that we produce. This allows us to meet our customers' expectations for lighter weight products, cost reductions (lighter is cheaper) and improved performance. Our customers are engineers, and they look to finite element analysis as part of the design verification."

"There is an adage, 'measure twice, cut once'. In the mechanical engineering world, we use Femap with NX Nastran to calculate twice so we only test once. This pays off in time-to-market, lower costs and safer products on the roads. In today's global market, we're as likely to see our wheel components in the Outback of Australia as we are on an 'out n' back' to the neighborhood grocery store. We must design our products with care and Femap with NX Nastran plays a big role in helping us do that."

Joe Brotherton, Director of Product Development
KIC Holdings
www.kic-group.com

What is FEA?

FEA is an engineering computational analysis methodology that helps to determine the strength of a product (part or assembly) in response to loading that might typically be experienced in its operating environment. It can also help determine why parts have failed.

FEA simulates the behavior of a real component or assembly with an idealized mathematical model (or finite element model) representation including the physical conditions (loads and boundary conditions) in which it operates. The finite element model is then analyzed by a finite element analysis solver, which calculates results data that reflect the design behavior to the applied boundary conditions, and can help to identify weaknesses or potential failures in the design.

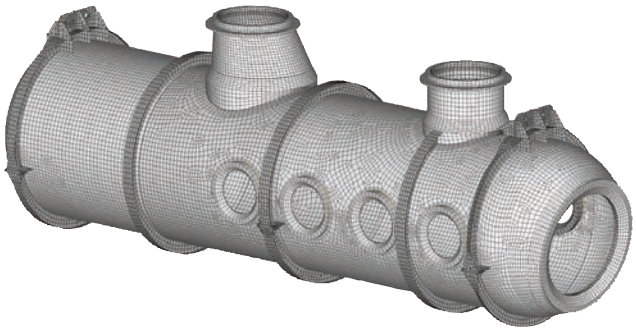
Finite element analysis allows engineers to get an in-depth understanding of all of the non-operating and operating characteristics of the products they develop from several points of view including the geometric shape, materials used, physical constraints and loading conditions. Product characteristics including stress, normal modes (natural frequencies of vibration) and buckling loads can be calculated and form the basis on which the product response within its operating environment can be understood. Other, more complex, product characteristics can be determined with more advanced types of analyses including dynamic response, thermal response, acoustic response, contact, motion and other multi-physics environments. These more complicated analyses require engineering analysts with more specialized analysis skills and are typically performed later in the design phase in lieu of physical testing.

Where does FEA fit in the development process?

Today, FEA fits in both the design engineer's and engineering analyst's process. Early in the design process, FEA plays an important role in promoting innovation through the ability to digitally experiment with the design. In order to do this, the simulation functionality must be presented in an environment that is familiar to the design engineer, that of the CAD system itself which is possible with an embedded FEA solution. Besides ease of use, other aspects help to bring FEA closer to CAD including model associativity that allows the design's analytical properties, such as geometry topology, material properties, loads and boundary conditions inherent in the CAD model, to also carry over to the finite element analysis model. Therefore, any changes made to the CAD model will carry through and update the analysis model automatically. Also with embedded FEA post analysis, the CAD system's geometry manipulation tools can be used to make any necessary model refinements quickly and easily – in the case of Solid Edge, synchronous technology can be leveraged.

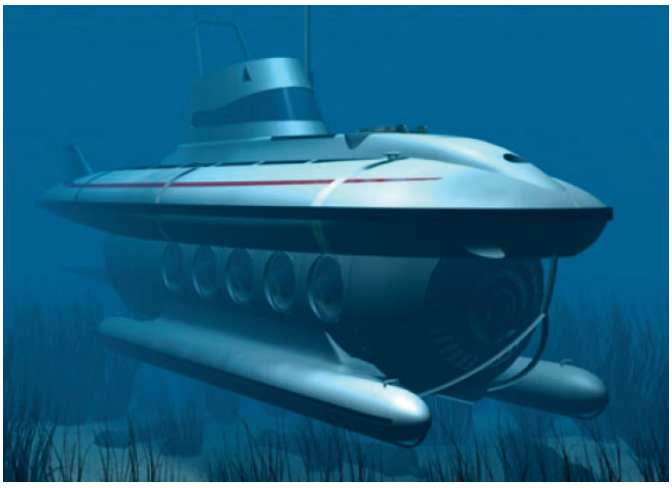
When it comes to performing the more advanced detailed simulation a greater FEA, expertise is generally required and performed by more experienced engineering analysts. The FEA software employed needs to have a much greater exposure to finite element model definition and requires a more specialized approach. Easy access to CAD data is still essential. However the greater level of functionality required usually demands a more specific toolset and environment, with access to various types of solver to cover the applicable types of physics.

Design engineers, who have some exposure to CAE, need to work in the CAD environment and cover all of the basic analyses early in the design cycle, to gain an understanding of the problem, firm up the design itself and determine the best solution according to their knowledge. The design engineer can then pass the basic solution to the engineering analyst for more in-depth studies that demand more advanced types of physics. The engineering analyst might double-check or verify that the preliminary analysis has been satisfactorily completed before proceeding, but doesn't necessarily have to repeat that preliminary analysis. The engineering analyst needs to focus on more advanced analyses – which may include heat transfer, fluid, dynamic response, nonlinear analyses or motion dynamics. As a rule of thumb, today's design engineers can handle roughly 80 percent of the required engineering analyses, leaving 20 percent to the engineering specialist for more advanced investigations.



"What makes Femap unique is that it is independent. It doesn't have a particular solver preference and it isn't aligned with a particular CAD program. It supports them all. And when you need to create your own geometry from scratch, that's where Femap really shines. Femap is an engineer's pre- and postprocessor. When engineers need to get real results, accurately and competently, they use Femap. It's industrial-strength and stable."

George Laird, President, Predictive Engineering www.predictiveengineering.com



Custom submarine designed and analyzed for recreational use.

Siemens PLM Software's solution

Siemens PLM Software's focus on CAE and the mid-market manufacturing enterprise has resulted in the industry's first comprehensive, preconfigured offering that combines digital product design (Solid Edge), analysis (Solid Edge Simulation and Femap with NX Nastran), manufacturing (Solid Edge CAM Express), and data management (Teamcenter® with Rapid Start) software in one package from one vendor – also allowing for connectivity to other CAD geometries and analysis solver technologies. For simulation, Siemens offers a scalable portfolio of FEA solutions with two levels capability based on end user requirements.

Solid Edge Simulation is a mid-range simulation capability embedded inside Solid Edge. This provides an intuitive, easy-to-use engineering analysis environment that accesses the industry-standard NX Nastran solver for stress, normal modes and buckling analyses, delivering fast and accurate results. Solid Edge Simulation is the key component that is focused on bringing analysis closer to the design process and is intended to make FEA more accessible and easier to use by both occasional users and experts, while maintaining the integrity of the both the CAD model and the analysis.

Forming a scalable and comprehensive CAE solution, Femap offers in-depth finite element modeling functionality that allows access to advanced analysis solutions, such as dynamic response, nonlinear, and heat transfer analysis. Femap is also highly-integrated with all versions of NASTRAN, the industry's leading FEA solver technology, and in particular NX Nastran. Femap offers a native Windows user interface and file associativity with Solid Edge, which further enhances general usability and productivity.

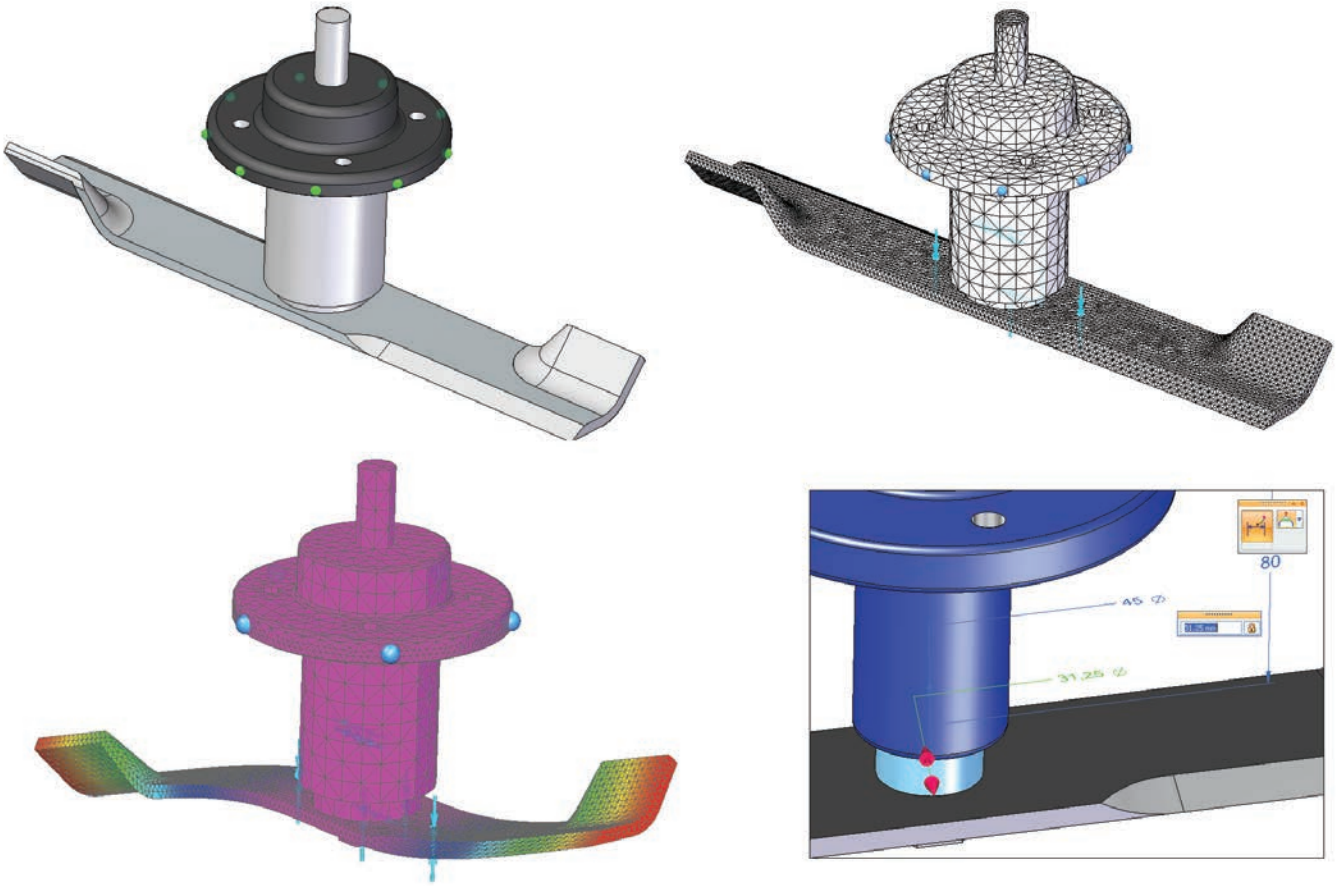
Both Solid Edge Simulation and Femap deliver pre- and post-processing capabilities that provide the ability to update and improve product designs based on the analysis results.

Siemens FEA capabilities and benefits

In general, the Siemens package of FEA solutions is affordable, easy-to-use, easy-to-implement and provides a low total cost of ownership. SMBs will appreciate what Solid Edge Simulation and Femap with NX Nastran can do for their design-analysis process.

The CAE portfolio of solutions provides a scalable solution to extend a company's analysis needs when necessary. While Femap is CAD indepdendent, it offers direct file associativity with Solid Edge and supports all major commercial solvers and all versions of NASTRAN. Femap and Solid Edge Simulation were designed with all engineers in mind – both the design engineer and the engineering analyst – and support the most common FE modeling analysis needs as well as more advanced highly-specific analysis types. With both products, the CAE portfolio offers a built-in upgrade path allowing for expanded analysis capabilities as business and simulation needs expand.

Solid Edge Simulation is an embedded CAE solution inside Solid Edge that is based on Femap finite element modeling technology and uses the industry-standard NX Nastran solver. With Solid Edge Simulation, it's possible to analyze parts and assemblies and obtain results due to a static loading, find the natural frequencies of vibration or determine buckling loads. Solid Edge Simulation provides a full complement of load and constraint definitions, with meshing control, and comprehensive postprocessing functionality to

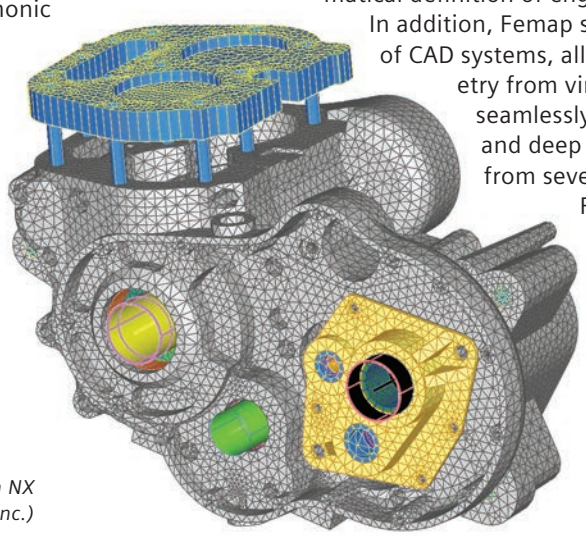


From CAD assembly to FE model, results and model refinement using Solid Edge Simulation.

understand the behavior of the design quickly and efficiently. For post analysis, users can take advantage of Solid Edge synchronous technology to make any necessary order-free design refinements (not possible in typical history-based CAD systems) quickly and easily.

Femap with NX Nastran combines two of the world's most popular and powerful structural analysis programs for simulating product performance characteristics of structures and mechanical components. As such, Femap combined with NX Nastran provides a very cost effective Windows-native CAE solution that combines Femap widely used pre- and postprocessing capabilities with the well known and respected analysis capabilities of NX Nastran.

Based upon a 15-year history of working closely with Nastran solvers, Femap seamlessly integrates with NX Nastran. It directly supports a broad range of NX Nastran capabilities, including linear and nonlinear statics, normal modes, transient/dynamic and frequency/harmonic response, response spectrum, random response, buckling and rotor dynamics. There are also additional NX Nastran options available for aeroelasticity, superelements, optimization, DMAP and advanced nonlinear. Femap with NX Nastran provides a comprehensive range of detailed functionality to directly define and control all aspects of finite element modeling, NX Nastran solutions and subsequent post processing operations.



Motorcycle engine analysis using Femap with NX Nastran. (courtesy of Predictive Engineering Inc.)

Femap open technologies are Windows-based, making them readily accessible. This not only provides a high degree of familiarity for the majority of users, but it also ensures that Femap brings powerful digital simulation directly to the engineer's desktop easily and affordably.

A market-leading component of Siemens PLM Software, Femap provides an independent backbone to a number of other well known and industry respected CAD and CAE solver products.

Femap is based on an advanced set of open technologies that enable it to work simply and easily within customer engineering simulation environments. Femap leverages Parasolid® software, a widely accepted solid modeling kernel used in CAD/CAM/CAE systems to create and edit the mathematical definition of engineering parts and assemblies. In addition, Femap supports a number of other types of CAD systems, allowing it to interface with geometry from virtually any source, directly and seamlessly. Femap also works with a broad and deep range of finite element solutions from several types of solvers. This makes Femap a very logical and flexible solution that is simply tailored for even the most demanding customer needs.

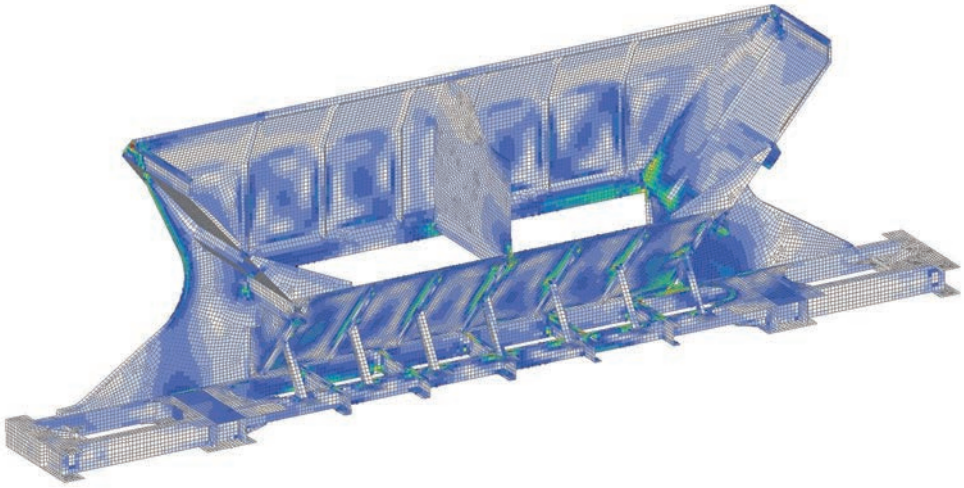
Conclusion

SMB manufacturing and engineering companies fail to utilize the latest PLM technologies are foregoing a competitive advantage. SMBs face challenges that can be mitigated with the strategic use of Siemens PLM Software's Solid Edge Simulation and Femap with NX Nastran. By bringing product design closer to engineering, time to manufacturing can be reduced, product quality maximized and profitability increased.

Twenty years ago, design engineers did not have the knowledge, training or tools to analyze their designs. Today's analysts and engineers no longer have to build separate finite element models based on their CAD files in order to run FEA analyses. Solid Edge Simulation is an FEA application embedded inside Solid Edge that allows CAD and commonly used FEA technologies to work together within a single familiar user interface, giving engineers the liberty of digital design experimentation. When they need to run complex, high-end analyses, analysts are able to do more in-depth analysis with Femap.

Siemens PLM Software has been helping large manufacturing companies to be successful in the automotive, aerospace, shipbuilding, electronics and other industries for more than 35 years. SMBs can now take advantage of what Siemens PLM Software has learned from serving these large manufacturing businesses. Siemens PLM Software has a comprehensive PLM solution to the engineering issues facing manufacturing SMBs that helps them become more competitive and profitable.

Consider investing in Siemens PLM Software's FEA portfolio with Solid Edge, Solid Edge Simulation, Femap with NX Nastran, Solid Edge CAM Express and Teamcenter with Rapid Start today. Contact a Siemens PLM Software sales representative for more information and a demonstration.



Analysis of a bulk cargo wagon using Femap with NX Nastran. (courtesy of Cideon Engineering GmbH)

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About Siemens PLM Software

Siemens PLM Software, a business unit of the Siemens Industry Automation Division, is a world-leading provider of product lifecycle management (PLM) software, systems and services with nine million licensed seats and 77,000 customers worldwide. Headquartered in Plano, Texas, Siemens PLM Software helps thousands of companies make great products by optimizing their lifecycle processes, from planning and development through manufacturing and support. Our HD-PLM vision is to give everyone involved in making a product the information they need, when they need it, to make the smartest decisions. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

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