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Leveraging the Design Chain

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In the product development process at most mid-sized and large companies, designs are defined in an engineering department and passed along in serial fashion (i.e., "thrown over the wall") to other design chain groups, each with an important perspective and insight into how the product should be configured. Manufacturing may find a faster, less costly way to fasten a housing to a frame, for example. Or marketing might want a more ergonomically contoured handle. Any suggested improvements or problems along the way send the design back to engineering.

Changes are made. The configuration is updated. The cycle is repeated until the individual requirements of these different groups in the design chain are satisfied and the product rolls out the door.

The time and cost of making these changes increases significantly with each step of the development cycle, with delays and expense escalating tremendously if problems crop up on production lines, for example. Moreover, designs are generally far less than optimal, with quick-fix changes solving isolated problems but usually detracting from the overall design. Components may be grossly over-designed with needless weight and bulk, for example, to strengthen failed assemblies.

Virtual prototyping and up-front analysis are aimed at identifying and correcting performance problems early in design with computer modeling and simulation. And getting the input of everyone in the design chain early in development was the goal of a variety of movements such as simultaneous engineering, concurrent engineering, and most recently collaborative engineering.

Major Challenges of Team-Based Development

One of the huge challenges in implementing these types of team-based approaches is balancing all the many diverse, often-competing variables working at cross-purposes to one another. A component must meet minimum strength requirements yet be as lightweight as possible, for example. Or an assembly must be configured to be as compact as possible yet allow easy access to internal parts. Variables can be dimensional as well as those relating to materials, resonance, heat flow, weight, cost or a variety of other parameters. A product might involve these competing requirements, all of which are important and cannot be overlooked.

Engineers have at their disposal robust tools for design, simulation, and virtual prototyping to define and evaluate product configurations, of course. For the most part, however, these solutions can handle only a limited number of variables at the same time. Thus, users have the tedious and time-consuming task of performing multiple design-simulation cycles as they attempt to satisfy all the requirements.

One of the most frustrating aspects of such cycles, however, is that optimizing the design for one variable often adversely affects the configuration according to other variables. Minimizing weight and resulting material costs could lower durability, for example. Or decreasing part thickness might make an assembly susceptible to damaging resonant vibration. Engineers can go back-and-forth in a seemingly endless loop trying unsuccessfully to satisfy multiple requirements with individually performed simulations.

Schedules, deadlines and time restrictions typically make this back-and-forth approach impractical. In most cases, the design is based on a few key variables while the rest are held constant at some minimally acceptable values. The approach results in a design that works but is usually far less than optimal in meeting multiple variables. This defeats the primary objective of team-based development: configuring the product to optimally meet the multiple, often-competing requirements of everyone in the design chain.

Mechanical Design Synthesis

A variety of technologies are coming together in providing a new class of tool that automatically optimizes designs based on multiple variables. In these solutions, numerous iterative simulations are automatically performed based on boundary conditions and ranges of variables entered by the user. Design of experiments (DOE) technology generates simulation response curves based on various sampling and statistical methods, including probabilistic design and Monte Carlo simulation, for example.

Mechanical design synthesis is a next-generation solution combining these optimization technologies with CAE simulation methods and parametric CAD into an integrated solution. These types of tools find that optimal part dimensions for resonant frequency is below a certain level, for example, or weight and stress are minimized.

One of the first commercially available solutions of this type, DesignXplorer® from ANSYS, Inc., has a slider bar for each key variable allowing users to interact dynamically with the model, changing parameters and seeing how this affects the overall design. Feedback is immediate, so engineers can run through multiple 'what-if' scenarios that would otherwise be too time consuming to perform with conventional tools.

The underlying mathematics of the solution do not limit the number of variables to be considered, so factors such as manufacturability and other issues can be taken into account which otherwise would wait until after the design was completed. Users can study, quantify and graph various structural and thermal performance simulation responses as a function of design parameters for parts as well as assemblies. Bi-directional associativity with CAD packages allows designs generated through the system to be translated immediately into solid models.

Because of this speed and interactivity, performance simulation iterations can be done to match the rapid pace of parametric CAD iterations. Product teams can thus use the tool to make informed decisions earlier in the design process when concepts are just starting to take shape by exploring various product configurations, evaluating different part geometries and materials, and examining design tradeoffs.

Collaboration engine technology built into DesignXplorer serves as middleware, enabling multiple people across a design chain to efficiently work together on a project, either simultaneously or off-line at their convenience. This capability is especially useful in coordinating up-front development efforts across the design chain. Implementing the solution in this manner is especially valuable in companies where product development teams are dispersed among different facilities, and often, different partner and supplier companies. In this way, mechanical design synthesis serves as a valuable decision-support tool for engineers in determining the best direction for product development in the early stages of the cycle.

Hitting the Mark in Product Development

One of the most straightforward benefits of using mechanical design synthesis is a reduction in product development time. The technology allows companies not just to work incrementally faster in getting products out the door but rather to re-orient product development processes in dramatically accelerating the development cycle.

At General Motors, for example, vehicle development relies heavily on multi-variable optimization methods that cascade down from full-vehicle simulations to variations in individual components. Through the use of these types of up-front math models, product development efficiency improved 50%, cost savings exceeded $10 billion, and vehicle development time was compressed by 18 months.

Engineering consulting firm Vulcanworks, Inc has developed their proprietary Advanced Engineering Environment system based on mechanical design synthesis and the ANSYS Workbench Environment to automate routine, repetitive tasks in evaluating the influence of many different variables. Significant timesavings have been seen in projects such as automotive suspensions, engine components, steering assemblies, and body structures. In the redesign of an automotive frame structure to lengthen the wheelbase and raise occupant seating, for example, 720 person-days (12 people for 12 weeks) were required to complete the project compared to only 6 person-days (2 people for 3 days) using automated mechanical design synthesis. Similarly, work on a suspension system that takes 60 person-days using conventional methods was done in only 2 person-days.

Beyond product development time compression, a far-reaching business benefit of mechanical design synthesis is a lowering of the risk of product failure in the market by enabling all members of the design chain to participate in product development early in the cycle. This greatly reduces the chances of a new product totally missing what customers want, need, or are willing to pay for a product. Some industry observers estimate that 35% to 50% of newly launched products miss their target markets, thereby failing to make revenue projections and falling short of business plan expectations. Such lack of success, even in a single product line, can have a huge negative impact on corporate profits, and in some cases, can threaten the survival of companies trying desperately to hang on in the face of fierce competition and a continuing economic slump. Mechanical design synthesis provides a way to take advantage of the talent, expertise and experience of diverse groups in the design chain to satisfy all their requirements, and thus, increase the chances of a product's success in the market.

"Broadly and fundamentally, there is a major trend to involve the entire product development community up-front, early in the design effort - not just design and engineering, but production and tooling, quality, marketing and sales as well," explains Don Brown, president of the consulting firm D.H. Brown Associates. "Rather than trying to hurriedly develop a design that merely works and occupies space, initiatives strive to concentrate first on basic design requirements. In other words, what customers expect in the end product. The collective experience of the group - the good, bad, beautiful, or ugly - must be considered early in the life and context of the particular product. Then, a whole parameterized system can be assembled to address the full range of performance issues and tradeoffs."

Voice of the Customer

Capturing the many aspects customer demands and expectations – know as the "voice of the customer"– is no simple task, of course, and requires the efforts of many different groups in the manufacturing enterprise, according to Dr. Howard Crabb, president and CEO of consulting firm Interactive Computer Engineering. He authored the book T*he Virtual Engineer: 21st Century Product Development* and spent more than 30 years at Ford Motor Company, where he led initiatives to implement solid modeling and predictive engineering performed at the concept level of design.

Crabb explains that marketing actives in such organizations now include not only promotion and sales efforts to launch a product, but also up-front initiatives at the beginning of product development to provide input on customer purchase preferences and buying trends. Much of this information can be obtained from direct experience with customers, interviews, competitive benchmarking, focus groups and quality function deployment (QFD) studies. Likewise, other groups such as product support and customer service can provide valuable feedback on what customers want. Indeed, collaborative input from many different groups in the enterprise and supply chain is often necessary to factor in all the important customer requirements and balance the numerous, often-conflicting attributes of a winning product.

"In a broad sense, the most successful manufacturers include people and technology from across the enterprise to add value and strategic impact in product development," says Crabb. "Each group contributes a unique, distinctive competency, with decision-making vested in cross-functional teams in the best position to use their expertise and most current information to determine what product attributes will work best in the market. Such design chains are absolutely critical in product development, because no one individual or group can possibly have all the answers. It's got to be a collaborative effort."

No longer can information on performance, trends, operations and other issues reside statically within individual departments or be gathered after the fact into historical archive reports, notes Crabb. Translating market demands and customer needs into a final product requires efficient information sharing across the enterprise and into the product development process, especially in the early stages of design where the input can have the greatest impact.

"Product development today extends far beyond the walls of the engineering department, even beyond the individual factory walls," Crabb explains. "In a globally competitive environment where one lost opportunity can sound the death knell for an entire company, basing customer-focused designs on input from groups throughout the extended enterprise and getting those products to market fast become overriding determinants of whether a company thrives, survives or dies."

Who's on the Team?

Norman Reilly, author of *Team Based Product Development*, echoes the importance of the multidisciplinary team in product development. "Teams are important because nobody knows everything," says Reilly. "Well-organized corporate-wide teams can substantially reduce the amount of time devoted to all aspects of the complete product development process. They also significantly enhance the probability that the final product meets intended expectations."

According to Reilly, teams deliver these benefits because they provide an interdisciplinary knowledge base that includes expertise in engineering and design as well as marketing, finance, procurement, production, logistics support, costing, scheduling, customer support, quality, and testing. He also notes that customers and suppliers should be included: anyone needed to support a complete picture of a successful end-to-end product development process.

"In the product development setting," explains Reilly, "the interdisciplinary team approach contributes substantially to accuracy and completeness, reduces errors of omission, enables the execution of concurrent strategies, reduces surprises, reduces risk, enhances the thoroughness and consistency of the review process, breaks down organizational barriers, saves time through organized and cooperative focus on the right issues in the right sequence, substantially contributes to getting to market faster, and promotes pride of ownership in outcome."

Reilly cites an example of cross-functional design-for-manufacturability teams at Cadillac made up of representatives from engineering, manufacturing, suppliers, finance, and the autoworkers' union. These teams led to simpler design, ease of assembly, and reduction in variation. Among the results, customer problems dropped 70%, reliability and durability improved 65%, and lead-time was shortened by one year.

Design Chains in the Extended Enterprise

Product development efforts are expanding to include organizations beyond companies' traditional boundaries: suppliers, partners, co-developers, and others that together comprise the extended enterprise. A growing number of products in many industries now are developed through these types of cooperative relationships, thus broadening the concept of design chains to encompass an entire network of virtual corporation companies.

Probably one of the most extensive network of partner companies being assembled to work on a single product is the Joint Strike Fighter program to design and build a new family of supersonic stealth fighter planes for the U.S. Defense Department, Britain, and eight other U.S. allies. Primary contractor Lockheed Martin Aeronautics Co. will coordinate the efforts of 80 suppliers in 187 locations to design and build components, assemblies, and subsystems for the aircraft.

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When the entire system is in full swing, 40,000 people will be collaborating via the Internet on various aspects of the plane's design.

The importance of collaborative relationships, being connected and interdependency in today's business world is addressed in the book *X-Engineering the Corporation: Reinventing Your Business in the Digital Age* by James Champy, chairman of Perot Systems consulting practice and co-author of the former bestseller Reengineering the Corporation.

"Where reengineering showed managers how to organize work around processes inside a company, X-engineering argues that the company now must extend its processes outside – hence the X, which stands for crossing boundaries between organizations," explains Champy. "When an organization's processes are integrated with those of other companies, all partners can pool their efforts and effectively become a new multi-company enterprise, far stronger than its individual members could ever be on their own."

According to Champy, using technology-enabled processes to connect business with other business and companies with their customers can result in dramatic improvements in efficiency and create value for everyone involved. "What is driving this sweeping change," says Champy," is a combination of global competitive pressure and the frustrating inefficiency and redundancy that still persists in work relationships between organizations and with customers."

According to Ed Miller, president of consulting and research firm CIMdata, Inc., initiatives throughout the automotive, aerospace and electronics industries are leading companies in a growing number of markets to outsource not just parts manufacturing but also growing levels of design responsibility. "Subcontractors that never thought much about design now find themselves concerned with configuring geometry, selecting materials, analyzing stresses, evaluating reliability, and other aspects of product development," says Miller. "Virtual product development teams are thus distributed through multiple companies, so communication and coordination of activities are critical, and the ability to collaborate becomes essential."

Miller asserts that extended enterprises are thus emerging as companies evolve from developing and marketing their products and services locally, to developing, manufacturing, marketing, selling, and supporting on a global basis.

"This creates unique challenges to those companies. Global companies that can design and manufacture anywhere gain market share and market presence. Product design may occur around the clock, around the world," says Miller. "A design that is finished for the day in North America may be improved by a designer in Asia, to be completed by another designer in Europe. A key factor in this continuous design cycle is communication among everyone involved in development of the product so they all hold the same product vision."

In this way, contends Miller, today's extended enterprises leverage the capabilities of suppliers and other partner organizations to build on each companies' strengths. "No longer do companies have to provide expertise in all areas. They rely on their suppliers and partners to provide them with products and services that fall outside of their core competencies," says Miller. "The only practical way to accomplish this in any complex extended enterprise is through the use of technology solutions to share product information among all the different companies in developing innovative designs that will meet market demands."

In this respect, the intra-company design chain is evolving into an extended enterprise design network of companies, each with a stake in the success of the product and increasingly depending on the efficiency of the entire product development process connecting everyone together. Solutions such as mechanical design synthesis and supporting collaborative technologies thus become essential in optimizing products according to the growing number of variables inherent to the tremendous size and complexity of these design networks.

For many companies, becoming part of an extended enterprise will be the only means of survival in the coming years, and the design chain – or more appropriately, the design network – will be the lifeblood of work and business that will sustain them and strengthen their position in the fiercely competitive global markets.

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