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Process Compression

TECHNOLOGIES AND STRATEGIES FOR FASTER PRODUCT DEVELOPMENT

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Numerous factors contribute to the success of a manufacturer and the products it produces. Time to market, efficiency of operation, product quality, engineering innovation, and market-driven designs, among others. The linchpin holding all these elements together is the product development process, from the early conceptual stages of design through release to manufacturing and beyond, with engineering activities often devoted to retrofits, upgrades, and other engineering changes throughout the entire product lifecycle.

Product development certainly isn't the only function of significant importance in the manufacturing enterprise, of course. Activities in marketing, sales, procurement, production, testing, field service and many other areas are critical to success in the market. Indeed, input and feedback from all these groups plays a huge role in current team-based product development initiatives. And it is in product development, especially in the earliest stages of the cycle, where some of the most important decisions will be made with the greatest impact on the product's cost, performance, manufacturability and marketability.

"The interdependencies of a wide range of problems escalate the urgency for action across all fronts, and explode the priorities," comments Don Brown, chairman of consulting firm D.H. Brown Associates. "In the early conceptual stages, requirements are negotiated with marketing, performance targets are set, design envelopes are established, materials are specified, ideas are compared, all of which require a delicate balance. This is the most critical moment in the product lifecycle, where far-reaching decisions are made that irreversibly determine the timing, cost and quality of the product. Not only is the success of the product at stake, but in this period of economic pressures the company's survival may be impacted as well. For many industries, the classic economic recession piles on the pressures already in place from intense international competition, and accelerated technological innovation."

Small wonder then, that manufacturers are focusing considerable attention on improving their product development process, especially in light of today's economic and competitive challenges in worldwide markets across nearly all industries.

Companies have a variety of solutions available, particularly simulation tools and approaches that leverage their company's expertise and intellectual capital by enabling engineers, designers, and analysts to do their jobs faster and more efficiently. Solutions include virtual prototyping, mechanical design synthesis and tradeoff studies, knowledge capture, process automation, and applications integration.

These approaches allow 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. This process compression in product development thus enables companies to produce radically better designs orders-of-magnitude faster.

Tools and Technologies

Wide ranges of software tools are available for simulation-based approaches. Significant advances have been made in these technologies, with tools now aimed not merely at performing analysis faster but in more effectively integrating it into product development to accelerate the product innovation process.

At the forefront of this trend is technology from engineering simulation solutions provider ANSYS Inc. The company provides a range of software solutions for simulating and optimizing the performance of mechanical and electronic systems. ANSYS Inc. develops and globally markets engineering simulation solutions used by designers and engineers across a broad spectrum of industries, including aerospace, automotive, manufacturing, nuclear, electronics and biomedical. The company develops open and flexible simulation solutions that enable users to simulate design performance directly on the desktop, providing a common platform for fast, efficient and cost-effective product development, from design concept to final-stage testing and performance validation.

Virtual Prototyping. One of the greatest bottlenecks in product development is physical prototype testing. In this process, a product concept is translated into detailed engineering drawings. After a lengthy design review, a hardware prototype is built and tested. Any problems are then fed back to engineering, where the design is modified. These changes are then translated into new components and the prototype re-tested. This cycle is repeated until satisfactory performance is achieved, with several iterations usually required.

This build-and-test process is both expensive and time-consuming. Automotive mock-ups each take months to build and cost $300,000 to $500,000, for example. Also, designs are often far less than optimal, with quick-fix changes solving isolated problems but usually detracting from the overall design. To strengthen failed assemblies, components may be grossly overdesigned with needless weight and bulk, for example, thus adding to the material costs and adversely affecting fuel economy.

Virtual prototyping overcomes these problems by evaluating designs through computer simulation and analysis, thereby reducing reliance on hardware testing. Various engineering simulation solutions are used in these types of applications. The aim is not to entirely eliminate physical testing but rather to use a simulation-driven product development approach to guide the design and reduce the dependency on physical testing to identify problems and find solutions. By studying product configurations in the early phases of development, engineers can make changes and refine designs easily and inexpensively. By performing this type of simulation early in development, designers and engineers have the time and resources to evaluate alternatives, run 'what-if' scenarios, and come up with innovative designs.

Mechanical Design Synthesis and Tradeoff Studies. Designers often lack sufficient time to produce optimal designs that balance competing engineering requirements of weight, volume, stress, heat flow, resonance, cost, manufacturability, and a multitude of geometric restrictions and variables. Many of today's products involve a dozen or more such competing require-

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ments, and conventional CAD and simulation tools are intended to handle only a limited number of variables simultaneously. Users were thus faced with the tedious and time-consuming task of painstakingly running multiple simulations using exhaustive search methods in attempting to iteratively zero in on an often-elusive good solution satisfying most of the requirements. More often than not, engineers develop the design based on only one of the most critical variables and neglecting the rest.

A relatively new technology that accelerates mechanical design synthesis and tradeoff studies combines optimization technologies with CAE simulation methods and parametric CAD into an integrated solution that balances competing engineering requirements in an optimal design configuration. In one of the first commercially available solutions of this type – DesignXplorer from ANSYS Inc. – for example, a slider bar for each key variable is provided for users to dynamically interact with the model in real time, changing parameters and seeing how this affects the overall design performance. Feedback is immediate, so engineers can run through multiple 'what-if' scenarios that would otherwise be too time consuming to perform with conventional tools.

In a goal-driven approach, users can study, quantify, and graph various performance responses as a function of design parameters for components and systems. Bi-directional associativity with CAD packages allows 3-D designs generated through the system to be immediately updated. Because of this speed and dynamic interactivity, DesignXplorer enables product teams to make informed decisions earlier in the design process and arrive at optimal product configurations.

Process Automation. At most companies, engineers, designers, and analysts spend considerable time performing routine, repetitive tasks and procedures. Time is wasted that could be more usefully spent on creative efforts, doing real engineering and critical decision-making. Procedures are often inconsistent from group to group, depending on habits and personal preferences of the people involved, so that no best practices or standard operating procedures have been established. And the knowledge of all these procedures reside primarily in the heads of the people performing them and are generally lost and must be regenerated when these people get moved to other projects, leave the company, or are otherwise unavailable.

Process automation can be used to capture the engineering design rules and procedures used in the organization and compile this information in a knowledge base. These guidelines and standards are unique to each company and dictate generally how products are configured based on design requirements. The size of an axle might be in a certain proportion of vehicle weight and wheelbase, for example, or dimensions of a bearing may relate directly to load requirements and size restrictions. Through scripting and customization features, an application development platform solution such as AI*Workbench from ANSYS Inc. facilitates the capture of such design rules, provides process guidance, and automates how they are used.

This approach saves considerable time in completing routine tasks, with the software completing tasks in hours that otherwise would take days or weeks to manually perform. This also provides a basis for standardizing the procedures across the enterprise, and maintains a secure knowledge base detailing how the work gets done.

Applications Integration. The use of numerous different application software packages is generally required throughout the product development process. Ordinarily, these packages are incompatible and operate in a disjointed fashion independent of one another. In many cases, users must exit one program to utilize another, manually reenter data from one to another or go through cumbersome translation programs, and learn many different application interfaces. This takes time, introduces errors, interrupts a smooth workflow, and is a distracting process that diverts the time and attention away from the project.

The AI*Workbench application development platform has specific functionality for integrating separate programs into a single application specifically geared toward a specific company. This facilitates more efficient processes through a common, customized interface and links between otherwise disjointed software packages. Not only does this save time, but also the dynamic interaction with multiple application programs enhances creativity.

Real-World Process Compression

Companies in a variety of industries are applying the concepts of process compression and achieving impressive results on a wide range of different projects and applications. "These examples demonstrate the confidence industry has in these approaches and the commitment of companies in using these tools to their fullest advantage."

In a major push to accelerate its product development cycle, Toyota made implemented a concerted front-end loading initiative involving the use of early simulation in conjunction with other process changes and slashed development time and cost (including the number of full physical prototypes) by between 30% and 40%. In ongoing front-loading efforts, Toyota is using computer-aided engineering technology to identify functional problems earlier in the development process and also transferring problem and solution information from previous projects to the front end of new projects. In this way, the automaker expects to solve at least 80% of all design-related problems before the first prototypes are built. Additional time and cost savings are also anticipated by eliminating some portions of testing second-generation prototypes, which are now less important in overall problems solving.

In the General Motors vehicle development process, part of the synthesis process relies on up-front simulation math models to provide insight into the tradeoffs between product requirements for given market segments, enabling the automaker to achieve a 50% improvement in product development efficiency, cost savings exceeding $10 billion, and a compression of vehicle development time by 18 months. In this robust synthesis effort,

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the synthesis process relies heavily on multi-variable optimization methods that cascade down from full-vehicle simulations to variations in individual components.

Engineering consulting firm Vulcanworks Inc. has developed a proprietary system based on mechanical design synthesis to automate routine, repetitive tasks in evaluating the influence of many different variables on designs. Their Advanced Engineering Environment uses the ANSYS AI*Workbench application development platform in providing the simulation solution based on the processes, product types, and design goals of each client. This approach has been used on a variety of automotive mechanical systems such as suspensions, engine components, steering assemblies, and body structures as well as non-automotive projects including fuel cells and marine applications. In the re-design 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 design synthesis. Similarly, work on a suspension system that normally takes 60 person-days was done in only 2 person-days.

Business Benefits

Companies can radically compress product development by utilizing these technologies. Virtual prototyping reduces the time and cost of physical testing by identifying and correcting potential problems early in the design cycle when they are readily fixed. Mechanical design synthesis balances competing engineering requirements to arrive at optimal designs much faster and more effectively than would otherwise be possible. Process automation performs routine, repetitive tasks and procedures more quickly and accurately than if performed manually. Application integration links together and coordinates the interaction with otherwise disjointed programs that users must spend time operating and exchanging information separately.

In this context, "compression" does not mean "reduced" in the sense of a lessening of value or capabilities, but rather concentrating essential elements of the cycle into a more compact and faster process that has the potential to be more highly value-added in the business enterprise. The resulting compression in product development can be manifest in many ways, depending on the business priorities and company goals of the particular enterprise. Generally, benefits boil down to time savings, cost reductions, quality improvements, or greater product innovation. Areas targeted depend on the company and its business objectives related to increases in sales margins, market share, and market size.

Most recently, a renewed emphasis on product innovation as a competitive advantage has prompted a growing number of companies to use process compression as a way of focusing development efforts on unique differentiating features and performance. Product innovation is playing a critical role in the automotive industry and is gaining increasing attention as a strategic competitive advantage and overriding market issue by upper level automotive executives. "You ask me for volumes, products, sales, productivity. But nobody ever asks me for creativity, technology, innovation," says Jurgen Schrempp, chairman of DaimlerChrysler. "That's where I make my money. The point is not to get three dollars out of the cost: The companies making the most money are the innovative ones, not the low cost ones."

In the book *The Future of the Automotive Industry*, Andreas Feige and Robert Cooker of Arthur D. Little note that product development must address all of these goals. "The challenge in the product creation process lies in developing a vehicle concept that is as fascinating as possible while meeting future customer requirements," explains Feige and Cooker. "The best concepts are the ones that can be executed in the shortest possible time with the lowest possible product costs and the highest possible quality."

This assertion is echoed by Charles Foundyller, president of market research firm Daratech Inc. "Compressing product cycles and time-to-market while boosting product quality to reduce recalls and warranty expenses, all while lowering product development costs, are urgent priorities for manufacturing companies."

According to Foundyller, most users surveyed by Daratech said that time-to-market is their company's most pressing concern. "Potential gains to industry in getting fresh designs to market can often be measured in hundreds of millions of dollars - in some cases billions," says Foundyller. "When a new product is a hit with consumers and the manufacturer has the market to itself for a period of time, profits can be sky-high. Conversely, being unable to respond quickly to a competitor's hit design can cost a fortune in lost sales opportunities."

In his book *Winning at New Products*, Robert Cooper asserts that speed in getting innovative products to market is a company's pivotal competitive weapon. "The ability to accelerate product innovation - to get new products to market ahead of competition and within the window of opportunity - is more than ever central to success."

Cooper notes that the ability to respond to customer needs and market changes faster than the competition is a major competitive advantage. Another payoff of speed is higher profitability, since money has a time value, and deferred revenues are worth less than those acquired sooner.

Fewer surprises is also a benefit of speed to market. "The ability to move quickly to market treats change as an opportunity rather than a threat," says Cooper. "The product as originally conceived is more likely to meet market requirements; and the short time frame reduces the odds that market conditions will dramatically change as development proceeds."

Time-Based Product Development

The need to shorten product development time through the use of analysis and simulation technologies is seen as critical for manufacturing companies in the book *The Virtual Engineer* by Dr. Howard Crabb. He is president and CEO of Interactive Computer Engineering 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.

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lution in CAE tools and processes, has become a strategic imperative. With the recognized gains in market share and profitability from being first to market, companies are developing innovative ways of getting products designed faster," says Crabb. "In the automotive industry, the installed base of people, processes, and tools is undergoing a major renewal effort that is being driven by time-based market competition. With the investment for a newly-developed vehicle platform now measured in the billions, and market forces compressing the product development and launch cycle to less than 3 years, this new time-to-market reality has forever changed the way vehicles will be developed and tested."

Crabb cites one example where an automotive company reduced prototype build times by more than 30 weeks through the use of engineering simulation and virtual prototyping, resulting in a 5-month head start in time-to-market for the new model that contributed more than $20 million to the company's bottom line. He notes one automaker reducing major component physical prototypes 50% (from six to three) and expects that software prototyping will eventually reduce physical prototype testing by 75%.

Most manufacturing companies must at least double or triple their product development and engineering productivity by the year 2010 through the revamping and integration of CAE and collaborative technologies and processes, Crabb contends,"The long-held tradition in which engineers complete a design and 'toss it over the wall' to manufacturing is as dead as the companies that persisted in doing it. Companies looking to survive and thrive," says Crabb, must identify and establish best practices to re-engineer the product design and manufacturing process."

According to Crabb, the increased use of CAE simulation and more effective processes is critical to achieving dramatic reductions in product development time and cost, and key to companies achieving their key business objectives. "Product development time is reduced by evaluating a design concept in hours rather than months and exploring all the alternative and extreme conditions, which are impossible to prototype physically," explains Crabb. "The ability to evaluate concepts quickly and cost-effectively provides management with a distinct strategic advantage. It allows product designers to choose from concepts that are already optimized rather than merely ensuring that they have performed the function to schedule. This advantage turns product development into a time-based competitive advantage."

Integrating Design and Analysis

A key element in process compression is integrating analysis closely into the product development cycle, a direction that is sorely lacking in many organizations according to Dr. James Crosheck, a retired structural engineer with Deere and Company and now head of the consulting firm Effective Engineering Solutions. "Competitive pressure demands faster, more focused product development. For companies to reach this goal, however, they absolutely must change their view of the development process to include a strategic position for simulation," says Crosheck. "Until now, analysis has been done almost as an afterthought at many companies, performed apart from design and out of the product development loop."

Crosheck notes the huge gains are possible by closely linking analysis with design, and he points to what is required to reach these benefits. "If companies want to go beyond incremental time and cost savings of a few percent and make an order-of-magnitude impact of 10-fold or 100-fold improvement, simulation must be an integral part of the design process, tightly coupled with engineering and sufficiently interactive so that it can be a powerful tool for making critical decisions early in product development. In this sense, simulation is just as much a management decision-support tool as it is an engineering design evaluation solution."

Huge gains notwithstanding, justifying the return on investment for implementing these types of simulation tools and processes often is a daunting task, according to Crosheck. "The ROI game," as he describes the process, "has hoops to jump, political fights to wage, numbers to justify, and savings to quantify."

His insight into such decisions and message to senior-level managers is profound as it is enlightening and simple to understand. "Companies don't decide to use simulation. They decide to significantly reduce product development time. And absolutely the only way to get big time savings is to use simulation. You just can't do it any other way."

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