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INDUSTRIAL MANAGEMENT

Design Tools Move into the Fast Lane

New software turns ideas into reality in record time

Even before the starter's gun set off a roar of engines at this year's Indianapolis 500 race, Dallara Automobili was celebrating. All three cars in the first row shared a common feature: Their chassis were designed and built by Dallara in Varano dé Melegari, about 20 miles west of Parma, Italy.

Dallara has recently racked up an impressive string of race-car wins, including four of the past five Indy 500s plus last year's Daytona 500. Much of the credit goes to the latest generation of computer-aided design (CAD) and computer-aided engineering (CAE) tools. Without them, says Dallara technical director Luca Pignacca, "it would have been absolutely impossible to do what we've done."

The new software is also sending a roar through design and engineering circles worldwide. All the major CAD and CAE suppliers have hatched programs that combine the once-disjointed processes of creative design and rational engineering. The tools Dallara uses, from Parametric Technology Corp. in Needham, Mass., have virtually eliminated design errors and tripled designer efficiency -- helping the company move more quickly from computer design to 40%-scale models. "Now we can spend a hell of a lot more time fine-tuning performance in the wind tunnel," says Pignacca.

In addition, the new tools are getting much more accurate at simulating the real-world behavior of finished products. As a result, "virtual prototypes" -- computer models -- are starting to replace the physical prototypes that engineers have always built to double-check new designs. This convergence of technologies is slashing the need to make design revisions and speeding new products to market more quickly than ever.

The new CAD-CAE hybrids have been evolving for a decade, thanks to gains in computer power. Today, engineering programs can automatically check a design while it's taking shape on the computer screen. This is done using a mathematical tool known as finite element analysis, or FEA. In the past, FEA chewed up so much computing power that it had to be done after the design process -- but that has now changed.

In essence, FEA works by dividing the CAD model into a complex 3-D grid, or mesh. Then the computer simulates the transmission of pressure or heat, say, along the grid lines to determine how well all the segments of the 3-D model will withstand the forces that the final product will face in the real world.

This can help spot design defects and prevent faulty products from reaching the market. Because designers usually make choices based on experience, it's easy for them to overlook better approaches that simulations can uncover. And if a designer disputes simulation results based on FEA programs such

as Abaqus, "the simulation always proves correct," declares Mark W. Bohm, a general manager at Hibbitt, Karlsson & Sorensen Inc., the Pawtucket (R.I.) developer of Abaqus.

At Milsco Manufacturing Co. in Milwaukee, FEA helped senior design engineer John S. Scott avoid a potential problem with a new line of seats for SUVs and trucks. Using CosmosM software from Structural Research & Analysis Corp. in Los Angeles, Scott found that after some aesthetic changes were made to the first prototype seat, the armrest ended up with a weak spot. He worried that the armrest might eventually break if people repeatedly pulled on it to climb into a vehicle, so Scott strengthened the armrest.

Catching such potential problems in the design stage can save tens of thousands of dollars by avoiding changes on the production line, such as ordering a new set of expensive molds. "It also frees up time in our testing labs," says Scott. As a result, Milsco Manufacturing has been able to take on a wider range of jobs and expand into new markets, such as golf-cart seats.

Even with today's powerful computers, though, the usefulness of FEA alone would be limited when it comes to exploring design alternatives. Evaluating multiple design approaches may entail hundreds or thousands of FEA runs, and that would bog down the design process for hours or weeks. This is where the next big advance comes in, known as "design of experiments," or DOE. The approach can significantly streamline the analysis of the so-called design space -- not just the existing design but also the range of feasible alternatives. "Analyzing an engine block with FEA can take a day," says Keith D. Perrin, a CAD-CAE expert at Electronic Data Systems (EDS) Corp. in Plano, Tex. "You can't afford to do that 5,000 times," he adds. In any case, even that many repetitions may be inadequate for a product built out of multiple parts and materials. Nailing down the right mix of materials, part shapes and thicknesses, and other variables might take 50,000 iterations.

By analyzing how various design elements affect one another, DOE figures out which components have the most influence on performance. The FEA program can then concentrate on just that handful of crucial variables, adjusting them up or down to find an optimum solution. Sprinkle in some engineering smarts, and you've got knowledge-based engineering. With EDS's latest software, Unigraphics NX, says Perrin, "you tell it your overall design goals and the things that can't change, and it will use DOE, FEA, and optimization tools to explore alternatives to reach that goal."

The next step beyond design optimization is "behavioral modeling." As the software explores multiple combinations, it organizes the results in a tree-like structure of cause-and-effect relationships. Each big limb represents a major variable, such as the size of a motor in a kitchen appliance. Sub-branches show the options available using various brands of motors and different motor mounts. When this database is complete, designs can be revised almost instantly, says Andreas Vlahinos, a former University of Colorado engineering professor who became enthralled with the technology and founded a startup: Advanced Engineering Solutions in Castle Rock, Colo.

Carmakers and other large manufacturers are taking the new capabilities seriously, and virtual prototyping is the hot buzzword in Detroit. "That's now a mainstream part of our product-development process," says John L. Givens, director of powertrain synthesis and analysis at General Motors (GM) Corp. "And we have a special training program to teach engineering to designers," so they can become more proficient at using systems that combine CAD and CAE.

Soon, big companies like GM "will put pressure on their small vendors to take on more of the engineering chores in product development," predicts Suchit Jain, marketing vice-president at SolidWorks Corp. in Concord, Mass. Then the companies that still resist using FEA by itself will wake

up to how cost-effective the software can be. SolidWorks released a study this year that found an average payback of $285,000 on a $50,000 CAD-FEA investment by a company with five designers.

Because of such benefits, Vlahinos of Advanced Engineering Solutions says all it will take to get reluctant companies off the fence is one successful job. "Then they'll be eager to move up to DOE," he says. "Eventually, everyone will have behavioral modeling as well."

Tomorrow's CAD-CAE systems will also bring relief to managers, Vlahinos predicts. The software will be too smart to tolerate faulty designs. "It will sit there like a little hammer on the computer. Whenever you miss the design target," he says, "it hits a wake-up gong -- and corrects the design." Companies should then be roaring through product-development cycles at top speed.

By Otis Port in New York