# MACHINE DESIGN

 Machine Design (ISSN 0024-9114) is published semimonthly by Penton Media, Inc., 1100 Superior Ave., Cleveland, OH 44114-2543. Copies not qualified for domestic requester circulation: one year, $105; two years, $165. 

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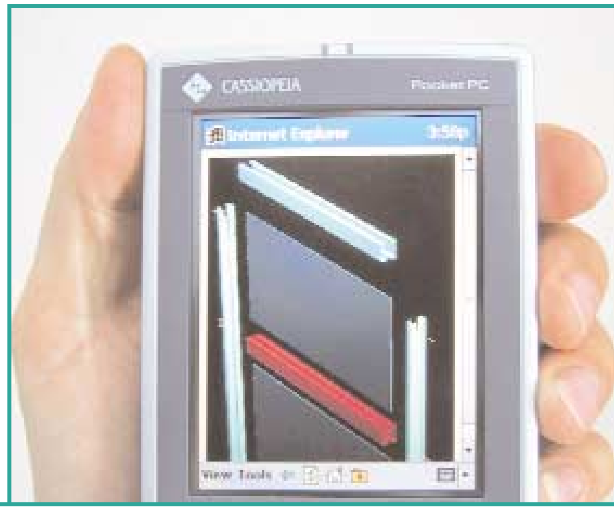
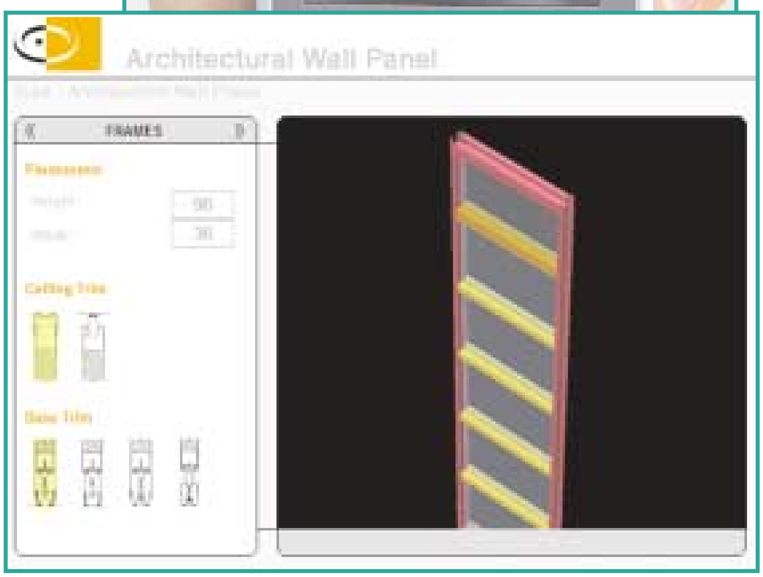
# Forget general-purpose software — GET FOCUSED

*Most general-purpose design and simulation programs can be customized so nonspecialized users turn out the work of experts.*

**Paul Dvorak**
Senior Editor




Detailed assembly instructions can be sent to construction sites and received on handheld computers.




The product configurator design by Vlad Zila for an architectural company needs just a few selections and dimensions before showing a section of a wall partition.

General-purpose CAD and simulation programs let talented engineers model and analyze almost everything — from running shoes to space shuttles. But most design departments don't build a wide range of products. More often, it's a few product lines with variations in each. And modeling the next version in a long line of widgets ordinarily means making the same hundred menu picks as the last dozen versions.

A better way to model or test the next design is with a tailored CAD or simulation program that asks users only for the information needed to complete a solution. For instance, if lap joints get constant analysis, the software would only ask for the number of bolts, their pattern, and a load. Mesh would be automated, as would be constraints and the presentation of results.

As it turns out, when CAD programs are tuned to handle repetitive tasks, they usually become product configurators, systems that resize a single product, such as speed reducers or electric motors, into thousands of variations.

Of course, custom software is not new. IT departments are always banging out code for company-specific financial analyses. And there are all sorts of special programs for designing frequently encountered odd problems, such a piping nozzles.

Using focused CAD software to avoid repetitive operations solves nonengineering problems as well. Take manufacturing, for example. It has huge information-processing needs. "From the time orders enter a company until products ship, up to 90% is spent in processing and only 10% on manufacturing," according to Vlad Zila, professional engineer and president of **Genexis Design,** Markham, Ontario, Canada (*www.genexisdesign.com*). "Manufacturing firms would rather spend 90% of their time on engineering and 10% on information processing." Design automation tied into a company database could let them do so, and in the process, eliminate errors from repeatedly and manually inputting the same information.

Focused simulation software may be

the best bet for small to medium-sized companies. "They know FEA is valuable but cannot figure out how to make it work for them," says Philip Raymond, president of **Enductive Solutions,** Scotts Valley, Calif. (*www.enductive.com*) "They just don't have the time to develop the necessary FEA experience," he adds.

What's more, says Raymond, these are difficult times for some older engineers because they have been using make-and-break analysis for many years. "They were comfortable with their research, but see margins and operational costs becoming an issue. For them, an analysis package they can use on their problems may save the business."

Focused software we found spans several design and simulation examples. In general, say our experts, it promises to eliminate repetitive tasks and deliver insight into the physics of problems engineers have been wrestling with for years.

## CUSTOM CAD LEADS TO A PRODUCT CONFIGURATOR

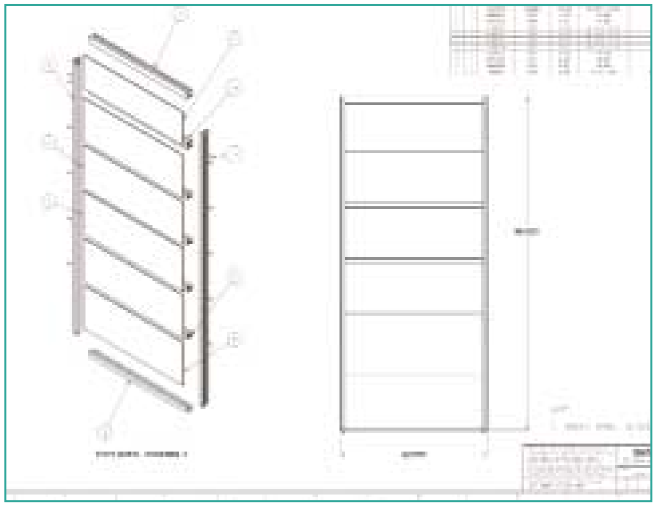
A CAD-neutral product configurator generates vivid images of architectural panels, and then production drawings and schedules for the partitions based on simple menu picks such as heights, widths, wall coverings, and locations for doors and windows.

"We are developing a universal, modular, scalable architecture — a build-to-order system that develops information online," says Zila. "The system can be adapted to design tasks for products that come in many variations such as electric motors and hydraulic cylinders," he adds.

Assembly instructions could be made available to workers on site through wireless technology such as handheld computers, so paper instructions need not delay a delivery.

Designing hundreds of offices and thousands of partitions with a general-purpose CAD system would be a numbing experience because of the hundreds of repetitive selections. In addition, later manual operations could lead to other errors.

The Genexis configurator solves the problems. A 3D-CAD engine connects to a company database of assemblies, subassemblies, components, associated drawings, and rules for putting components together. The associated system lets changes in any part or assembly migrate into others. A browser or Web-based configuration tool handles project-management functions. "When users start a project, the system assigns an order number and deals with other uncreative administrative tasks," says Zila. "Tracking tools follow the order so others can monitor how it's being processed. This gives access to the company database, which can be from SAP or other enterprise-wide information system that routes information to finances, engineering, costing, and procurement."



Zila's product configurator generates production drawings and a bill-of-material after submitting an order.

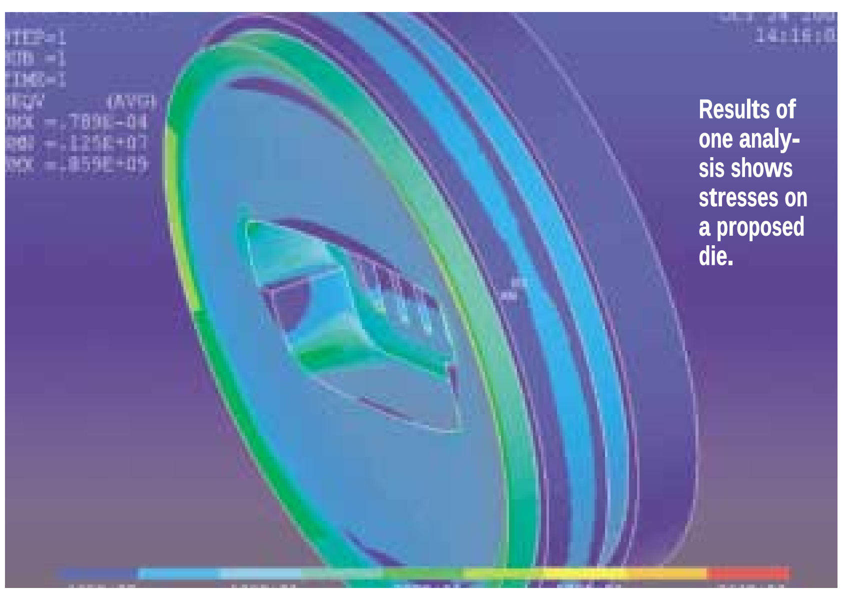
Zila says these operations are often quite separate because companies have different software systems running them. But in the configuration system, all company departments swap information.

"Users see the office as it's put together. The configurator immediately presents all changes on screen," says Zila. When satisfied with a configuration, they submit it to the production facility. The system generates parts, assemblies, and drawings into Web or Acrobat files. "Then all stakeholders in the company can access the files, vendors too, to see what is proposed. All this happens in a secure environment."

Zila is developing the configurator so that it might eventually design an entire building. "The technology works, but we have to deal with inertial or psychological issues that tend to buck new ideas."

## WILL THE DIE BREAK? SOFTWARE TELLS

Extrusion equipment operators, along with engineers from Enductive Solutions, tamed a complex extrusion simulation so it can be run after typing in a few critical parameters. After adjusting four values — settings on an extrusion machine — the simulation software meshes a proposed die, completes a solution, and gives extrusion specialists results that tell whether or not the die will break. When the die appears in danger of damage, the



Results of one analysis shows stresses on a proposed die.

parameters are easily adjusted to find better working conditions. The system has the potential of annually saving $500,000 that would otherwise be spent on repairs and lost to downtime.

Extrusion technology has changed little in the last century. It works by heating a billet of aluminum and forcing it through a die to impart a required shape. But extrusion companies are feeling the effects of smaller margins and off-shore competition. What's more, dies cost from $20,000 to $50,000. Repairing a broken one costs almost as much and takes two to three weeks of downtime.

The simulator promises to minimize those penalties. Through a simple Visual Basic interface, users type in temperatures for the billet, sleeve, dies, and ram pressure. But the simulation is not trivial. Molten aluminum undergoes phase changes that must be included.

"We put together a GUI with a pull-down menu," says Philip Raymond, president of Enductive. "The user pulls in die geometry from the CAD system. Then at the press of a button, the system discretizes the geometry and analyzes it," he says.

A CFD solver looks at flow and circulation issues, and generates pressure and temperature-boundary conditions. The system passes loads and boundary conditions to a structural analysis. The resulting FEA looks for high stresses in the die.

"The system produces a 2D or 3D vector plot outlining either the stress or temperature profile," says Raymond. "Extrusion engineers can then tell at what point they think the die will break, usually when stresses exceed the yield of the die material, and make changes accordingly."

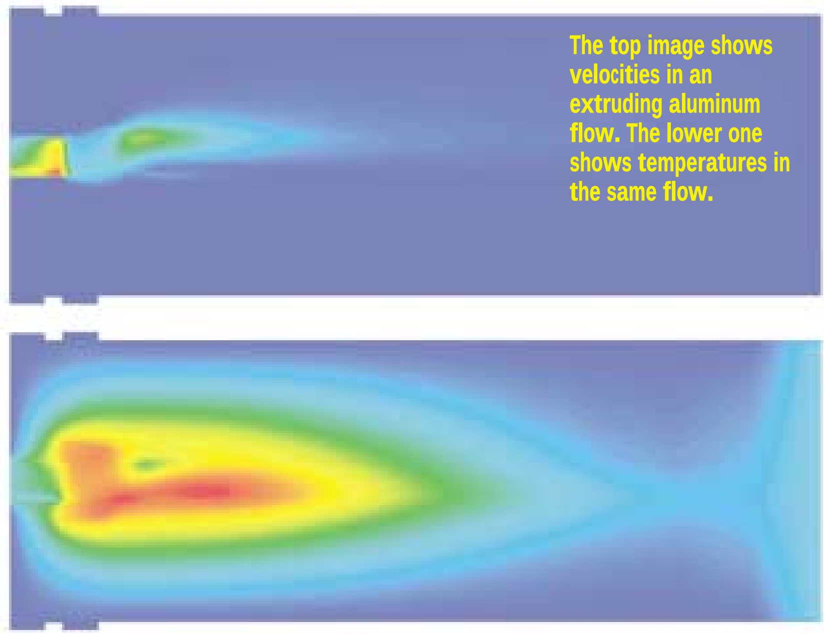
The software should help reduce the number of broken dies and maintenance downtime. It also lets extruder operators run more what-if scenarios, such as seeing what happens by doubling ram pressure or lowering the die temperature. Furthermore, says Raymond, they understand the physics of their processes in a way the make-and-break analyses never told them.

## HANDBOOK FEA MODELS READY FOR MORE GENERAL PROBLEMS

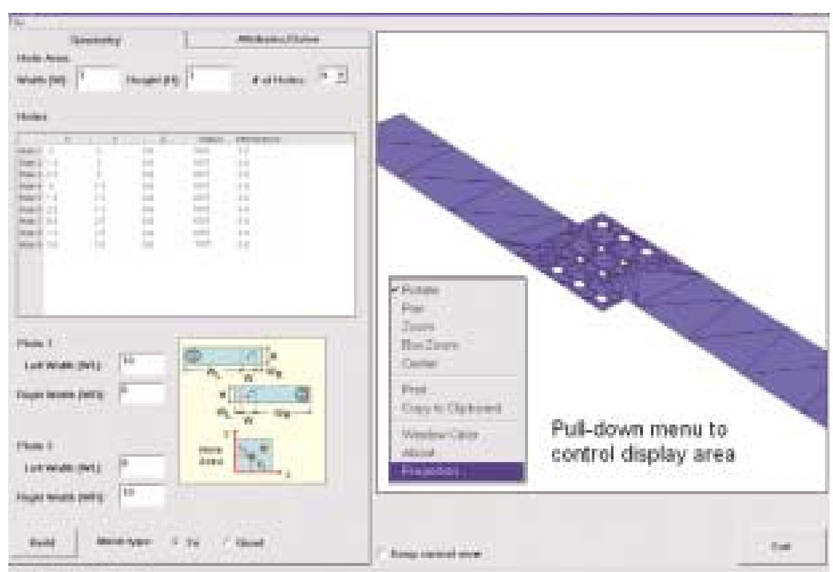
StressCheck is an unusual FEA program in that it was conceived as simulation software for use by nonspecialists. Its handbook format lets users scroll through prepared parametric models to find ones similar to the design at hand. Users then reshape models by typing in new dimensions, identify materials, assign load and constraint values, and then kick off a solution, which can include geometric and material nonlinearities. When engineers encounter new parts, the resident FEA guru can model them and add them to the handbook so designers can use them. The benefits of the system include consistent results and reliable answers.

The limitation in this arrangement of predefined handbook models, concedes developers with **ESRD,** Creve Coeur, Mo., (*www.esrd.com*) is that if designers require models other than those available in the handbook library, they have to wait for new models to be added.

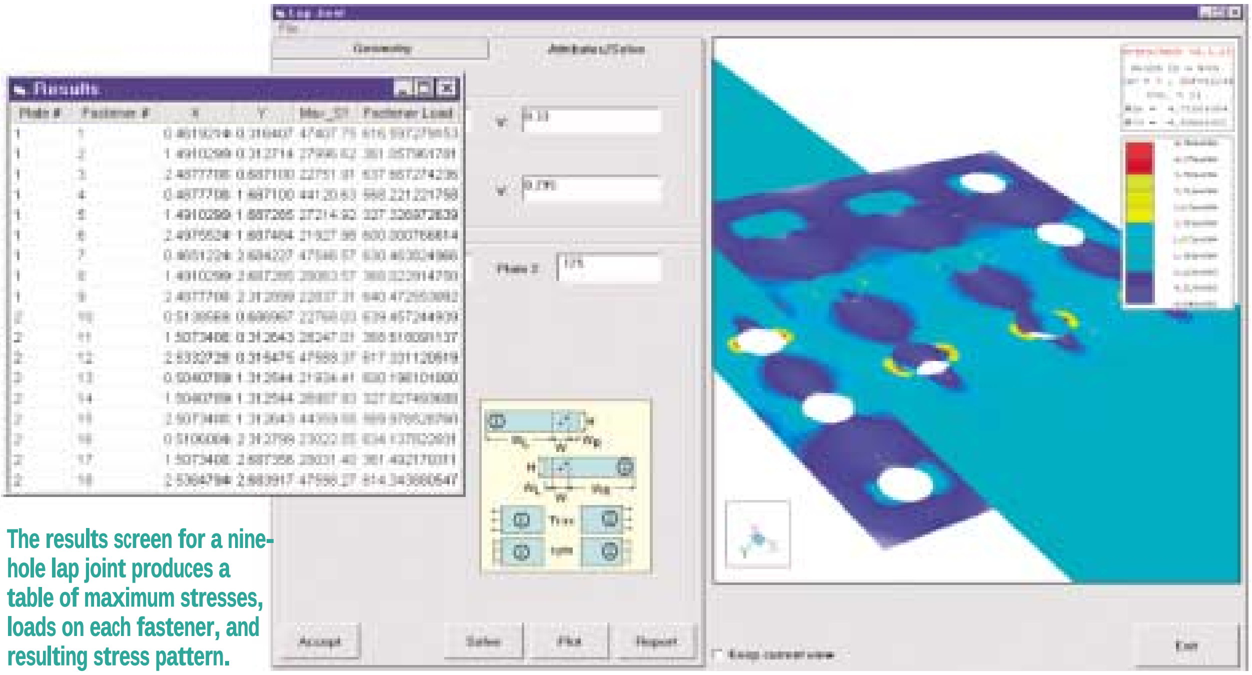
"At the request of a customer in the aerospace industry, we found a way to make the software more useful for design engineers," says Kent Myers, one of the founders of ESRD. "By providing an Application Programming Interface to the StressCheck analysis engine, it is now possible to construct FEA models under



The top image shows velocities in an extruding aluminum flow. The lower one shows temperatures in the same flow.




StressCheck from ESRD can be used as a "black-box" solver to analyze general problems such as fastened joints and stiffened panels. Users identify the number of holes in the joint or number of ribs in a stiffened panel, their locations, and a few dimensions. The handbook approach would need separate models for each design configuration .



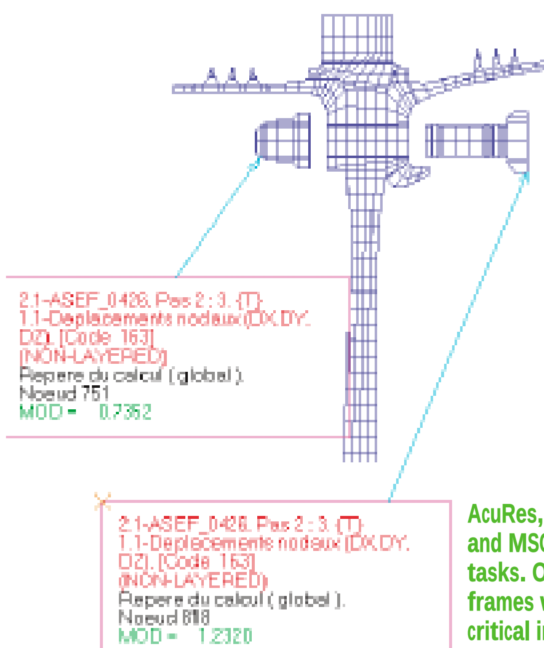

The results screen for a nine-hole lap joint produces a table of maximum stresses, loads on each fastener, and resulting stress pattern.

the control of user-developed design utilities. The engineering company may now revamp its standard design procedures, which are based on closed-form solutions and test data, so they are more reliable and representative of specific design problems."

A company may provide Web-based access to solutions based on predefined handbook models or driven by customized design applications, whichever is more appropriate. "Aerospace designers, for instance, frequently analyze for maximum stresses around holes in sheet-metal lap joints and for a variety of different hole patterns and shear loading. They also wanted it automated so results are more comparable," says Myers. "They're also expanding from simple models to more complicated ones that involve nonlinear effects."

Users now identify configurations by the number of holes in the joint, their locations, and any gaps between fastener and hole. Loads can put the joint in tension or compression, in which case, the software considers the nonlinear condition of hole propping.

Meyers tells of another client that developed a Web-browser front end using StressCheck as an analysis service to solve various engineering design problems. This setup uses advanced features in the software for composite materials and fracture mechanics. "In their setup, an individual sends data to the server that solves the problem, captures a jpeg image, retrieves results, and presents them in the Web interface."




AcuRes, a collaboration of Snecma Moteurs of France and MSC.Software, handles difficult postprocessing tasks. One feature of the custom software produces frames with dynamic annotations — callouts with critical information clearly identifying components to which they belong.

The benefit of the system is standardization, says Ricardo Actis, a senior research engineer with the software developer. "Problems are solved consistently regardless of who uses the software. What's more, engineering departments can capture the expertise of analyst groups. Analysts decide how problems should be solved and their expertise is recorded in handbook models or design utilities that are easily revisited and updated. And when analysts move on, their expertise stays behind, so it is easily accessed by the next engineer."

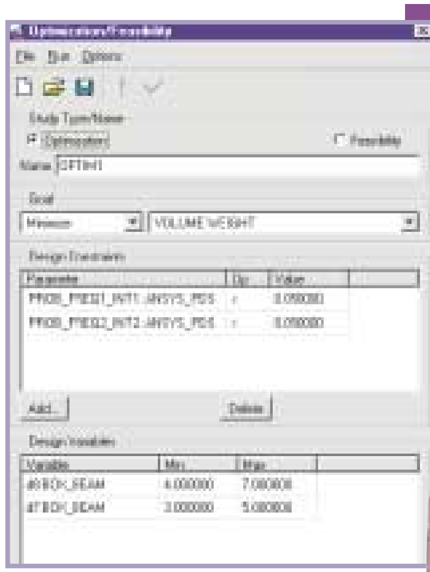
## POSTPROCESSOR FINDS GOLD IN MOUNTAINS OF INFORMATION

Engineers at **Snecma Moteurs,** a French manufacturer of jet engines, used MSC.Acumen (*www.mscsoftware.com*) to automatically postprocess mountains of information generated by their in-house solver, Samcef. The postprocessor, called AcuRes (Acumen Results), lets many skill levels easily extract plots and values.

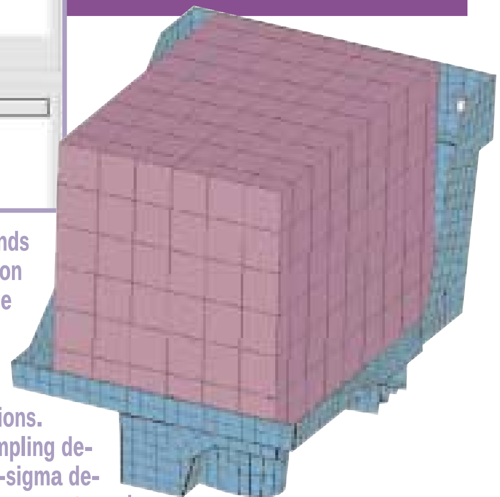
The aircraft supplier had been running into problems, such as outputs from Samcef coming from a range of different solvers, so their meaning was not always obvious. Even the MSC.Patran Results menu, for instance, can produce several fringe plots with different maximums and minima. So it was confusing as to which was most applicable. It was also difficult to obtain some plots, such as for nodal lines. And MSC.Patran menus are in English, less than optimum for French-speaking users.

Now when engineers extract information from a simulation, they start AcuRes and generate reliable and repeatable results. The menu includes several straightforward selections for deformation, fringe, and principal stress vector plots. A user may need to see, for example, a deformation plot superimposed over von Mises stresses for one load case. Users can ask for a screen capture of such a display. From the display option, users choose other load cases for which they need graphs, plots, and images.

In addition, the software presents general results such as maximum, minimum, and average for requested values. Information and explanations are in French, so there is no misunderstanding. And automated HTML reports of analyses can be sent to others.




**A dialog box from PTC's Behavioral modeling extension shows the optimization setup with a goal of minimum weight. The lower portion shows design variables and their limits for a box beam. Optimization is easily substituted for a sensitivity study that determines and plots effects of any Pro/E design variable to the natural frequency, or the probability of failure.**



**Another example for a battery tray finds the sensitivity and response distribution (stress, stiffness, fatigue life) from the scatter of several variables, such as modulus of elasticity, thickness, and loading, when they are defined in terms of probability distribution functions. Monte Carlo and response-surface sampling determine the response distribution. Six-sigma design criteria can be used to size the components and compare this design to one developed using traditional nominal-value figures. The example uses a battery, composite tray, and interface elements. The automatic reliability-based optimization reduced the tray's weight by 17%.**

## MIXING CAD WITH SIMULATION GIVES DESIGNERS NEW POWER

Combining the analysis capabilities of two independent design programs let designers with **Ford Motor Co.** go from functional goals and sizing parameters to the best designs that meet the company's quest for six-sigma quality. The software packages are Behavioral Modeling Extension (BMX) from **PTC,** Needham, Mass. (*www.PTC.com*), and Ansys Probabilistic Design System (PDS) from **Ansys Inc.,** Cannonsburg, Pa. (*www.ansys.com*)

BMX lets designers start with a goal and a few constraints. For instance, a bottle might need to hold exactly a quart and not exceed a particular height, width, or length. BMX in Pro/E calculates many containers that meet the goal and presents the results in a graph. The designer then selects a best one. "BMX drives designs through engineering requirements instead of dimensions, as most are," says Andreas Vlahinos, Principal of Advanced Engineering Solutions LLC, Castle Rock, Colo.

PDS software, on the other hand, lets user consider variability in material properties and dimensions. This lets users answer questions such as: If input variables for a simulation model fall within a range, what is the scatter of the output values? Or, which input variables contribute most to the scatter of an output parameter and to the probability of failure? "You can ignore variations and pay later, or incorporate them in the design and analysis and get an expected behavior," says Vlahinos.

For example, a designer can change a hole in a radiator support and the combined software package updates the bracket thickness to meet a quality criteria and minimum weight. "A good analyst with lots of time can do this already," says Vlahinos, "But it's too complex for a designer at early formation stages."

Geometric dimensions, such as the average part thickness can be controlled by designers. Uncontrollable or noise factors such as manufacturing imperfections (standard deviation of the thickness), environmental variables (loading), or product deterioration (material properties) are sources of variations that cannot be eliminated, explains Vlahinos. A rugged design should reduce a product's variation by reducing its sensitivity to the sources of variation rather than by *controlling* the sources.

Ford engineers would like designers to produce the same work as experienced analysts. To this end, they have collaborated with Vlahinos to integrate BMX and PDS. "We developed a little program with a lot of brains behind it that's usable by designers," he says. "Essentially, we automatically capture and reuse the expert's knowledge. This way, when designers shape something, certain design variables update automatically to assure that the design meets certain quality criteria. "Six-sigma has been implemented effectively in management and these techniques let us introduce six-sigma methods into engineering design." ■

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