Variational Design

Parametric vs. Variational Modeling: More Than Semantics

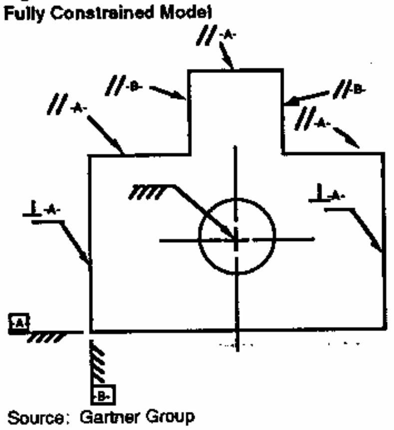
The CAD modeling foundation war is coming to a boil as vendors move to next-generation systems. We believe that variational technology will ultimately prevail because of its greater flexibility.

Key Issue
How will design tools change during the next five years?

One of the key components in a CAPE-mechanical application architecture is a robust modeling foundation that is trivial to use. In the past, CAD modelers were inflexible and difficult to use, requiring the user to enter explicit dimensions when constructing models. The new breed of parametric or variational modelers enables users to sketch geometry freely and express dimensions as parameters or variables that can be readily altered to edit the actual model or to create new designs from existing models. Another key feature of the new modelers is that they are highly associative, which means that changes made to the model can automatically be reflected throughout the entire design, including drawings, analysis models and numerical control tool paths. Because associative front-end modeling technology now plays a larger role in downstream applications, users must raise the level of scrutiny and importance when selecting a modeling foundation. Today, there are two technology approaches: parametric modeling offered principally by Parametric Technology Corp. (PTC) of Waltham, Mass. and variational modeling (see Note 1) offered by a number of vendors, most notably SDRC of Milford, Ohio.

Note 1
What Is Variational Design?
SDRC was the first company to incorporate variational design capabilities into its software. Similar to parametric systems, variational lets designers specify both geometric constraints (such as parallelism and "perpendicularly") as well as engineering (or mathematical) relationships (e.g., weight and structural constraints). Parametric systems work from the basis of altering geometrically defined relationships. While engineering constraints are possible, they are not tied to the parametric problem solver. In the PTC system, constraints are solved in an ordered fashion, whereas in variational systems both geometry and engineering constraints are solved using simultaneous equations via a problem-solving engine.

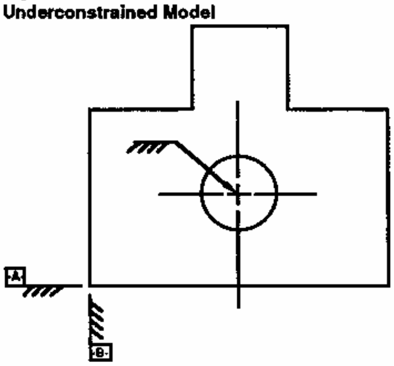
Figure 1
Fully Constrained Model



Source: Gartner Group

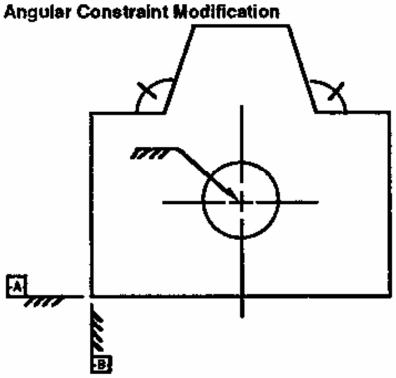
Constraint Input — One of the differences between parametric and variational modeling deals with how geometric constraints (e.g., perpendicularly and "colinearity") are handled. In parametric modeling, geometry must be "fully constrained" (see Figure 1) before dynamic model editing and solving can occur. In the variational approach, models can be edited even when they are "underconstrained" (see Figure 2). This is a more natural way of constructing a model since users do not often know exactly what constraints will be contained in the model at the time of creation. Applicon (Ann Arbor, Mich.) has added a new twist and allows models to be "overconstrained" (e.g., dual dimensioning). In addition, some systems (e.g., SDRC's and Applicon's) can automatically create inferred constraints, such as perpendicular and parallel lines at the time of geometry creation. This greatly improves modeling productivity.

Figure 2
Underconstrained Model



Source: Gartner Group

Figure 3
Angular Constraint Modification



Source: Gartner Group

Geometry/Constraint Modification — After the model has been constrained (fully in parametric systems or partially in variational systems), the geometry can be dynamically altered by "pulling" on the geometry. This allows the model to be re-sized or re-shaped quickly against the given constraints. Both parametric and variational systems behave exactly the same when dynamically modifying the model, although parametric modelers can perform the updates much faster because of their simpler mathematical approach. The inherent speed advantage of parametric modelers, however, is quickly offset when the model topology or constraints must be modified. Because parametric solvers are sensitive to the order in which constraints are created, the affected underlying geometry in parametric systems must usually be deleted and re-created when constraints are modified, such as changing a perpendicular constraint to an angular constraint as illustrated in Figure 3. This can become particularly troublesome on large models or assemblies where it is common to have several hundred constraints. We have observed users of parametric systems simply scrapping the old model and starting from scratch when major topological changes or constraint surgery became necessary.

Recommendations — Because of its inherent flexibility, geometry creation and editing productivity advantages, we believe that variational technology offers a more robust modeling approach for most users, particularly those designing more complex parts (0.8 probability). Until recently, the variational modelers were not nearly as plentiful or easy to use. Today, however, the advances in ease of use by a company such as SDRC with its new I-DEAS Master Series make variational modeling a viable commercial choice. In addition to SDRC, there is a growing list of vendors lining up behind variational technology, including Applicon, Computervision (Bedford, Mass.), Dassault (Paris), EDS (Maryland Heights, Mo.), Intergraph Corp. (Huntsville, Ala.) and Matra Datavision Inc. (Tewksbury, Mass.). While most of these companies' systems are still not as easy to use as PTC's, there is safety in numbers. Users who have simple prismatic parts that do not require a great deal of modification may still want to consider parametric modeling but should carefully weigh the performance trade-offs against the real potential that the models may have to be scrapped if major modifications are required.

PTC Alert
With the recent ease-of-use improvements in variational technology, and because variational systems are becoming more firmly entrenched within the market, we think there is sufficient cause to question the viability of PTC's parametric modeling approach. We believe that PTC may have to eventually perform major surgery or even rewrite its modeling foundation to remain competitive with the coming onslaught of variational systems (0.6 probability).

One Solution

I-DEAS Variational Analysis can greatly improve both the quality and speed of redesign. By evaluating interactively the effects of changes for various parameters (e.g., geometry, physical and material properties), it allows you to find the combination of design changes that satisfy the performance criteria and the objectives for the structure without having to perform multiple simulations.

Although requiring only one solve, I-DEAS Variational Analysis provides you with the flexibility to perform three different types of analysis:

- Standard Analysis - It is often useful to perform a standard analysis before a sensitivity or a parametric analysis. After a standard analysis, if the parameters are well known, and if the number of design variables is reasonable, you can directly perform a parametric analysis. But if the main parameters of the structure are unknown and the structure is a full new design, it is useful to perform the sensitivity analysis.

- Sensitivity Analysis - Sensitivity Analysis deals with a large number of parameters (up to 50) to enable the designers to find all the interesting parameters. I-DEAS Variational Analysis uses a polynomial expansion of the results versus each parameter for the original value of the other

- Parametric Analysis - Parametric Analysis deals with a reasonable number of parameters to enable you to find the best possible mechanical design. I-DEAS Variational Analysis uses a multi-parameter polynomial expansion of the results. The results are available for all the ranges of all the parameters. All the parameters can be modified simultaneously. It is a fully coupled analysis. Using the parametric results, you can then perform several optimizations interactively.

Easy to Use

To perform a variational analysis, you define a mesh and apply boundary conditions, just as you would for a traditional analysis. Next, you solve the model and create a variational results set. You can then interactively modify parameters and have the results immediately available, allowing you to create digital design handbooks. These design handbooks allow the non-specialist to make design decisions, fully aware of how those decisions will impact performance.

Post-Processing

Display and management of result data is also provided. Once you get the results, you can plot the results as an XY function or histograms, or use the Visualizer to see the results as a contour plot display.

- XY Graphing -You can display, review, and manipulate all results using extensive XY graphing capabilities. Results include:

- Displacements
- Stress and strain
- Strain energy
- Element forces
- Reaction forces
- Mass
- Eigen frequency
- Modal shape
- Mode tracking

- Histograms -You can weight parameters with respect to one or several scalar criteria. You can then use Histograms to sort out the parameters by displaying the weight in decreasing or increasing order.

Visualizer - You can use the Visualizer to review and make decisions about your results. The Visualizer enables you to view multiple results simultaneously, and allows you to easily print the display. Using the Visualizer, you can:

- Display contour plots.
- Create element displays.
- Display arrow plots.
- Review deformed geometry.
- Animate results.