Parametric Design Analysis for Evaluating a Range of Variables

Tools help to study engineering trade-offs in Simulation Driven Product Development.

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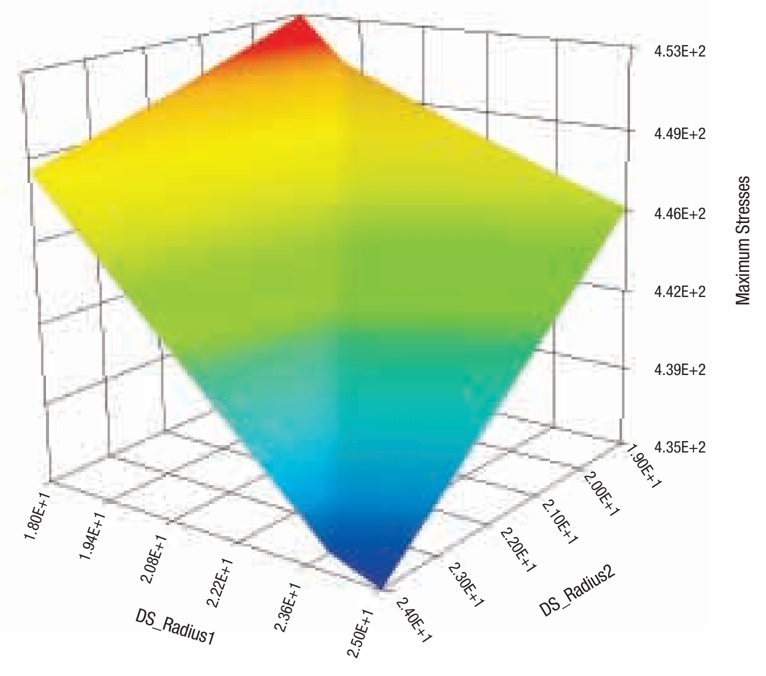
A major challenge in product development is balancing competing engineering requirements. Components often must be lightweight yet strong enough for maximum durability, for example. Users are thus faced with the tedious and time-consuming task of running multiple simulations to find a solution that satisfies most of the requirements.

Fortunately, tools are available to help designers perform parametric analyses in which simulation software automatically solves for entire ranges of specified variables and generates displays that enable users to readily spot trends and identify an optimal design. By clearly showing the relationship of multiple variables and their effect on performance, parametric analysis can guide the product development process to a design configuration that might not have been considered with pure point–solution simulation or that would have proved too time-consuming if individual analyses were manually performed.

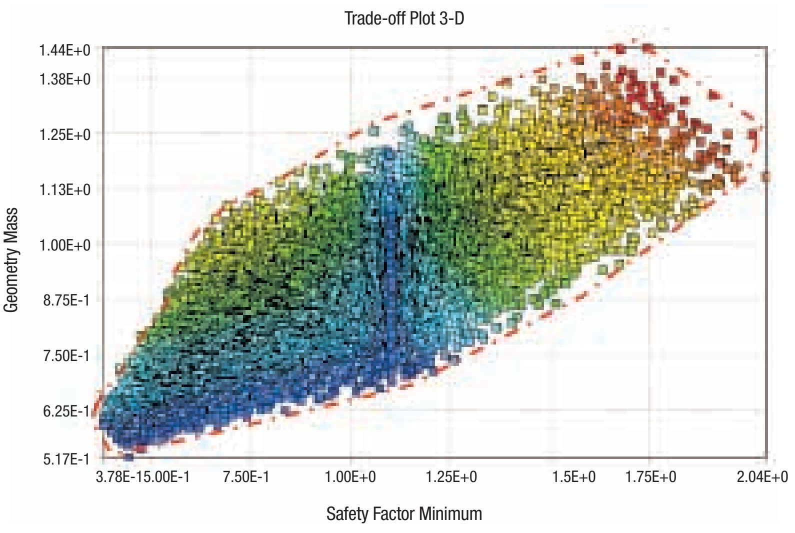
Geometric Parameters: A Key to Design Variations

A wide variety of parameters, such as material properties, can be varied to study the impact of those changes on the design, but a major source of variation is the geometry itself. While parametric computer-aided design (CAD) models have existed for decades, very few simulation tools allow them to be used effectively. Some tools, such as the ANSYS Parametric Design Language (ADPL), allow users to create parametric geometries, though the time required to set up such a model increases significantly with the complexity of the geometry.

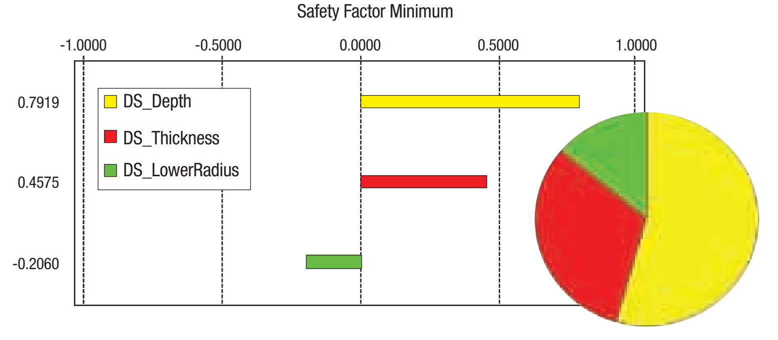
Typically, one of the most efficient ways of dealing with geometric parameters is provided by the ANSYS Workbench platform, which enables parameters of the CAD model to be driven directly from simulation. The ANSYS interface for major CAD systems not only reads in the geometry data but also imports the geometric parameters, along with attributes or material data in some cases. In this respect, the ANSYS Workbench environment provides an easy solution for defining and



Response surfaces, like this one, enable users to clearly visualize the complex relationship between multiple input and output parameters in parametric analysis studies.



In this trade-off plot, the red-dotted contour shows the boundaries of the design space. All feasible designs are within this boundary.



Key parameters in this sensitivity chart are readily identified by the importance of their effect on the performance. In this example, thickness and depth have the biggest influence on the safety factor.

performing parametric analyses. The additional amount of work required to move from a single point simulation to a full parametric analysis is no more than a dozen mouse clicks.

Benefits of Parametric Design Analysis

Parametric analysis is an excellent way to get accurate information about the influence of all parameters on the design objectives, such as system performance with respect to stress, heat flow, mass flow and other variables. With this information, the design team can make informed decisions throughout product development, especially in the early conceptual stage. As a consequence of the parametric analysis, the design team also can react quickly to any modification due to external constraints (for example, manufacturing) and can easily answer any "what if" questions.

Data Representation

Data representation is crucial in order to maximize the benefit of a parametric analysis. Tools such as ANSYS DesignXplorer software are based on response surface methods (RSMs) that help allow users to readily visualize and evaluate performance variations over the entire design space. Such approaches can be applied to any simulated physics applications including structural, computational fluid dynamics and multiphysics analyses. These methods are efficient in terms of computation time, since they use a limited sampling of the parametric space to build the response surfaces, which depict the mathematical relationship between input and output parameters. These 3-D color-coded contours readily convey large amounts of data that would otherwise be overwhelming to decision-makers, who will more easily be able to interpret a simple curve or plot than a list of numbers.

Among other graphical representations, the trade-off plot is probably the first to be considered. It represents the feasibility of a given design: A large sampling (10,000+ points) is performed on a response surface and performances of design variables are plotted. The accompanying trade-off plot indicates, for example, that for the product under analysis to be designed with a safety factor of 1.0, product mass will be in the range of 0.6 and 1.2 kilograms. If the product requirements specify a mass of 0.5 kilograms, therefore, one can see that there are no design solutions that can maintain a safety factor of at least 1.0 at that mass and with that specified design. A new design would have to be generated. On the other hand, if the product requirements specified a mass of 1.0 kilograms, the engineer knows that there is at least one solution. Other tools then exist to help users find the right specific solutions.

Simple 2-D plots (single or multivariate) are the easiest graphs to understand and convey information about the variation of performance with respect to the design variables. Sensitivity charts (bar or pie charts) also provide immediate information about the weight of each of the design variables on the product performance. They enable the engineer to identify the key parameters and know where the focus should be. This type of approach helps to reduce and eliminate time or money wasted on variables that do not influence the design. ■