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# Design for Six Sigma Solution

## Six Sigma Analysis in Three Steps

*Comprehensive characterization of the behavior of a product (a part or an assembly of parts) under operating conditions can be achieved in three steps:*

**Perform initial simulation:** A product is analyzed under all operating conditions. The model can simulate a single physics or complex multiphysics that involve multiple conditions and physics coupling. Design variables are then identified, including CAD parameters, loading conditions and material properties. Performance indicators such as maximum stresses, fluid pressures, velocities, temperatures and masses are chosen from the simulation results or are custom defined. Product cost, for example, can be chosen as a custom-defined parameter based on masses and manufacturing constraints.

**Identify design candidates:** Considering all design variables as deterministic parameters varying between a minimum and maximum value (thus defining the design space), a response surface is created for each performance indicator based on a DOE sampling of the design space. The design can be thoroughly investigated using a variety of graphical and numerical tools and valid design points identified by optimization techniques.

**Assess robustness of the design points:** Once one or several design points have been identified, the probabilistic analysis will help quantify the reliability or quality of the product by means of a statistical analysis. Probabilistic analysis typically involves four areas of statistical variability: geometric shape, material properties, loading and boundary conditions. For example, the statistical variability of the geometry of a product would try to capture product-to-product differences due to manufacturing imperfections quantified by manufacturing tolerances. Probabilistic characterization provides a probability of success or failure, not just a simple yes-or-no evaluation. For instance, a probabilistic analysis could determine that one part in 1million would fail or the probability of a product surviving its expected useful life.

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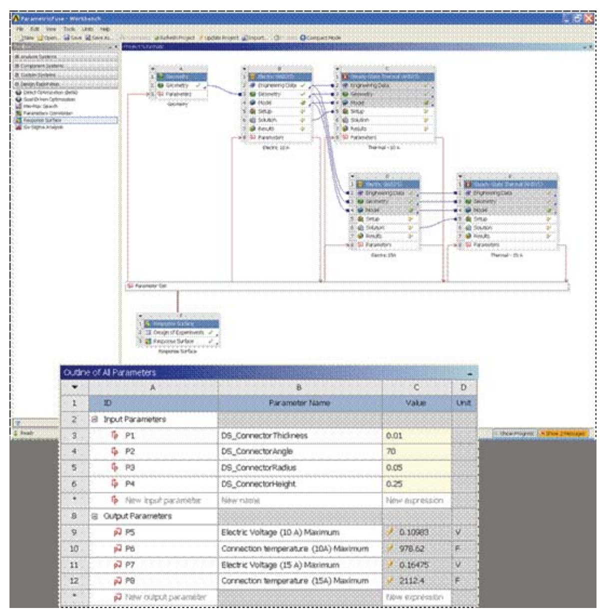
## Quantify the Quality of Products with ANSYS® DesignXplorer™

Design for Six Sigma (DFSS) builds quality into a product. By assessing the variations that a product experiences during manufacture and use, it is possible to optimize a product that performs its intended function regardless of these variations; such a product is "robust," and, therefore, Design for Six Sigma is sometimes called Robust Design.

Design for Six Sigma is an analysis technique used to determine the extent to which uncertainties in the model affect the results of an analysis. Based on a probabilistic characterization, Design for Six Sigma enables users to quantify the quality of a product by addressing issues such as minimizing warranty costs and assessing the reliability of the product. DFSS goes one step further than a probabilistic characterization by allowing users to optimize design variables to achieve a particular probabilistic result such as Six Sigma, which, including long-term effects, is 3.4 failures in one million parts.

Six Sigma initiatives attempt to optimize the manufacturing process so that it automatically produces parts conforming to Six Sigma quality. In contrast, DFSS optimizes the design itself so that the part conforms to Six Sigma quality even with variations in manufacturing. Quality is an explicit goal of the optimization.




**Design exploration setup of a multiphysics model**

### Design Exploration for All Physics

ANSYS offers an unparalleled breadth of solutions across a broad range of disciplines that can accurately address the fluid, structural, electromagnetic and thermal modeling of any product. Through the combined use of ANSYS DesignXplorer software and the comprehensive multiphysics solutions from ANSYS, Six Sigma analyses are available for virtually every simulation. ANSYS DesignXplorer supports all physics available from ANSYS® Workbench™ schematics: structural (both implicit and explicit), fluid flow and multiphysics. The technology also supports combined analyses in which multiple physics are analyzed independently or in a coupled manner.

## ANSYS DesignXplorer Product Features

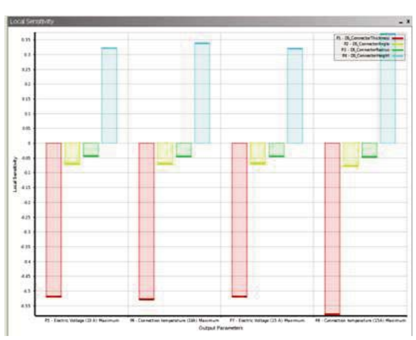
ANSYS DesignXplorer software has a powerful suite of DOE schemes: central composite design (CCD) or optimal space-filling. CCD provides a traditional DOE sampling set, while the objective of optimal space-filling is to gain the maximum insight with the fewest number of points. This feature is very useful when the computation time available to the user is limited.

After sampling, ANSYS DesignXplorer software provides four different meta-models to represent the simulation's responses: full second-order polynomial, Kriging, non-parametric regression and neural network. These meta-models can accurately represent highly nonlinear responses such as those found in high-frequency electromagnetics.

Once the simulation's responses are characterized, ANSYS DesignXplorer software supplies three different types of optimization algorithms: screening (shifted Hammersley), multi-objective genetic algorithm (MOGA) and nonlinear programming.

Several graphical tools are available to investigate a design: sensitivity plots, correlation matrices, curves, surfaces, trade-off plots and parallel charts with Pareto front display, and spider charts.

Correlation matrix techniques are provided to help the user sort the key parameters from a design before creating response surfaces.

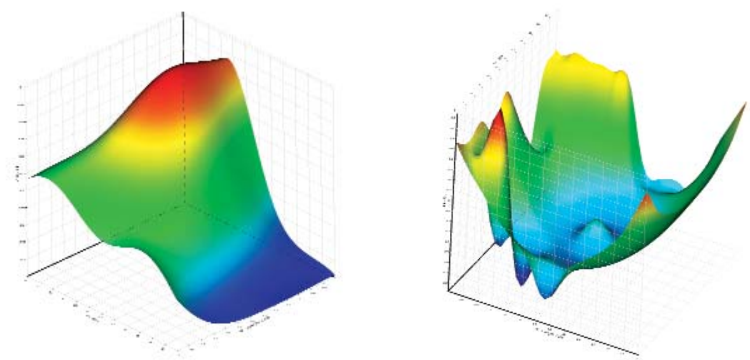


**Local sensitivities**

### Design of Experiments and Response Surfaces

Achieving a good design often means making tradeoffs between various objectives, and the exploration of a given design cannot be performed exclusively by using direct optimization algorithms that lead to a single design point. It is important to gather enough information about the current design to be able to answer "what-if" questions and quantify the influence of design variables on the performance of the product in an exhaustive manner. In doing so, the right decisions can be made based on accurate information, even in the event of an unexpected change in the design constraints.

ANSYS DesignXplorer technology provides a description of the relationship between the design variables and the performance of the product by using Design of Experiments (DOE) combined with response surfaces. DOE and response surfaces provide all the information required to take advantage of Simulation Driven Product Development™. When performance variations due to design variables are known, it is easy to understand and identify all changes required to meet the product requirements. Once the response surfaces are created, information about curves, surfaces, sensitivities and other variables can be shared in terms that are easy to understand and that can be used any time in the product development cycle without requiring additional simulations to test a new configuration.



**Response surface plots**

### The ANSYS Advantage

With the unequalled depth and unparalleled breadth of engineering simulation solutions from ANSYS, companies are transforming their leading edge design concepts into innovative products and processes that work. Today, 97 of the top 100 industrial companies on the *"FORTUNE* Global 500" invest in engineering simulation as a key strategy to win in a globally competitive environment. They choose ANSYS as their simulation partner, deploying the world's most comprehensive multiphysics solutions to solve their complex engineering challenges. The engineered scalability of our solutions delivers the flexibility customers need within an architecture that is adaptable to the processes and design systems of their choice. No wonder the world's most successful companies turn to ANSYS — with a track record of almost 40 years as the industry leader — for the best in engineering simulation.

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GSA Contract Holder

ANSYS, Inc.
Southpointe
275 Technology Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com

Toll Free U.S.A./Canada:
1.866.267.9724
Toll Free Mexico:
001.866.267.9724
Europe:
44.870.010.4456
eu.sales@ansys.com