FORD MOTOR COMPANY

Little things can make a huge impact on quality

2009 Ford Flex

Although variety is the spice of life, it's the bane of manufacturing companies. Designers and engineers must account for inevitable variation, minute or otherwise, in products coming off the manufacturing line. Some companies, like Ford, prepare for variation from the start of their product development cycle. Others cross their fingers, start manufacturing, and clean up the mess later.

To understand the problems that variation can present, one must remember that nothing manufactured is ever perfect. Computer-aided design (CAD) data represents theoretical nominal design intent—the ideal—not the actual quality or performance of the product that is shipped to the customer. CAD does not manufacture anything; real-world manufacturing and assembly processes do. The fact that a design looks right in CAD doesn't mean it's going to build right in the plant.

A product as simple as a one-inch diameter cylinder is never exactly one inch in diameter in real life. It comes out of the factory slightly thick, thin or out of round. Depending on the product designer's specified tolerances (and the plant's capability), the variance can be so dramatic that, when combined with other variable parts, the resulting product fails.

Risk looms with every design. By some accounts, as much as half of scrap and rework stems from poor tolerance and variation management. And companies spend enormous sums on the cost of poor quality, including redesign, engineering change orders, recalls, warranty, liability, release/launch delays, chronic manufacturing problems, and tarnished brand names. An estimated eight out of 10 Six Sigma "critical to quality issues" boil down to controlling dimensional variation.

"It's one thing to take a calculated design risk and come up short," explains Bob Gardner,

Challenge:

Uncontrolled dimensional variation can lead to costly scrap, redesign, and brand damage.

Solution:

Sigmund software helps Ford analyze tolerance and assembly builds during the design stage.

VARATECH® Sigmund
Design & Build Quality are Predictable

SOLIDWORKS

CEO of Varatech, a company that has created tolerance and assembly build analysis software called Sigmund® to address the problem. "It's another if you are totally blind-sided with problems at launch because of lack of insight on various critical relationships between variable parts. This is what happens if quality build objectives are not defined up front and tolerance data, if any, is simply sprinkled on arbitrarily at the end of a design. This situation can be very expensive."

Making design and product build quality predictable

It's critical to define quality build objectives up front, according to Gardner, who defines them as important assembly relationships that will affect fit, finish, and function. Ask yourself: what are the important traits of your product that translate into quality? For the body of a luxury car, one indicator of quality might be that a ball bearing can roll smoothly along the seams every time. That would be a quality build objective. Quality build objectives influence how the product will perform and how problem-free it will build in production.

Leading engineering teams derive quality build objectives from sources like competitive assessment, benchmark studies, marketing requirements, quality functional deployment (QFD) analysis findings, user requirements, failure analysis, and manuals like the Machinery Handbook for mechanism relationships.

Once quality build objectives are identified and quantified to produce measurable targets, these targets will drive the design. For example, Ford Motor Company uses Varatech's Sigmund in fork-in-the-road studies to determine which of several design concepts are most capable or robust relative to variation, geometric sensitivity, and meeting the pre-defined quality build objectives. Quality build objectives determine which Sigmund-powered studies are required—Worst Case, Modified RSS, and Monte Carlo Tolerance. These studies traditionally have been performed by hand or spreadsheet, without any linkage to the CAD software used in the design, making it arduous to develop, update, and maintain all tolerance/variation information. Sigmund, by contrast, makes it easy for designers to demonstrate with objective CAD-driven data that the design is capable of meeting all quality build objectives before design/tooling release. Teams can avoid all the delays and significant cost associated with poor quality from the start, and have a reference base to return to if necessary.

Ford: quality design is job one

Ford uses Sigmund with SolidWorks® 3D CAD software to ensure superior quality. Glenn Reed, a Ford mechanical technical expert based in Dearborn, Michigan is a power user. He uses SigmundWorks, Sigmund ABA and SolidWorks software to check new designs from global suppliers and staff engineers for infotainment systems, including DVDs, CDs, and radios. He ensures they meet functional intent and build objectives prior to tooling release.

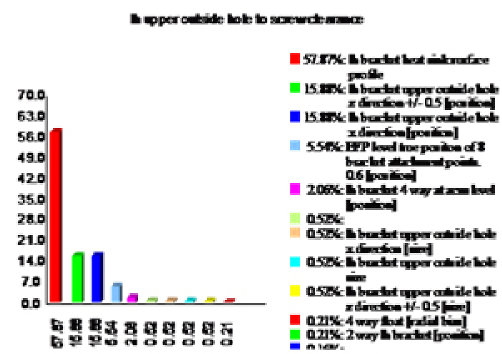
Reed starts work on a design by importing an IGES, STEP, or Parasolid file into SolidWorks software. "SolidWorks software is a powerful tool for importing designs—whatever the source— cleaning them up, and making them parametric using FeatureWorks®," he says.

Then he turns to SigmundWorks, Varatech's analysis product for SolidWorks software. As a Certified Gold Product, SigmundWorks is fully integrated with SolidWorks software and operates within its interface. To evaluate quality, Reed runs through thousands of what-if scenarios at a time, tweaking dimensions, tolerances, and variations at will.

"SigmundWorks helps us define and understand our build requirements from the outset," Reed says. "We understand the downstream impact of each feature, dimension, and tolerance in a design on the cost, complexity of manufacturing, and assembly."

"WHAT SIGMUND IS REALLY DOING IS ORCHESTRATING PRODUCT DEVELOPMENT." "OPINIONS TOO OFTEN SET PRODUCT DIRECTIONS, BUT OBJECTIVE DATA TRUMPS OPINION. WITH OBJECTIVE DATA, THERE'S NOTHING TO ARGUE ABOUT."

Glenn Reed
Mechanical Technical Expert
Ford Motor Company

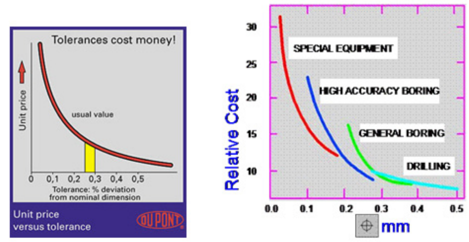


As shown in this Sigmund Sensitivity-Pareto Chart, only a few tolerances contribute to most of the variation. The tolerances that are to the right or don't show up may be opportunities for ***Cost Savings***!!!

The goal is to understand where precision is needed and where it is not.

Sigmund in action at Ford

For example, Reed used SigmundWorks to conduct hole-pattern-to-screw-boss-pattern studies on an interface between the electronic finish panel (EFP) and center finish panel (CFP) in the 2009 Ford Flex. The studies were designed to ensure the parts assemble together successfully and maintain uniform spacing around the buttons.



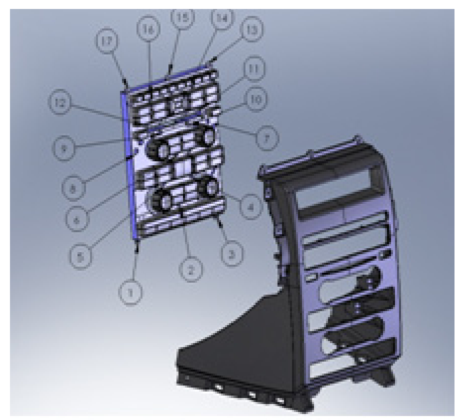
Cost of Precision Graph—*Tight Tolerances Drive Very High Costs*

The EFP is located to the CFP using a two-way locator and a four-way locator and secured with 17 fasteners. The initial SigmundWorks hole pattern match analysis showed problems with five percent of the assemblies using original 3mm diameter screw holes in the EFP. The holes were incrementally increased to 3.8 mm using the pattern match analysis until 100 percent projected build was achieved. “This type of hole-to-pin match analysis is virtually impossible to do by hand,” Reed says, “With Sigmund, we simply derived what was needed from a size and positional tolerance viewpoint to ensure proper assembly. It was easy and very fast.”

In another case, Ford was able to validate that a CD player assembly was performing as intended—except when operated with discs that were excessively warped. Even though exposing a disc to heat or sunlight is technically the customer’s fault, Ford used SigmundWorks and SolidWorks software to alter dimensions of the disc guide to make the system more robust to ensure proper disc loading and ejecting with slightly warped discs. Ford thus avoided even the perception of a design flaw.

In another instance, Ford discovered slightly wobbly radio knobs on a new car model that was just about to be launched. It’s a small matter with absolutely no impact on function, but it makes a large impact on perceived quality. Using Sigmund ABA assembly build analysis software, Ford pinpointed a hidden “geometric sensitivity” in a tiny clearance between two mating parts that was the culprit. In other words, a small gap created a large wobble because the assembly relationship magnified its impact (think of how a minor cant of the wrist can move the tip of a sword by a few feet). Ford was able to identify and easily close another feature interface to reduce the wobble. Objective data from Sigmund analysis provided confidence to modify the production injection mold tooling.

Ford typically runs at least 5,000 Sigmund-powered virtual simulated builds on an assembly design. It’s as if the plant were building 5,000 prototypes, all slightly different based on all possible combinations of variations within permitted tolerances. Sigmund then plots a histogram of the builds. If, in an early design, 20 percent of the builds fail, the edges of the histogram show the out-of-spec builds in red. Blue means within spec. Sigmund has is the ability to identify nominal design mistakes and assembly process mean-shifts in advance.



Uniform spacing achieved. 100 percent projected build.

It’s compelling to see Sigmund animate an assembly design. The powerful software cycles through thousands of virtual builds, vividly illustrating all the possible variations—minute and not so minute—that can affect the finished component. It’s a dramatic representation of how perfection in design is a myth in production.

More examples

Ford also uses Sigmund to complement other types of analysis, including finite element analysis (FEA). FEA geometry is typically based on a nominal model that will never exist. Adding real-world component and assembly variation to FEA geometry minimizes the typical difference between simulation results and testing. Sigmund considers real-world component and assembly variation and provides realistic representations of deviated real-world manufactured geometry. Sigmund therefore enables the development team to analyze what is actually going to be produced for more accurate representations of product performance as it leaves the plant door.

The example at left of a sheet metal radio chassis shows how original tolerances permit a non-square box that can create mechanism issues. FEA analysis (using NEiWorks) of the radio chassis enclosure's nominal geometry showed one result. Sigmund real-world deviated enclosure geometry caused the FEA results to be significantly different. Once manufactured, the compound effects of variation and loading on assemblies could put a significant number of these chassis out of square and onto the scrap heap. Ford was able to head off the problem with a quick tweak to its design.

"At Ford, Sigmund drives concept evaluation, design, material selection, quality program, supplier, and process selection," Reed says. "In fact, Ford has created a new rule affecting all suppliers. Prior to tooling release, suppliers must conduct Worst Case, Modified RSS, and Monte Carlo Tolerance studies using simulation software to demonstrate build objectives. It goes without saying that I like the idea."

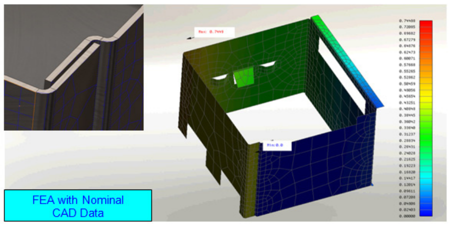
Although it takes some time and effort to perform tolerance and assembly build analysis at the outset of a project, that effort pales in comparison to the cost and effort of scrap, rework, warranty claims, and recalls.

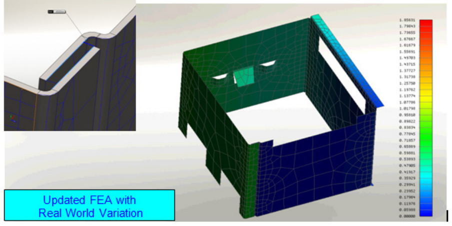
"What Sigmund is really doing is orchestrating product development," Reed says. "Opinions too often set product directions, but objective data trumps opinion. We can now say, 'Here are designs A, B, and C and the accompanying Sigmund studies. As you can see, Design B won't meet the objective, so you've got to relax your quality standard or pick between A or C.' With objective data, there's nothing to argue about."

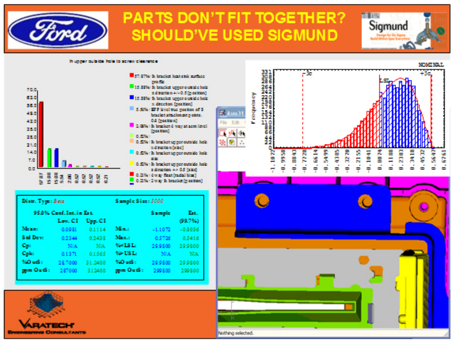
SigmundWorks is a Certified Gold Product, Sigmund ABA for SolidWorks software and Sigmund ABA Kinematics for SolidWorks software are Solution Partner products. Ford relies on Varatech and authorized SolidWorks software reseller DASI Solutions for ongoing software training, support and implementation.

For more information, visit:

www.dasi-solutions.com
www.ford.com
www.solidworks.com
www.varatech.com







The figure above shows typical Sigmund reporting:

1) View of documented build objective, which can also be an inserted AVI showing the animated variability of the assembly.
2) Statistics report providing top-level information like percent out of spec, Cpk, and PPM, or "parts per million" for Six Sigma, along with advanced statistical data.
3) Build objective sensitivity study providing ranking order (by percent contribution to the objective) of all component tolerances and assembly variations.
4) Graphic histogram indicating where the population of simulated values occurred relative to their specific build objective spec limits. The histogram also reveals the distribution type and indicates whether a mean-shift exists, which can often be caused by assembly process.

Ford Motor Company
Address: Customer Relationship Center
P.O. Box 6248
Dearborn , MI 48126
Phone: 1 800-392-3673
www.ford.com

Dassault Systèmes
SolidWorks Corp.
300 Baker Avenue
Concord, MA 01742 USA
Phone: 1 800 693 9000
Outside the US: +1 978 371 5011
Email: info@solidworks.com
www.solidworks.com