mechanical engineering

feature article

neatness doesn't **count**

The design for a fuel cell confronts the fickleness of the real world.

This article was prepared by staff writers in collaboration with outside contributors.

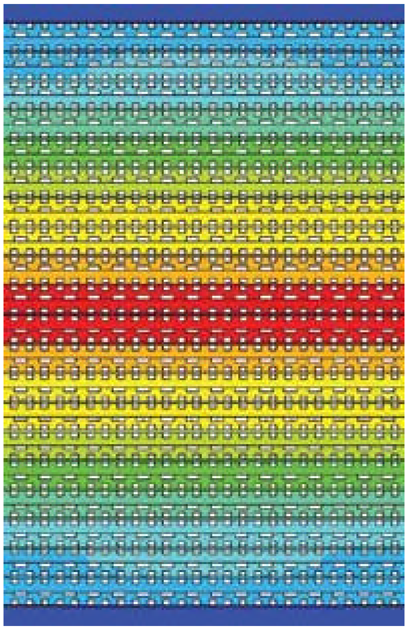
It started like a lot of projects, with a few coincidences. A fuel cell developer in Latham, N.Y., needed to know that its latest product could tolerate the randomness of commercial manufacturing. A couple of its engineers went to a technical conference where they heard an engineering consultant from Castle Rock, Colo., talk about probabilistic design. Meanwhile, the National Renewable Energy Laboratory in Golden, Colo., was turning its attention to probabilistic techniques for developing energy devices.

It came together as an experiment funded by the Department of Energy to use virtual prototyping and Six Sigma methods to understand the effects of mechanical design on the electrical performance of a fuel cell.

Plug Power Inc., working on a propane-fed fuel cell called GenSys, wanted a robust design—one that could perform as needed despite inevitable variations in materials and assembly. Company engineers turned to the consultant they had heard, Andreas Vlahinos, who operates Advanced Engineering Solutions LLC, to explore the latest design.

Vlahinos used finite-element simulations to predict how the product design would turn out in the randomness of the real world, where materials, parts, and connections are never exactly the same.

According to Vlahinos,



Above is a section of the finite-element model of the stack, rendered in Ansys software.

an ASME member and former professor at the University of Colorado, "Probabilistic design techniques have enormous positive impact on reducing product costs. This becomes obvious when the total product cost is considered to include the costs of poor quality."

Vlahinos worked with Kenneth Kelly, who heads the virtual prototyping efforts in the Center for Transportation Technologies and Systems at the DOE's National Renewable Energy Laboratory, and with two engineers from Plug Power, Jim D'Aleo and Jim Stathopoulos. Stathopoulos, who is quality systems manager for Plug Power, refers to himself as a Six Sigma "Black Belt," and so was on familiar turf. The DOE provided funding under two programs, the FreedomCAR and the Hydrogen, Fuel Cells, and Infrastructure Technologies Program.

The team chose four variables for a study of the stack, the heart of the fuel cell where hydrogen flows to generate electricity. Variations were predicted in the thickness of the bipolar plates and the proton exchange membranes, the elasticity of the plates, and the load of the bolts that hold the stack together.

A fuel cell outside Plug Power's headquarters.

According to Vlahinos, the bolts, for instance, could have a significant effect. At one extreme, if they squeezed too much, they could close off the stack and keep hydrogen from flowing through the membranes to produce electricity. The other extreme would be that they didn't squeeze the stack enough, and there would be no conductivity.

The big question, he said, was, "How much variation can you get away with?"

The iterations of the virtual experiments were done automatically by software called Probabilistic Design System, from Ansys Inc. of Canonsburg, Pa. The software ran nine experiments, from which it was able to extrapolate 10,000 data points to predict a range of manufacturing variations.

Results, published in a paper delivered at the ASME fuel cell conference last April, showed that compressive stresses on the membranes at the top and bottom of the stack were as much as 30 percent greater than stresses at the middle. According to the team, the standard deviation was five times greater at the top and bottom than it was in the middle. They reported that the majority of membranes appeared to be largely insensitive to manufacturing variations.

Plug Power has introduced the GenSys 5P, a 5 kW fuel cell system that runs on liquid propane.

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