Cooling Down Powered-Up **Fuel Cells**

Researchers use probabilistic methods and design optimization to improve heat-transfer characteristics of fuel cell stacks.

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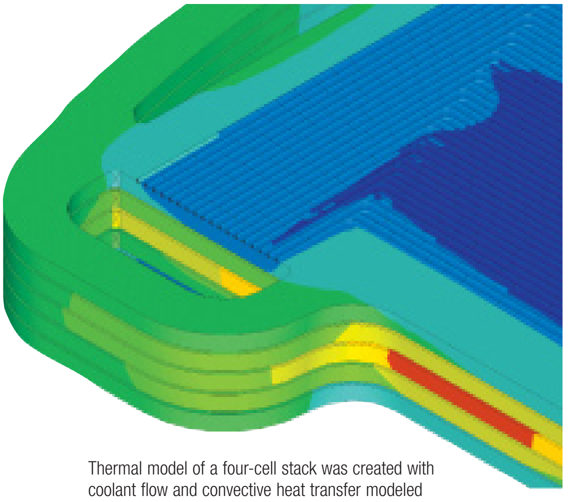
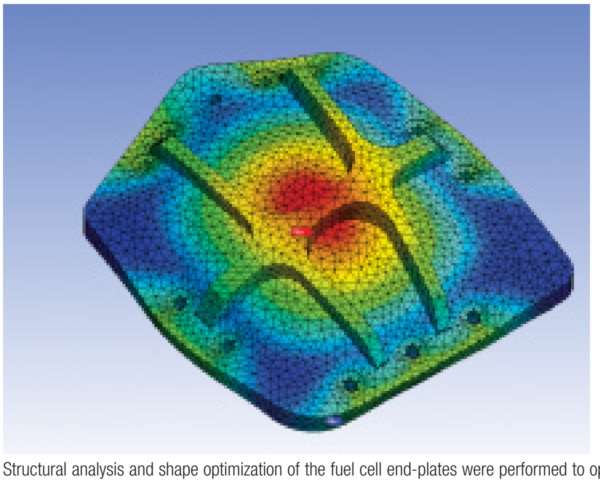
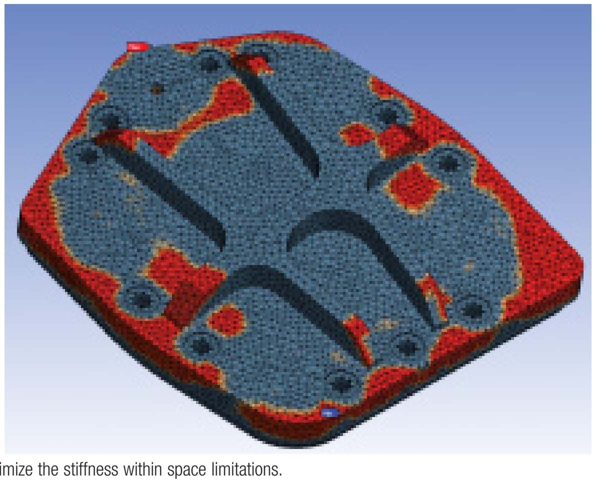


Thermal model of a four-cell stack was created with coolant flow and convective heat transfer modeled with pipe elements. Pipes also were used to model thermal contribution of air and hydrogen flow.

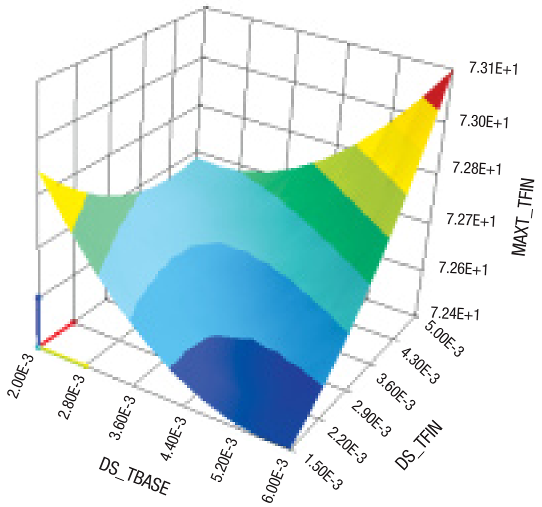
With pure water as the only byproduct, fuel cells are one of the most environmentally safe alternatives for providing power for vehicles and stationary applications: Stacks of the devices generate electricity directly from hydrogen and oxygen. One major concern in designing fuel cell stacks is dissipating heat created during the electrochemical conversion process. Thermal hot spots within the fuel cell stack may degrade performance, induce thermomechanical stresses and shorten the useful life expectancy of the stack.

Temperature distributions within the stack depend on many variables, including non-uniform heat generation, fluid properties and flow quality, fuel cell geometry, and the configuration of cooling plates between the cells. To arrive at a suitable design, engineers may resort to numerous prototype build-and-test cycles that are lengthy and costly — not to mention how they stifle innovation — because of the prohibitive time and expense of evaluating new ideas and what-if scenarios. These limitations can be alleviated somewhat with "deterministic" computer-aided engineering (CAE) methods that perform a series of individual analyses. Even in this scenario, engineers must run hundreds or even thousands of individual simulations to arrive at a satisfactory design.

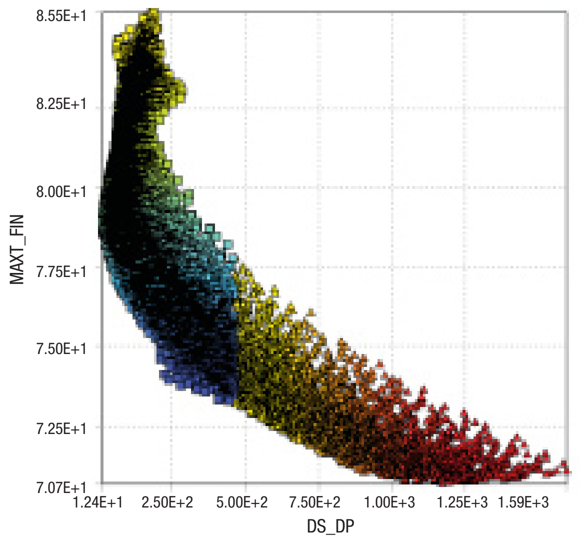




Structural analysis and shape optimization of the fuel cell end-plates were performed to optimize the stiffness within space limitations.



Response surfaces show the relationship between multiple variables, in this case visualizing the impact of fin thickness and base thickness on the maximum temperature of a cell stack.



After generating 10,000 virtual experiments, engineers create a scatter plot of performance requirements showing maximum temperature versus pressure drop. Dark blue squares represent data points that meet all design requirements and have minimal temperatures.

A more efficient way to optimize a design with many variables and uncertainty is to account for variation using advanced computational and probabilistic tools early in the design process. This approach is being used extensively on research for market-viable alternative energy solutions. In some of this leading-edge work, the ANSYS Workbench platform and ANSYS DesignXplorer software have been implemented for performing design of experiments in accounting for uncertainty and variation in materials, manufacturing and load conditions. Simulation tools also are used to streamline laboratory experiments by numerically evaluating the design space to assess and determine which variables have the largest impact on results. Laboratory tests validate the results and are fed back into the model to improve its predictive capabilities.

In one project studying fuel cell design, the engineering consulting firm Advanced Engineering Solutions, based in the United States, used an approach that was aimed at establishing optimal design methodologies for fuel cells. The company also was charged with improving product development time and costs by reducing the number of physical prototypes and laboratory tests required. In one case in particular, the research team used tools from ANSYS to develop a fuel cell stack thermal modeling process to assess design sensitivity on fuel cell thermal performance. The models were used to evaluate new cooling plate flow paths and to assist in the development of improved heat transfer characteristics.

The thermal modeling process incorporated an ANSYS Mechanical 3-D multi-cell stack thermal model that reflected real-world stack geometry and non-uniform heat generation in the membrane. ANSYS DesignXplorer technology was used for design space exploration and probabilistic design methods. Classical design of experiments techniques integrated with the model were used to define response surfaces and perform sensitivity and trade-off studies on heat generation rates, heat-sink fin geometry, fluid flow, bipolar plate channel geometry, fluid properties and plate thermal material properties. A Taguchi screening study was used to identify the most sensitive input parameters; robust design was used to understand the impact of variation on thermal performance.

Researchers at Advanced Engineering Solutions then used the ANSYS thermal model to develop an alternative coolant flow path design that yielded improved thermal performance. The team found that this approach shaved months off the development process and led to innovative designs through improved understanding of fuel cell behavior, especially the impact of a wide range of design variables. ■

References

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