ITW USES MULTIPHYSICS SIMULATION TO COOK UP SMART MICROWAVE OVEN DESIGNS

Engineers at ITW use multiphysics simulation and applications to analyze smart appliance designs, improving the tools kitchen professionals need to cook food faster and more evenly with solid-state, convection heating capabilities.

By **THOMAS FORRISTER**

WHAT MAKES AN ELECTRONIC DEVICE "smart"? Connectivity, certainly, is a large factor, and it is now commonplace to seamlessly switch from a phone or tablet to a computer using Bluetooth, wireless internet, or 4G LTE and 5G protocols. Another sign that earns the smart (and sometimes artificial intelligence) label is a device's computing capabilities, which help us more easily perform everyday tasks. Take the smart home concept, for example. Thanks to the broader software capabilities of many devices, consumers are now able to automate their lives and save energy costs by using robot vacuum cleaners and adjusting lighting and heating settings on a timer.

Inside the kitchen, appliances such as refrigerators, dishwashers, and microwave ovens with smart features are becoming part of daily life. Smart appliances also have a place in *professional* kitchens. By designing cutting-edge smart appliances for these professional spaces, Illinois Tool Works (ITW) Food Equipment Group, the world's largest commercial food equipment company, is revolutionizing the way chefs cook, manage their time during service, and build menus.

» *GENERATING MICROWAVES WITH SOLID-STATE TECHNOLOGY*

ITW PROVIDES INDUSTRIAL APPLIANCE PRODUCTS ranging from drink service refrigeration to hot holding equipment, and uses the COMSOL Multiphysics® software to build and distribute simulation applications, improving manufacturing processes and designs. One of their latest commercial offerings, IBEX (Figure 1), is a microwave and convection oven that is designed for the professional kitchen. The IBEX product includes a number of smart features and changes the way food is cooked by heating food differently than other smart combination ovens.

RF technology provides consistent performance during the varied load conditions required for cooking. Engineers at ITW are harnessing the power of RF energy with a solid-state RF power amplifier and receiver, which directs the energy in a smarter, more uniform, and more efficient way than with a traditional magnetron — depending on the type of food or how much food it is heating. This technology achieves the quality of a combination oven, but with a rapid-cook oven time.

The targeted heating capabilities help automate tasks for chefs and other kitchen staff. Aside from the efficiency of solid-state heating, the IBEX oven is able to use algorithms to help professionals program recipes and custom menus, as well as perform common functions as they go about their work. No smart device would be complete without the connectivity factor: The IBEX has a USB port to easily expand menus via upload or transfer.

Adding smart features helps kitchen professionals, but what about tools that aid in designing the equipment? "When trying to optimize food heating with microwave/RF energy, simulations can be used to gain an approximate understanding of what to expect," says Christopher Hopper, sr. RF systems engineer at ITW. "Using simulation to get an idea of the heating patterns available in a solid-state oven allows for a more informed experimental setup."

He adds that the team also saves on food and labor costs, because there

Figure 1. The IBEX solid-state microwave/convection oven by ITW.

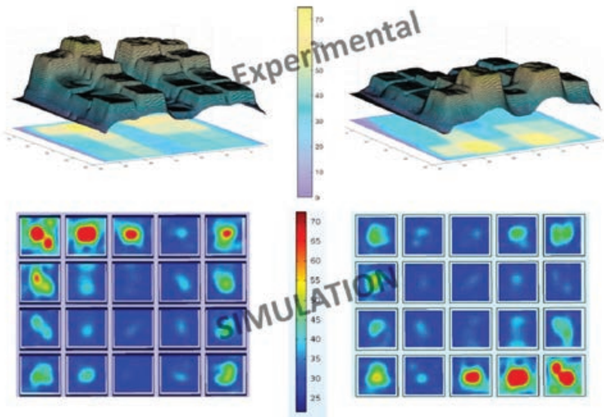

Figure 2. The improved uniformity when combining different heating patterns.

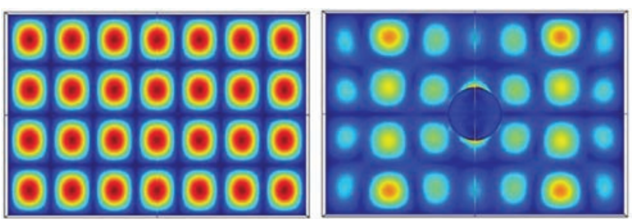

Figure 3. Electric field pattern comparison for loaded and unloaded cavity modes within a microwave oven.

are virtually no trial-and-error runs of an experiment — they can do it all ahead of time to find the optimal design for both the appliance and the related experiments.

WORKING SMART WITH A COMBINATION OF SIMULATION AND EXPERIMENTS

SETTING UP EXPERIMENTS by first using the COMSOL® software and add-on RF Module helps Hopper and his team study varying loads, uniformity, hot spots in the food, and more. Then they take advantage of LiveLink™ *for* MATLAB® to reduce computational time by combining parametric sweeps with complex postprocessing. Hopper finds this interfacing capability especially beneficial, as he uses the MATLAB® software extensively.

One of their important experiments considers the efficiency of the solid-state RF IBEX design. Hopper and his team were interested in how well the oven can maintain a high efficiency for different food containers that have varied volumes and load distribution, so they used simulation to help them test the containers and identify where there was room for uniformity improvement. A cubic arrangement of thin layers and an array of cylinder-shaped loads were compared. For each type of container, the solid-state oven could maintain highly efficient energy delivery to the load.

Current rapid-cook ovens on the market are unable to adjust parameters such as phase, frequency, and output power, which leads to large swings in efficiency when the load volume, distribution, and number of items change. Alternatively, the effectiveness of convection or combi ovens depends on the surface area of the load, so increasing the number of items does not necessarily lead to an increase in time required for cooking or reheating. In contrast, the IBEX oven's efficiency stays high for a multitude of load configurations, thus combining the quality of a combi/convection oven with the speed of commercial rapid-cook ovens.

However, simply having the ability to control frequency, phase, and output power is not enough to maintain highly efficient energy delivery. Instead, they relied on the closed-loop feedback system to evaluate opportunities for improving cooking configurations. Closed-loops, as opposed to open-loop-type ovens, allow the device to learn the initial conditions, apply specialized heating configurations, and adapt to the changing physical properties of the load during cooking. By using closed loops as a form of control, engineers can feed the system's generated output back into the system. By comparing the actual output with the desired output, they can design this type of system to automatically sense and monitor the difference in output via an error signal, and thus change the loads, food properties, and other conditions to improve the cooking process.

Using feedback from the cavity/load system, they are able to run tests to see that cooking configurations can be combined to improve uniformity and consistent energy delivery (Figure 2) while using less nominal power to achieve the same result.

From there, the team can continue to refine tests and confirm and understand the simulation results. "COMSOL Multiphysics® allows our team to perform accurate coupled electromagnetics and thermal simulations of food materials, or loads," says Hopper. "The properties of these loads change with temperature and frequency, and we have found that the software can account for these changes and provide good approximations for the heating pattern, electromagnetic field magnitude, and power loss density."

For example, when they create simulations of loaded and unloaded cavity modes, the team can see where hot spots are most likely to be located (Figure 3). Evaluating likely heating patterns and potential cavity and cookware absorption using simulation can assist them in structuring their experiments in which thermal and electromagnetic data will be collected using multiple frequencies (Figure 4). Furthermore, they can be sure that the simulation results are accurate by creating an intentional temperature difference between foods like bread and eggs.

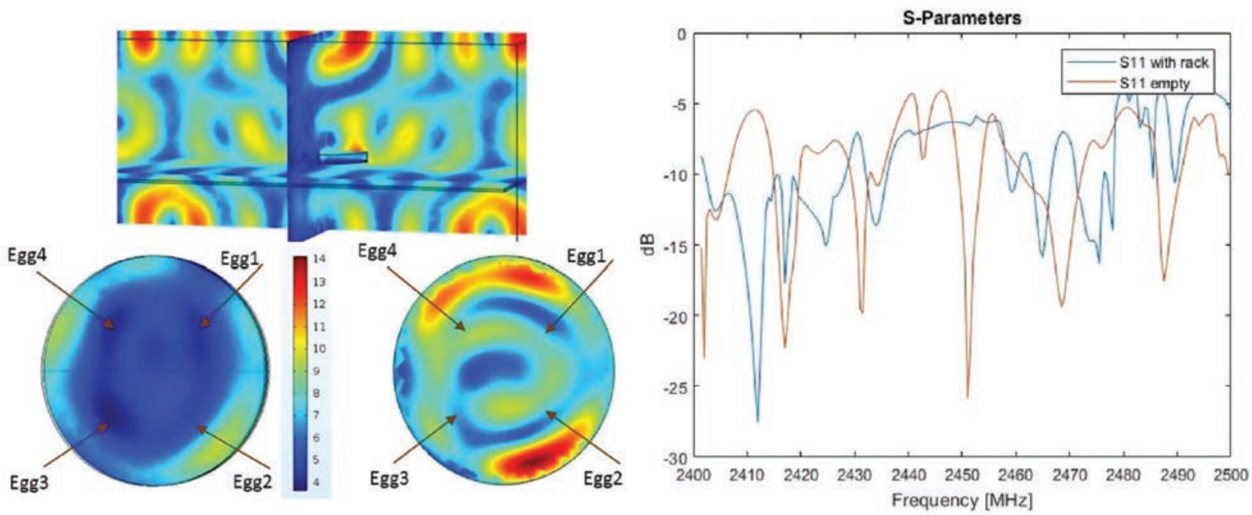

Figure 4. Left: The probe placement in the oven and eggs for collecting thermal and electromagnetic data. Right: S-parameters for an oven with and without a rack.

THE MORE COOKS IN THE SMART APPLIANCE DESIGN KITCHEN, THE BETTER

IN ADDITION TO MORE complex simulations, Hopper creates simulation applications so that colleagues are able to interact with the design by changing parameters such as frequency or phase response, temperature and time (in terms of recipe creation), sample size and location effects, dielectric properties, and more.

There are many advantages to deploying applications within an organization. "When working in a diverse team with different skill levels and backgrounds, I have found that tailoring applications to a person's interests and job duties lightens the workload on the simulation experts," says Hopper.

He also sees building simulation applications as an opportunity to educate others. In fact, some of the applications of the IBEX oven (Figure 5) have been created specifically to introduce new team members and interns to the basics of wave interference, dielectric and loss factor dependencies, and RF heating.

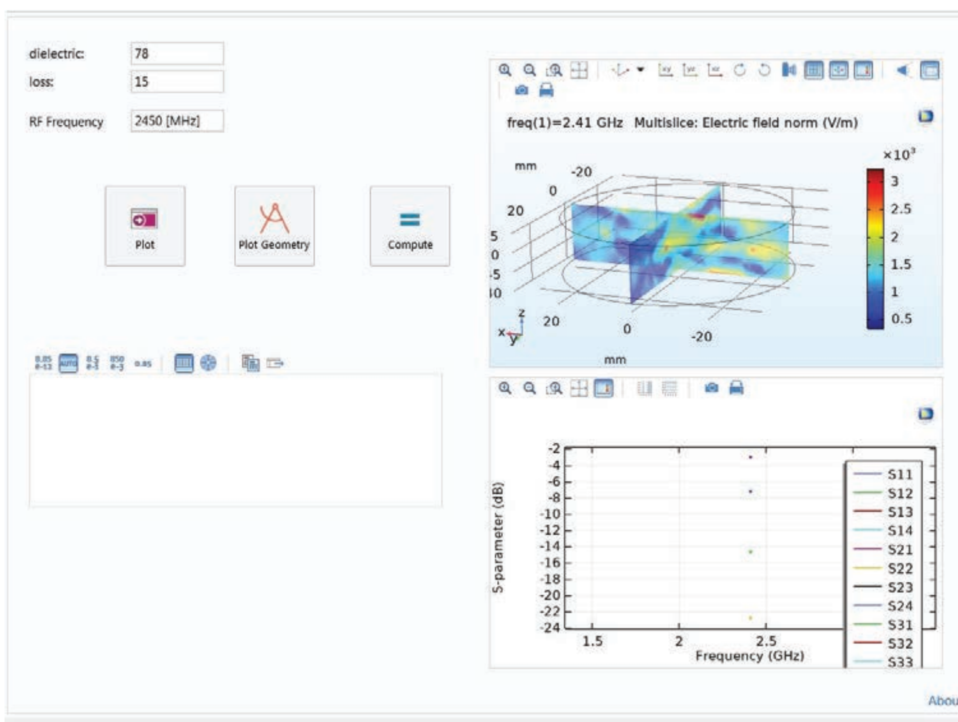

Figure 5. User interface for an IBEX oven simulation application.

Solid-state cooking devices present many promising advancements in the culinary arts, with targeted food heating being just one of them. By continuing to use important ingredients like simulation, applications, and postprocessing tools, engineers and manufacturers in the food equipment industry can design more efficient and reliable smart appliances for both professional and home kitchens. ◎