# SIMULATION TURNS UP THE HEAT AND ENERGY EFFICIENCY AT WHIRLPOOL CORPORATION

*Researchers at Whirlpool Corporation are using simulation to test innovative and sustainable technologies for new oven designs.*

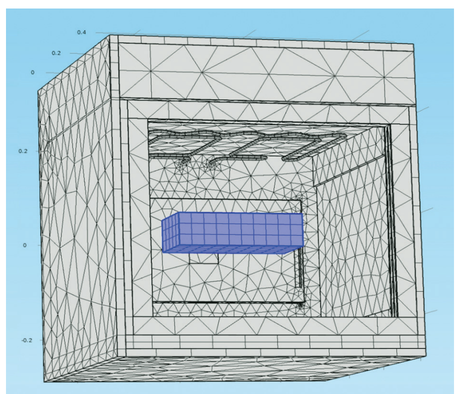

**FIGURE 1:** Left: Whirlpool's Minerva oven set up for the "brick test." Right: The meshed geometry.

By **ALEXANDRA FOLEY**

**IN TERMS OF** energy consumption, ovens have the most room for improvement of any appliance in the kitchen, with only 10 to 12 percent of the total energy expended used to heat the food being prepared. This is one of the reasons why Whirlpool Corporation, the world's largest home appliance manufacturer, is exploring new solutions for enhancing the resource efficiency of their domestic ovens. Using a combination of experimental testing and finite element analysis (FEA), Whirlpool engineers are seeking solutions to improve energy efficiency by exploring new options for materials, manufacturing, and thermal element design.

In partnership with the GREENKITCHEN® project, a European initiative that supports the development of energy-efficient home appliances with reduced environmental impact, researchers at Whirlpool R&D (Italy) are studying the energy consumption of their ovens by exploring the heat transfer processes of convection, conduction, and radiation. "Multiphysics analysis allows us to better understand the heat transfer process that occurs within a domestic oven, as well as test innovative strategies for increasing energy efficiency," says Nelson Garcia-Polanco, Research and Thermal Engineer at Whirlpool R&D working on the GREENKITCHEN® project. "Our goal is to reduce the energy consumption of Whirlpool's ovens by 20 percent." Even if only one electric oven is installed in every three households in Europe, the resulting increase in efficiency would reduce the annual electricity usage of European residential homes by around 850 terawatt-hours. This would lead to a reduction of about 50 million tons in $CO_2$ emissions per year.

## » LIGHT AS A FEATHER, NOT THICK AS A BRICK

**A LOAF OF** bread should be as light as a feather, not, as they say, as thick as a brick. Ironically, the standard test for energy consumption in the European Union, known as the "brick test," involves heating a water-soaked brick and measuring temperature distribution and evaporation during the process. "A brick is used since it offers a standard test for all ovens. The brick is created to have similar thermal properties and porosity as that of many foods, making it a good substitute," says Garcia-Polanco.

During the experiment, a wet brick with an initial temperature of 5°C is placed in the oven's center and is heated until the brick reaches a previously defined "delta" temperature (in this case, 55°C). The temperature and amount of water evaporated from the brick are recorded throughout the experiment. Using simulation, Garcia-Polanco and the team created a model of Whirlpool's Minerva oven to explore its thermal performance during this test (see Figure 1).

## » ACCURATE SIMULATIONS PROVIDE THE RIGHT SOLUTION IN LESS TIME

**THE SECRET TO** efficient cooking lies in the heat transfer rate, which describes the rate at which heat moves from one point to another. Inside an oven, food is heated by a combination of conduction, convec-

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> —**NELSON GARCIA-POLANCO, RESEARCH AND THERMAL ENGINEER AT WHIRLPOOL R&D**

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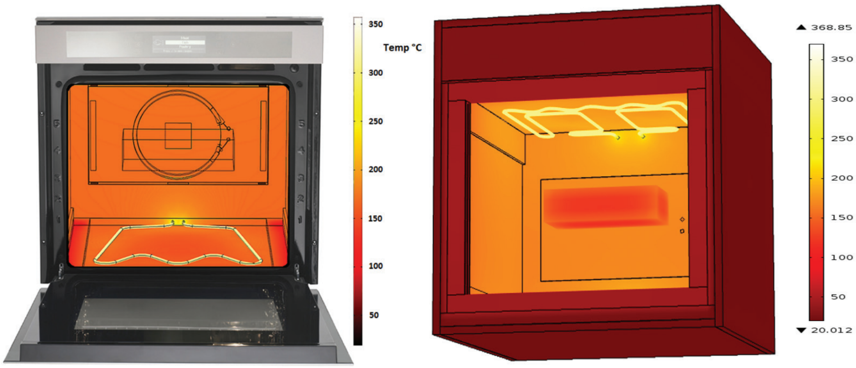
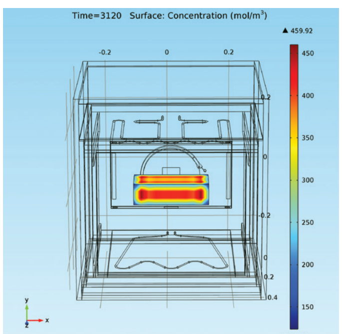



**FIGURE 2:** Predicted temperatures of the oven surfaces (color scale in °C) after 50 minutes in a broil cycle (right) and a bake cycle (left).



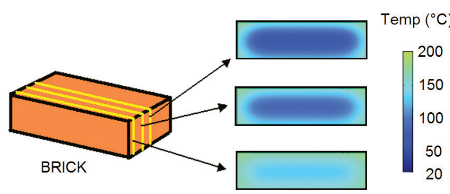
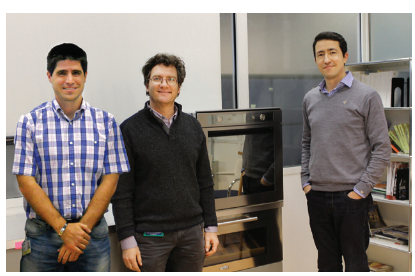




**FIGURE 3:** Left: Brick surface moisture concentration (in moles per cubic meter) at the end of the simulated test. Right: Predicted temperature profiles at different slices of the brick after 50 minutes at 200°C.

tion, and radiation. "The static cycle heats the oven from the bottom (bake) and the top of the cavity (broil) using the corresponding heating elements, while the forced convection cycle uses the same configuration along with an internal fan," says Garcia-Polanco. "Therefore, radiation is most important during a static cycle, and convection dominates during the forced convection cycle." The simulation took into account the different heat transfer rates of the various heating methods (see Figure 2) as well as a combination of different elements including material properties, oven shape, and the type of food being prepared.

There are several factors that proved especially important when considering the transient behavior of the oven model. "We considered the emissivity of the glass door, the thickness of the walls, and the material properties of the walls," says Garcia-Polanco. "We made a detailed comparison of the results of both the simulation and actual



From left to right: Joaquin Capablo, Energy Engineer; John Doyle, Principal Engineer, Energy & Environment; and Nelson Garcia-Polanco, Thermal Engineer.

experiment throughout the heating cycle, which helped verify that our simulation was accurate."

In addition to predictions of the temperature of the oven surfaces, detailed information about the temperature profiles and moisture concentrations within the brick were acquired. "We looked at the temperature behavior within the brick," says Garcia-Polanco (see Figure 3). "When we compared data from our simulation with the experimental data, we found that our predictions about the internal temperature of the brick closely matched that of our experimental data." Knowing that the simulation is accurate will allow Whirlpool's team to probe the oven and brick at any point in space and time with confidence in the results they obtain. "For our future experiments, this knowledge will help us to save both time and money by reducing the number of prototypes and design iterations we go through before settling on a final oven design."

The team also looked at the water concentration in the brick throughout the experiment. The experimental results were very close to the simulation, with an average predicted value of 166 grams of evaporated water after 50 minutes and an actual value of 171 grams. "Knowing the rate at which water evaporates from the brick will help us to conduct further studies into different strategies for reducing energy consumption without decreasing the final quality of the product," says Garcia-Polanco.

## » *A RECIPE FOR HIGH-QUALITY, HIGH-EFFICIENCY COOKING*

**THE RESULTS FROM** this verification study will help further the mission of GREENKITCHEN® project to empower innovative households to reduce national energy consumption and improve energy efficiency in Europe. A proven, reliable model simplifies the verification of new design ideas and product alterations, helping designers to find the right solution in less time. "This study confirmed that our model is accurate, allowing us to be confident in the results when we test future design ideas," concludes Garcia-Polanco. "Our next steps will be to use this model to optimize the use of energy resources in the oven and to deliver a robust, energy-efficient design to the European market." ◎