Computer Simulation Helps Customize Food Steamers

The use of computer simulation provided design insights that helped improve steam circulation and heat distribution in a commercial food steamer, making it possible to increase the capacity of the steamer by including additional trays. The manufacturer of the steamer was interested in customizing their products and increasing the capacity and functionality of the device for unique customer requirements, but recognized that it would require design changes due to uneven heat distribution in the original design. With no way to observe and understand the movement of steam inside the steamer, this would have required a long and expensive trial and error process. Instead the manufacturer of the steamer decided to work with a company that specializes in using advanced Computer Aided Engineering technology (CAE) for simulating the operation of mechanical products and developing interfaces that allow designers to change the design and view the effect on performance.

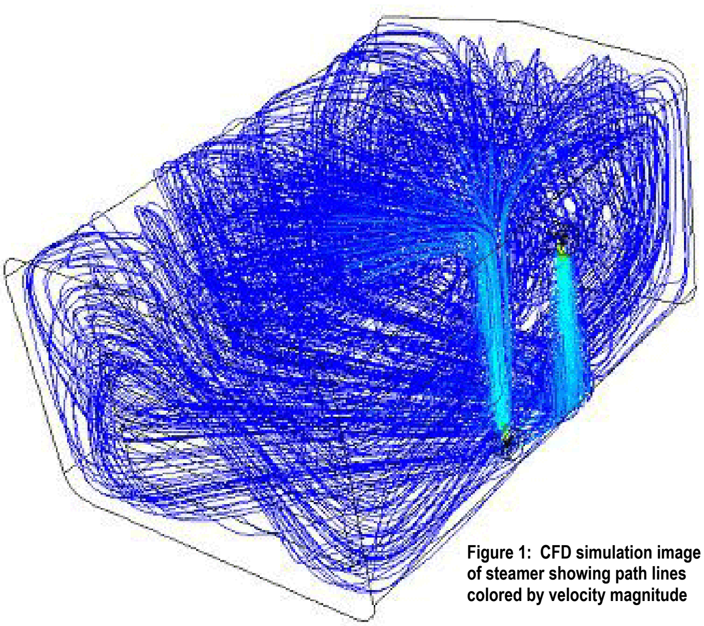

Figure 1: CFD simulation image of steamer showing path lines colored by velocity magnitude

Simulation of the steamer using Computational Fluid Dynamics (CFD) showed that the uneven temperature distribution is caused by the location, speed and direction of the steam jets in the steam chamber. This simulation capability permitted engineers to manipulate the jets without building a physical prototype and iterate to an optimized design that allowed the capacity of the steamer to be substantially increased.

The steamer is built by one of several divisions of a company that provide products for the food service industry. In the past, the company had always used traditional engineering design methods that involve development of an initial design concept based on experience or hand calculations, building a prototype, testing it to see if it worked, and then repeating the entire process multiple times in an effort to improve the design. There are several problems with this approach. First of all, it's expensive and time-consuming to build a prototype to evaluate each design concept. Second, the information can be obtained from physical testing is limited. Engineers have no difficulty determining key performance variables such as steam inlet heat and the temperature of different trays. But in many cases there is no way to determine why the proposed design does or does not work, such as by looking at the crucial flow patterns and temperature distributions inside the steamer. For example, a jet inside the steamer might be pointed in a direction that inadvertently creates a recirculation zone that prevents steam from spreading throughout the device. This type of problem could not be detected by conventional physical testing so the only way it could be solved was by trial and error.

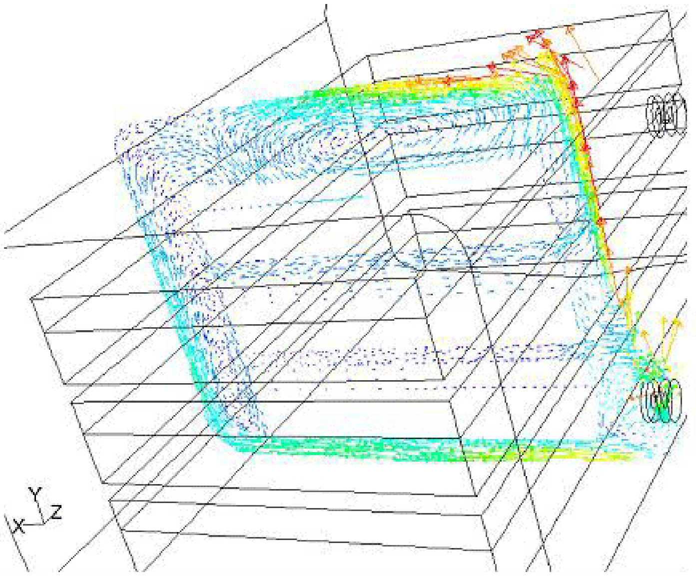

Figure 2: Velocity vectors in the food steamer

Moving beyond trial and error

Engineering research and development wanted to move beyond the trial and error approach by adopting CAE methods that would allow them to gain greater insight into the performance of their design concepts and bring products to market at a lower cost and with fewer delays. They were aware that CFD packages had demonstrated the ability to accurately simulate the operation of a steamer without the need for construction of a prototype. A key advantage of a CFD analysis is that it provides fluid velocity, temperature and pressure conditions throughout the area that is modeled, far more information than can be obtained by physical testing. Visualization of the fluid flow inside the steamer has the potential to provide insights that make it possible to improve the design. In the example above, for instance, the engineer would be able to spot the recirculation zone, immediately see that it is caused by the position of a steam jet, conceive of a new position that might solve the problem and change the model to validate the performance of the improved design.

But there are a number of obstacles in developing an in-house CFD capability. For one thing, CFD software is rather pricey, typically costing on the order of $25,000 per copy per year. An even greater obstacle is the specialized training and experience required to produce accurate results. The users are typically engineers, often with graduate degrees, that have undergone extensive training and have years of experience in using these tools. This is because there are many assumptions that must be made by the user of the software in defining the geometry, creating the mesh, selecting boundary conditions, determining materials properties, etc. Each of these decisions can have a significant impact and an inexperienced user could potentially do more harm than good by generating misleading results. While the steamer designers are very good at what they do, management did not feel that it would be practical or necessary to provide them with the training that they would need to accurately simulate the food steaming process.

A different approach

A firm called Enductive Solutions offered a different approach to the steamer manufacturer. The firm has the mission of creating CAE solutions that focus on applicability, simplicity, ease-of-use and integration. The deliverable is often a customized graphical user interface (GUI) which ties together all the unique design components and the specific tools and hardware in the process, so that time is saved, tedium is reduced, and integration is achieved. In this case, the first step was to address the immediate concern of how to increase the capacity and efficacy of the steamer. The company began with physical testing that was intended to develop boundary conditions for and validate the CFD model that would be developed. The steamer was instrumented with appropriate velocity probes and thermocouples and tested under four different conditions. The testing showed that uneven heat distribution within the steamer would make it impossible to increase its capacity and efficiency without significant design changes.

Enductive engineers then analyzed the data, created a summary and generated the necessary data for boundary conditions and material properties for CFD simulation. They obtained a copy of the computer aided design (CAD) file used to design the steamer and used it to create the simulation geometry. They derived boundary conditions such as the mass flow rate of gas into the steamer based on test results and information provided by the steamer manufacturer. They prepared the CFD simulation by creating a mesh and case file and ran the solution to convergence. They performed additional iterations with adjustments in the density of the mesh in order

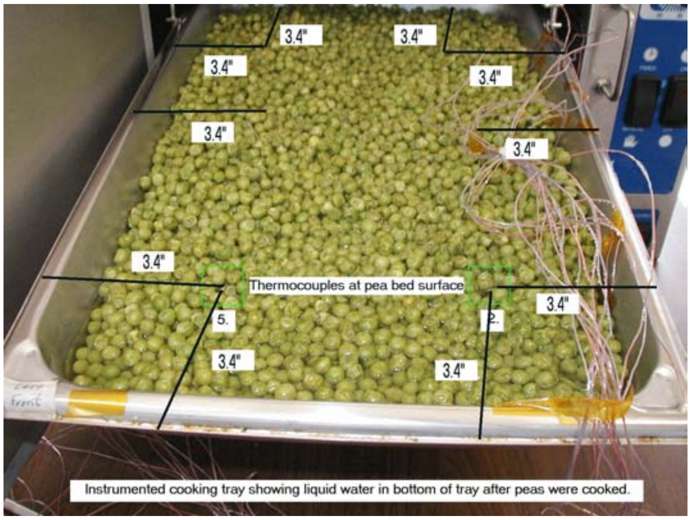

Figure 3: The steamer was instrumented with appropriate velocity probes and thermocouples and tested under different conditions. Seen here is an instrumented cooking tray showing liquid water in the bottom of the tray after the peas were cooked

to assure that the results were not dependent on the mesh. The CFD simulation helped to explain the uneven temperature distributions shown in the physical testing results. They showed that the effect of the location, speed and direction of the steam jets was far more important than the flow rate of gas entering the unit as defined in the analysis by the mass sink boundary conditions that were derived from the experimentally measured temperature distributions.

Performing additional analysis

To validate this analysis, Enductive, on their own initiative, performed additional simulation using a uniform mass sink distribution on the surface of all three trays. This contrasts with the position-dependent mass sink distribution used in the original simulation to model the heat absorption characteristics of the frozen peas. Comparing the results of these two simulations showed almost no difference in the flow patterns. This leads to the important conclusion that the temperature distribution is determined to a large degree if not entirely by the flow pattern induced by the steam jets. Thus the operation of the steamer can be greatly improved by any change that results in a more uniform flow distribution, such as, for example, relocating the jets or introducing manifolds, steam exhaust valves or recirculating fans. Another major benefit of the ability to eliminate the need for temperature distribution to set the boundary conditions is that the CFD simulation can be used as a predictive tool for improving the performance of the steamer without the need for thermal distribution measurements.

The next step was encapsulating the CFD analysis within an interface that prompts the user to enter only a few critical design parameters such as the vessel size, tray locations, steamer type, etc. The tool then performs the appropriate CFD analysis and returns the results necessary to evaluate the performance of the design such as the temperature distribution and flow patterns through the inside of the steamer. This calculation can be done on site or also deployed to a CAE specific Applications Service Provider (ASP). The user can enter the parameters needed to perform the analysis in a matter of minutes and does not need to spend the time that would otherwise be required to become an analysis expert. At the same time, the use of a ASP to perform the analysis eliminates the need to purchase and maintain expensive software and hardware. "The analysis returns the precise information that the user needs to determine the performance of the proposed design and, just as important, helps provide obtain an understanding of why it does or does not work so that it can quickly be improved," said Phil Raymond, President and COO of Enductive Solutions. "The basic idea is to put advanced CAE tools in the hands of the people who need them most - front line engineers - to reduce engineering expenses and bring products to market faster while avoiding the need to spend the time that would otherwise be required to become an analysis expert."

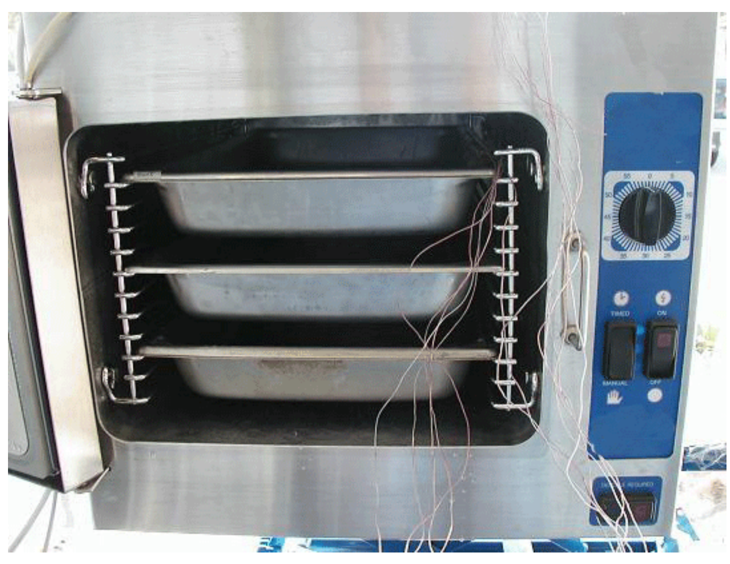

Figure 4: The opening of the food steamer with trays shown