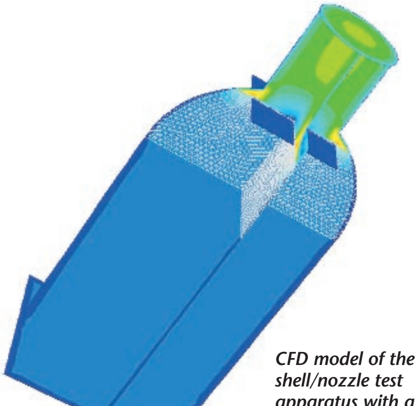
Impinging on an Optimal Distribution

By Kevin J. Farrell, Project Engineer, Research, Heat Transfer Research, Inc., College Station, TX



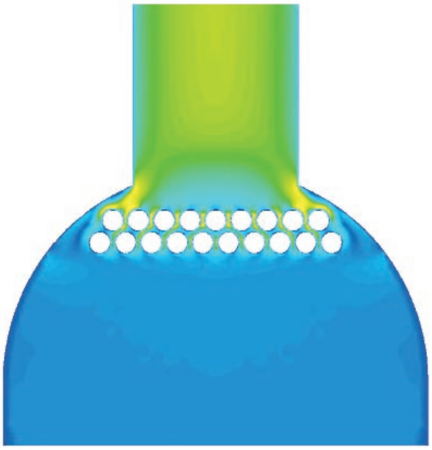
CFD model of the shell/nozzle test apparatus with a square impingement plate, colored by velocity magnitude

Engineers at Heat Transfer Research Inc. (HTRI) have recently used FLUENT to predict the performance of impingement devices in heat exchangers. Impingement devices are typically placed inside the shell of a shell-and-tube heat exchanger, between the nozzle and tube bundle, and are used to protect the tubes from the potential corrosive and vibratory impact of high-velocity inflow jets. The device is intended to provide erosion protection by breaking up and slowing down the shell side fluid while increasing the static pressure drop. They can, however, add to the cost of the heat exchanger and have been known to create vibration problems in some instances. It is therefore important to determine whether or not they are needed in a specific application, and if so, which type of device would be best. At HTRI, engineers recently performed a series of CFD simulations to compare the performance of each of the main impingement device types – solid plates, perforated plates, and rod grids – and evaluate the sensitivity of each to changes in major design parameters.

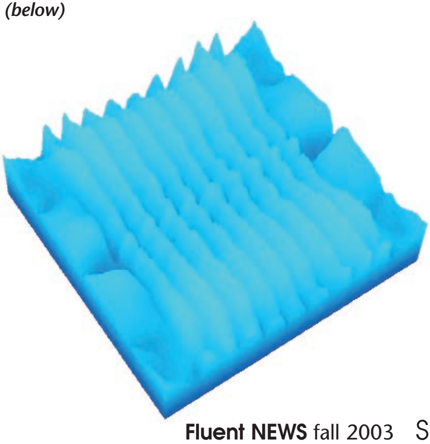
Tubular Exchanger Manufacturers Association (TEMA) standards require an impingement plate when inlet nozzle flow conditions exceed certain standards. The commonly used HTRI heat exchanger design software *Xist*™ defaults to these standards to determine if an impingement device is required. If one is, the software uses a round plate with diameter, thickness, and location that are functions of the heat exchanger geometry. To help the *Xist* user select the most effective impingement device, HTRI engineers wanted to analyze the performance of various types of impingement devices. Using CFD, they were able to optimize the design of impingement devices to protect the tubes from erosion while minimizing pressure drop and protecting against tube vibration.

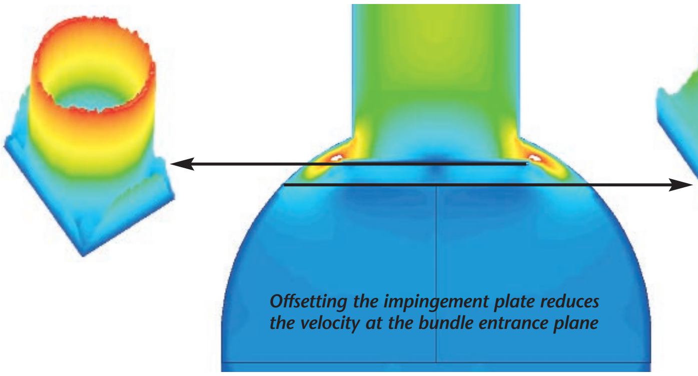
The initial CFD model was designed to duplicate the experimental apparatus that was previously used to study the different types of devices. A fully turbulent inflow profile was applied one nozzle diameter upstream of the shell inlet. A uniform atmospheric pressure boundary condition was applied to the outlet plane and a no-slip, impermeable wall boundary condition was applied at the smooth interior surfaces of the test apparatus and impingement device. The main tube bundle was modeled as an anisotropic porous medium and a dimensionless inertial resistance coefficient was calculated using HTRI proprietary methods. A hybrid mesh of tetrahedral and hexahedral elements was created with a higher density of cells in selected regions to capture secondary flows. The realizable k-ε model with non-equilibrium wall functions was used, with air as the working medium.

Parametric analyses were performed on each of the devices simulated. When the results were compared to the earlier measurements, the pressure drop for each scenario was found to match closely. The velocity data did not match quite as well, but the researchers attributed the discrepancies to measurement uncertainties. Engineers varied the spacing of each device with respect to the nozzle-shell junction, tried different sizes and types of plate-type devices, and looked at different rod-grid layouts. The general conclusion was that plate type impingement devices accelerate the flow around the plate edges, while rod grid devices provide a much more uniform velocity profile, a lower pressure drop, and reduced velocity excursions that can lead to vibration. The benefits of rod grid devices must, however, be weighed against the higher cost of these devices and the loss of working tubes in the heat exchanger. ■



The rod grid (above) provides a fairly uniform distribution of velocity at the bundle entrance (below)





Offsetting the impingement plate reduces the velocity at the bundle entrance plane