Case Study

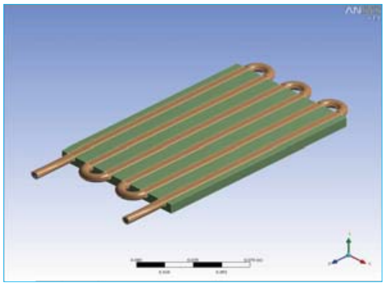

Figure 1: Representative geometry of a shell tube type heat exchanger

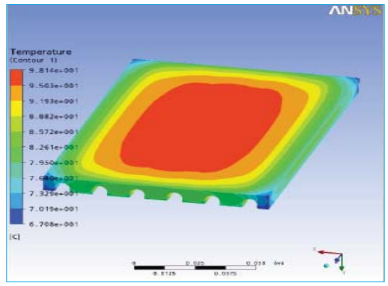

Figure 2: Solid block temperature distribution

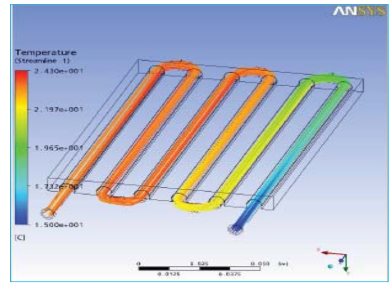

Figure 3: Cooling liquid streamlines in the heat exchanger, colored by fluid temperature.

Heat Exchanger Cooling Analysis

Heat exchangers are commonly used devices in many industries to provide cooling for critical machine parts. Different types of heat exchangers have been developed over the years for various applications, such as shell tube heat exchangers, thin-fin heat sink, etc. The performance of heat exchangers has always been an important part to the lifecycle and operation of many systems. Whether developing a new heat exchanger or optimizing the design of an existing one, understanding the coupled fluid flow and heat transfer physics, or the "conjugate heat transfer" process, associated with heat exchanger operation, is essential to provide better cooling performance.

Figure 1 shows a conventional shell tube type heat exchanger. The cooling tube is embedded in a heated solid block, in a looping configuration to provide more contact surface area between the cooling fluid and the solid block, in order to increase heat transfer between the liquid and solid. The tube is generally made of copper, with a thin, shell-like wall to allow a convenient heat flow path. The cooling fluid (water is the most commonly used) is introduced a low temperature at the inlet and loops through the the piping system, picking up heat along the way, before leaving the system at a higher temperature. The heat transfer takes places on the tube surfaces that are in contact with the heat solid block, where heat is transferred from the high temperature solid to the lower temperature liquid through the shell tube wall.

The most important goal of the conjugate heat transfer analysis is to identify the heat transfer char-

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acteristics such as wall heat transfer coefficient of the tube, solid block temperature distribution, possible hot spots, etc. Since this is a coupled analysis, there are two fields which must be solved simultaneously. For the cooling liquid, conservation of mass, momentum and energy equations, coupled with turbulence transport equations are solved. For the solid block, the heat conduction equation is solved with a heat source input. The pipe wall is solved as a solid as well. The inner pipe wall, where the cooling fluid is in contact with the wall, is the 'fluid-solid interface'. There are no boundary conditions specified at this location. Instead, the heat flux balance on the interface is solved to account for the heat transfer from solid to fluid. The interface between the exterior pipe wall and the block is generally assumed to be perfectly conducting, although additional modeling can be implemented to account for thermal resistance between the exterior pipe wall and the solid block.

The governing equations for these domains, coupled with appropriate boundary conditions, are solved simultaneously until a thermal equilibrium is reached. With the cooling flow factored in as a part of the solution, the conjugate heat transfer analysis does not assume any 'heat transfer coefficient' on a fluid-solid boundary, and is able to predict the heat exchanger physics accurately. It takes the guesswork and assumptions out of the analysis, thereby producing more reliable results. Also, if required as input to subsequent analyses or hand calculations, effective heat transfer coefficients can be calculated as part of the CFD analysis results. Conjugate thermal-fluid analysis has always been an integral part of the ANSYS CFX software. In this example, CFX was used to perform an analysis of the shell tube heat exchanger shown in Figure 1. Figure 2 shows the solid block temperature distribution. With the given heat source, the solid block temperature ranges from 60 C to 100C. Figure 3 shows cooling flow streamlines, which are colored by flow temperature. The cooling flow enters the heat exchanger at 15 C. With heat transferred from the solid throughout the looping pipe, the temperature gradually increases and exits the heat exchanger at about 25C.

Based on these results, the overall heat exchanger efficiency and performance can be predicted. Design iterations can be easily implemented which can predict the influence of design parameters such as tube diameter, number of loops, loop distribution, etc. Ultimately, an optimal design can be achieved which maximizes performance while minimizing cost.

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