3D COMSOL Multiphysics® Model of a Plate Heat Exchanger to Support a Laboratory Teaching Environment

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Abstract

Introduction: Heat exchangers are an important type of process equipment, widely used in the chemical, petrochemical, and power industry. As such, chemical engineering students operate heat exchange equipment in the setting of a unit operations teaching lab at Worcester Polytechnic Institute (WPI). Unlike other equipment typical in this setting, such as a transparent reacting vessel, a packed tower, or a double pipe heat exchanger, the fluid flow pattern inside the plate heat exchanger is not easily visualized. Moreover, course evaluations often indicate that the heat exchanger lab is difficult because convective heat transfer does not come intuitively to some students. This study couples a 3D COMSOL Multiphysics® model of a plate heat exchanger to a physical exchanger implemented in the teaching lab. Simulative experiments in COMSOL Multiphysics® allow students to adjust flow rates, flow direction, and thermal fluid types to study the effects these parameters have on heat transfer, thus strengthening their working knowledge of fluid and heat transport when completing the physical operation of the exchanger.

Use of COMSOL Multiphysics®: A 3D geometry of the exchanger was built within COMSOL to match the design specifications of the exchanger used in the lab, with each plate assigned as high-strength alloy steel. Laminar, incompressible flow was preliminarily modeled in the exchanger, with water and ethylene glycol as the process fluids in both co-current and countercurrent operation. Heat transfer was then modeled, assuming a constant fluid velocity conducted from the first study, and assigning thermal insulation boundary conditions on the outer faces of the exchanger. As a final study, the fluid flow was coupled to the heat transfer, resulting in a multiphysics model that simulates non-isothermal flow and conjugate heat transfer. Our present model has smooth heat transfer surfaces, but we are currently adding chevron patterns to the surfaces like those in the physical exchanger.

Results: Figure 2 shows the velocity magnitude in the hot fluid section of the exchanger, flowing at 4 L/min. Figure 3 displays the velocity streamlines on both sides of the exchanger, allowing for visualization of the flow field. Figure 4 shows the temperature profile of the fluid and solid regions in the exchanger modeled in countercurrent operation. Students can easily study the effect of changing the flow rates and flow direction in the exchanger on temperature profiles, pressure drop, heat transfer coefficients, and heat exchanger effectiveness.

Conclusions: Physically operating the heat exchanger shown in Figure 1 does not allow for an easily visualized fluid field or well understood heat transport physics. Repetitive operation of the equipment results in equipment fatigue and increased operational costs. Using COMSOL as a simulative tool for the exchanger allows for better student understanding of fluid mechanics and conjugate heat transfer, and demonstrates itself as an effective and accurate tool for supporting a laboratory-based teaching environment.

Figures used in the abstract

Figure 1: Heat exchanger purchased from DudaDiesel.com and implemented into the chemical engineering teaching laboratory at WPI.

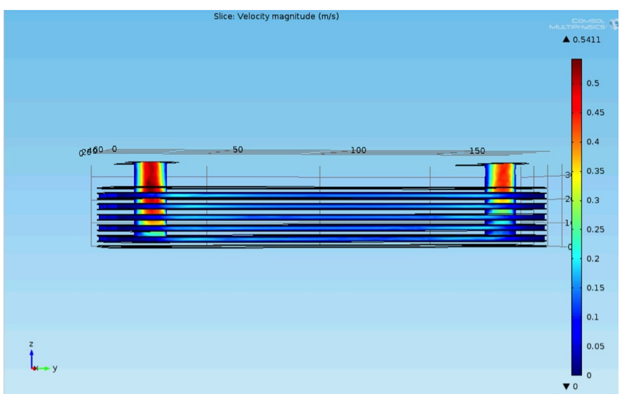

Figure 2: Velocity magnitude within the ten plate heat exchanger. Ethylene glycol enters the exchanger at 4 L/min and flows through five channels.

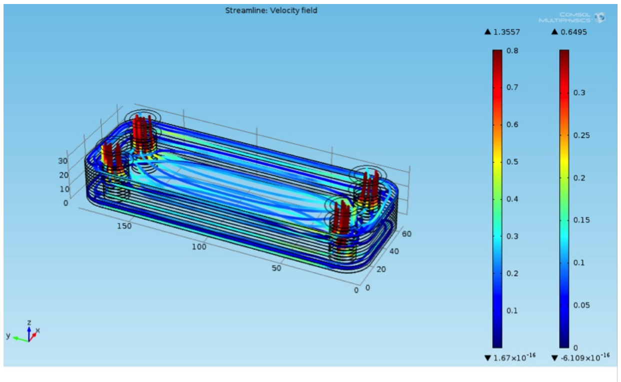

Figure 3: Velocity streamlines in countercurrent operation of the ten plate heat exchanger. Water and ethylene glycol enter the exchanger at 4 L/min and 8 L/min, respectively.

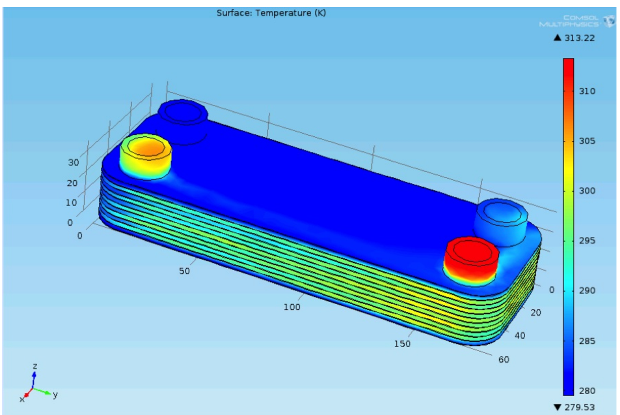

Figure 4: Temperature profile in countercurrent operation of the ten plate heat exchanger. Water and ethylene glycol enter the exchanger at 4 L/min.