Dynamic Modeling of Heat Exchangers with Phase Change

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Abstract:

We are looking for a simple dynamic model for heat exchangers with phase change such as condensers and evaporators in refrigeration cycles. The model should be robust and accurate enough so that it can be used for model-based control and optimization of this type of processes. There are several modeling approaches to describe the dynamic behavior of heat exchangers. A fixed control volume (FCV) model has the possibility of being highly accurate. An important advantage of this approach is that it is possible to capture the geometry and dynamics of different types of heat exchangers. For example, plate heat exchangers, which are used in a variety of processes due to their compact size and favorable heat transfer capabilities, can be modeled using this approach. FCV models also enable the introduction of the momentum balance and pressure drops as well as thermodynamic non-linearities along the heat exchanger.

Several challenges need to be addressed in order to apply the FCV modeling approach successfully. A clear issue is that the size of the control volumes may be a source of stiffness. Additionally, stiffness due to multi-scale behavior is present when non-isobaric conditions are considered, as pressure propagates much faster than thermal dynamics. Moreover, if phase change occurs, as in condensers and evaporators, there is a sharp and instantaneous change of thermodynamic properties at the transition point between phases. This discontinuity may lead to numerical errors, especially if the step size is not chosen appropriately.

Highly accurate models using FCV are used for design and to study flow and temperature distribution in heat exchangers. However, when modeling for control and optimization purposes there is a trade-off between accuracy, robustness, and efficiency. We analyze the implications of the selection of states and step size as well as possible model simplifications and assumptions. We also discuss the options to handle the calculation of thermodynamic properties. Finally, we present a simplified model of a heat exchanger and simulation results using the proposed model.

Keywords: dynamic modeling, simulation, heat exchangers