Computational Approach to Quantify Condenser Operations

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EXTENDED ABSTRACT

Summary

Multiphase flow problems appear in various chemical engineering applications, including film condensation on the cold surface of the tubes of a condenser, in fluidized bed or bubble reactors and many other industrial applications. This study quantifies the efficiency of a condenser to abate volatile organic compound (VOC) emissions that include organics from pharmaceutical industries. The condenser model contemplates simultaneous heat and mass transfer in a multiphase flow in the condenser tubes [1], [2]. Despite progress in computational fluid-dynamic methods, the quantification of transport phenomena involving multiple phases is still a challenge. Existing lumped condenser models fail to accurately predict heat and mass transfer phenomena and a more detailed analysis needs to be considered. This study quantifies heat and mass transfer in a tube of a condenser using a fluid mechanics model under steady state and dynamic conditions.

Methodology

The formation of the liquid film in the tubes of a condenser is modeled using a first principles approach [3]. Continuity and momentum equations are used to describe the transport of the VOCs from the bulk to the condensed film. Close to the cooling panels, condensation of the undesired VOCs occurs and a thin liquid film is formed. The model considers the interaction of the bulk flow with the thin film formation and how the bulk velocity and temperature can influence the formation of the liquid film. The proposed method evaluates the velocity field, temperature gradients and species transport throughout the whole domain of interest. The system of equations consist a nonlinear and coupled system of partial differential equations (PDEs). The system of PDEs is solved numerically using a finite volume discretization approach. The discretization method of the equations used in this paper is the Finite Volume method implemented in MATLAB [4], [5] based on a staggering grid approach [6]. For the integration of the equations over time, a implicit Euler method is used [7].

Significance

The study shows that the condensation rate of the VOCs is influenced by the mass and heat transfer in steady and transient state. The two phase model predicts both mass and heat transfer control regimes in contrast with existing models [2]. The proposed multiphase model can accurately predict the flow and pressure fields, the temperature as well as the condensation rate for the system under dynamic operation where it is heat or mass controlled. The specific effect of various operating conditions on the overall efficiency of the condenser is discussed and will provide quantification for the effects of gas velocity on condensation, the specific condensation rates for different VOCs, and the effect of changes in the inlet concentration. It is expected that with more accurate models describing the multiphase film condensation phenomena occurring in cryogenic condenser the efficiency of VOCs recovery will be improved.

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