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Numerical study of heat and mass transfer characteristics on a falling film horizontal tubular absorber for R-134a-DMAC

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The present study investigates the flow, heat and mass transfer behavior of a falling film horizontal absorber by employing a two-dimensional numerical technique. The refrigerant, R-134a (1,1,1,2-tetrafluroethane) is absorbed by the falling film of the R-134a-DMAC (dimethyl-acetamide) solution. The related governing equations are solved using a developed computer code in MATLAB. The velocity, temperature and concentration fields in the domain are computed for varying operating parameters. The peak value of mass flux is found to decrease with increase in the solution flow rate and for higher solution flow rates the peak occurs at further downstream location on the tube surface. The local heat transfer coefficient is higher for lower solution flow rate and vice-versa. The mass transfer coefficient increases up to certain angular position and then begins to decrease. Optimum solution flow rate for maximum total mass flux corresponds to a particular tube diameter.

1. Introduction

In present era, the technology developments and energy issues have made the absorption refrigeration an economic and effective alternative to the vapor compression cooling systems. Absorption chillers are widely used in the air conditioning industry, because they can be operated by hot water, flue gases from the boiler and direct fired natural gas, instead of electricity. The overall performance of an absorption system is greatly influenced by the characteristics of heat and mass transfer in the absorber where the refrigerant vapor is absorbed into the absorbent. The most common refrigerant-absorbent mixtures used in vapor absorption refrigeration systems are water–lithium bromide and ammonia–water. It is challenging to model and analyze the absorber with appropriate equations that mimic the actual conditions.

A model of vertical-tube falling film has been developed by Patnaik et al. [1] for the absorption of water vapor in aqueous solution of lithium bromide. The model is based on the solution of three ordinary differential equations to find the axial solution concentration, axial solution temperature distribution and coolant temperature distribution. At the entrance region of the absorber tube, the numerical solution exhibits instabilities under certain conditions, which is corrected by introducing a damping factor. It has been addressed that for vertical tube absorber with no additives, the sub-cooling is indeed large. Additives in the falling film result in an increased mass transfer coefficient, thereby reducing the sub-cooling. A physical model has been presented by Choudhury et al. [2] to analyze the absorption phenomena on the basis of various interactions between the parameters and boundary conditions involved in actual situation for water vapor absorption in water–lithium bromide solution. They proposed that for higher solution flow rates, the heat transfer coefficient improves with increase of tube diameter and for smaller flow rates, the heat transfer coefficient is larger. A model for a horizontal tube absorber using water–lithium bromide as a working fluid has been presented by Jeong and Garimella [3] to predict heat and mass transfer in falling film and droplet mode flows. The incomplete wetting is considered by introducing the wetting ratio which is significant in determining the performance of an absorber. Analysis of combined heat and mass transfer for an ammonia–water absorption process has been carried out by Kang et al. [4] for two different absorption modes – falling film and bubble types. They found that the local absorption rate of the bubble mode is always higher than that of falling film mode leading to about 48.7% reduction in heat exchanger size. The heat transfer coefficients have more significant effect on the heat exchanger size in the falling mode than in the bubble mode. Cosenza and Vliet [5] investigated experimentally the absorption of water vapor into an aqueous lithium bromide solution flowing over internally cooled smooth horizontal tubes. From

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