International Communications in Heat and Mass Transfer 38 (2011) 425–428

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Characteristic analysis of adiabatic spray absorption process in aqueous lithium bromide solution ☆

Fengmin Su, Hong Bin Ma *, Hongtao Gao

Institute of Marine Engineering and Thermal Science, Dalian Maritime University, Dalian, 116026, China

ARTICLE INFO

Available online 8 January 2011

Keywords:
Absorption refrigeration
Adiabatic spray absorption
Model
Characteristic analysis

ABSTRACT

The absorber is a key component in a thermally-driven absorption system which significantly influences the whole system performance. The adiabatic spray absorption is one type of absorption process, in which the absorption fluid is dispersed into fine droplets having immense surface exposed to the vapor. In the current investigation, an improved analytical Newman model is presented which can consider the absorption heat effect. Using the model, the absorption characteristics of the adiabatic spray in aqueous lithium bromide solution is studied. The results show that the absorption heat significantly affects the absorption process. When the droplet radius decreases, the absorption rate can be improved and the maximum absorption time can be reduced. The current investigation can result in a better understanding of absorption mechanisms of the adiabatic spray absorption.

1. Introduction

In a thermally-driven absorption system, the absorber is one critical component and significantly influences the whole system performance. There exist three types of absorbers, i.e., falling film absorber, bubble absorber and adiabatic absorber. In the adiabatic spray, one of adiabatic absorbers, the absorption fluid is dispersed into fine droplets with diameters ranging from 100 μm to 500 μm resulting in immense absorption area. Because the spray absorber can produce much higher absorption surface area, the absorption rate is higher than other types of absorbers. Benbrahim et al. [1], Summerer et al. [11], Morioka et al. [6], Ryan [10], and Flamensbeck et al. [3] demonstrate that replacing a conventional absorber with a spray absorber can enhance the mass-transfer process which is practically feasible. Warnakulasuriya and Worek [12,13] experimentally studied the effects of the nozzle type, absorption temperature, and nozzle pressure on the drop formation and absorption performance of different solutions. The experimental results show that the absorption rate of the pressure-swirl atomizing nozzle is higher than that of the full-jet nozzle, and the optimal radius of the fine droplets is about 150 μm.

In order to better understand the absorption process, extensive theoretical and analytical investigations have been conducted and a number of mathematical models [4,5,7–9] have been developed. While these investigations have resulted in better understanding of absorption process, the effect of absorption heat has not been studied analytically. During the absorption process, the absorbed vapor releases lots of heat and significantly affects the mass-transfer power in the absorption process.

In the current investigation, an improved analytical Newman model considering the absorption heat effect is developed. Using the model, the absorption characteristics of the adiabatic spray in aqueous lithium bromide solution is studied. The current investigation can result in a better understanding of absorption mechanisms of the adiabatic spray absorption.

2. Theoretical modeling

In a typical adiabatic spray absorption process, the sub-cooled absorbent sprays into the vapor phase. As the fine droplets flow through the vapor phase, the absorption process takes place. Due to the surface tension effect, the spherical droplet is formed, similar to the one shown in Fig. 1. For the current investigation, lithium bromide is used as the absorbent while water is used as the refrigerant. When the sphere-shaped droplet at a radius, shown in Fig. 1, flows into vapor phase at a pressure of P and a temperature of T, the initial concentration of water in the lithium bromide–water solution is X_0. Because the saturated vapor pressure of the absorbent is lower than P, the absorbent absorbs the water vapor. If the interfacial mass-transfer resistance is neglected, it can be assumed that the droplet interface is in an equilibrium condition, which corresponds to the equilibrium concentration of refrigerant, i.e., X_i. Due to the concentration difference, $X_i - X_0$, the water molecules move from the interface toward the center of the droplet. For a fine droplet investigated herein, the bulk movement in the droplet is very small. The Peclet number of a drop flow is close to zero, i.e., $Pe \approx 0$. The mass-transfer process in the droplet depends mainly on the molecular diffusion.

☆ Communicated by P. Cheng and W.Q. Tao.

* Corresponding author.
E-mail address: mah@dlmu.edu.cn (H.B. Ma).

0735-1933/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2010.12.038