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Heat and mass transfer enhancement for falling film absorption process by SiO_2 binary nanofluids

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ABSTRACT

The objectives of this study are to visualize the dispersion of nano-particles in binary nanofluids, to find the effect of key parameters such as SiO_2 nano-particles concentration on the distribution stability in the H_2O/LiBr nanofluids, and to measure the vapor absorption rate and heat transfer rate for falling film flow of binary nanofluids. The binary nanofluids are H_2O/LiBr with SiO_2 nano-particle. The key parameters are the base fluid concentration of LiBr, the concentration of SiO_2 nano-particles in vol%, and kinds of additives. It is found that the concentration of SiO_2 nano-particles should be less than 0.01 regardless of the existence of the distribution stabilizer. It is also found that the maximum improvements of heat transfer rate and mass transfer rate reach 46.8% and 18%, respectively, when the concentration of SiO_2 nano-particle is 0.005 vol%.

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Amélioration du transfert de chaleur et de masse lors du processus d’absorption sur un film tombant faisant appel aux nanofluides binaires au SiO_2

Mots clés : Eau-bromure de lithium ; Distribution ; Stabilité ; Système à absorption ; Amélioration

1. Introduction

The absorber is one of the most critical components in the thermally driven absorption system. In order to design a more effective absorption system, many researchers have focussed on how to improve the performance of the absorber. The techniques for the enhancement of the absorber performance are generally categorized into three methods, which are, 1) mechanical treatment (Kang et al., 2000), 2) chemical treatment (Daiguji et al., 1997) and 3) application of nano technology.

Recently, some studies were carried out for the development of new heat transfer media such as in which solid/liquid mixture. However, problems such as sedimentation, cohesion

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Nomenclature

A	area, m^2
Abs	absorption rate
C_p	specific heat, $kJ\,kg^{-1}\,K^{-1}$
F	correction factor for log mean temperature difference
h	heat transfer coefficient, $kW\,m^{-2}\,K^{-1}$
H	enthalpy, $kJ\,kg^{-1}$
$\dot{m}$	mass flow rate, $kg\,s^{-1}$
$\dot{m}_{abs}$	absorption rate, $kg\,s^{-1}$
Q	heat transfer rate, kW
R_w	wall resistance, $K\,W^{-1}$
T	temperature, °C
U	overall heat transfer coefficient, $kW\,m^{-2}\,K^{-1}$
x	concentration of LiBr, %
Greek	
β	mass transfer coefficient, $m\,s^{-1}$
Subscripts	
abs	absorption
b	base fluid
c	coolant
eq	equilibrium
in	inlet
o	reference
out	outlet
sol	solution
v	vapor

and corrosion of particles happen in the case of solid/liquid mixtures. In order to solve these problems, many researches on nanofluids (Choi, 1995) have been carried out actively due to the rapid development of nano technology and surface engineering.

Nanofluid is defined as solid/liquid mixture where nano-sized solid particles of which diameter is under 100 nm are stably distributed in the liquid. It is well known that the distributed nano-particles with a high thermal conductivity can greatly enhance the effective thermal conductivity of the nanofluids (Eastman et al., 2001; Das et al., 2003; Keblinski et al., 2002). Especially, binary nanofluid of which base fluid is a binary mixture such as H_2O/LiBr solution is one of the most prospective working fluids in absorption system because it can not only remove the absorption heat effectively, but also improve the mass transfer performance significantly (Lee et al., 2009).

A lot of studies on the abnormal enhancement of thermal conductivity of nanofluids has been carried out experimentally and theoretically. These studies have conducted on 1) thermal conductivity mechanism, 2) convective heat transfer characteristics, 3) falling film heat transfer (Kang et al., 2008; Lee et al., 2009; Ruan and Jacobi, 2011) and 4) phase change of nanofluids (Xuan and Li, 2000). However, problems such as sedimentation of nano-particles happen in the binary mixtures, so the distribution stability of binary nanofluids is one of the most important factors for the absorption applications (Kang et al., 2008).

The objectives of this study are to visualize the dispersion of particles in binary nanofluids, to find the effect of key parameters such as SiO_2 nano-particles concentration on the distribution stability in the H_2O/LiBr nanofluids, and to measure the vapor absorption rate and heat transfer rate for falling film flow of binary nanofluids. The binary nanofluids are H_2O/LiBr with nano-particle of SiO_2. The key parameters are the base fluid concentration of LiBr, the concentration of nano-particles in vol%, and kinds of additives. The binary mixture H_2O/LiBr is a representative natural refrigerant for absorption refrigerating systems in real world.

2. Experiment

2.1. *Distribution stability test*

There are two general methods for the preparation of steric stabilized dispersions: 1) the addition of a steric stabilizer to a preformed dispersion and 2) the direct generation of the dispersion with a stabilizer. The former method is really only satisfactory for aqueous dispersions that can be stabilized by an alternative method (e.g. electrostatically) during the preparation (Napper, 1983). In this study, a novel two-step method is developed to prepare for stable binary nanofluids. Fig. 1 shows the proposed preparation method from this study. First, Poly vinyl alcohol (PVA, Junsei Chem., JPN), Gum-Arabic (GA, Daejung Chem., KOR) and SiO_2 nano-particles of about 20 nm in diameter are suspended in deionized water (DI water) using an ultrasonic disruptor to make statically stabilized nanofluids. Then, the nanofluid is mixed with LiBr/H_2O binary mixture using a magnetic stirrer. Fig. 2 shows the photograph of SiO_2 nano-particles (Sigma–Aldrich Co., USA) used in the present study.

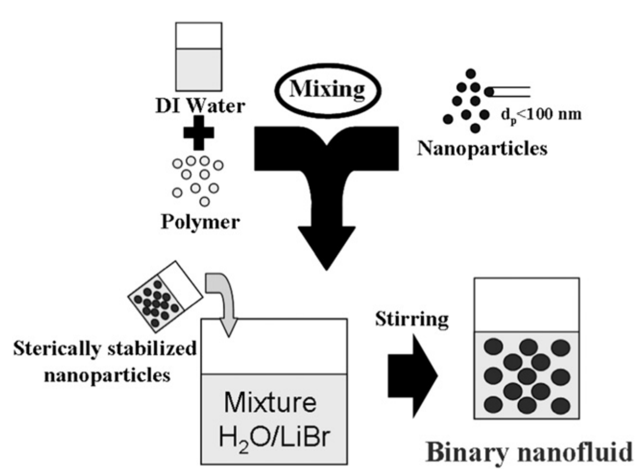

Fig. 1 – Proposed preparation method for stabilized binary nanofluids.

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