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Improving the thermal performance of diffusion absorption refrigeration system with alumina nanofluids: An experimental study

Adnan Sözen [a,*], *Engin Özbaş* [b], *Tayfun Menlik* [a], *M.Tarık Çakır* [a], *Metin Gürü* [c], *Kurtuluş Boran* [a]

[a] *Gazi University, Department of Energy Systems Engineering, Technology Faculty, Teknikokullar, 06503 Ankara, Turkey*
[b] *Ondokuz Mayis University, Yesilyurt D.C. Vocational School, Samsun, Turkey*
[c] *Gazi University, Department of Chemical Engineering, Engineering Faculty, Maltepe, 06570 Ankara, Turkey*

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ABSTRACT

In this study, the effect of the passive heat transfer improvement method of ammonia/water couple with alumina (Al_2O_3) particles in nano-size were examined in diffusion absorption coolers regarding to the heat performance of the system. Adding nanoparticles into fluid leads to significant improvement in heat transfer since the surface area and heat capacity of the fluid increase due to nanoparticles. Therefore, in this study cooling/absorption fluid mixtures with Al_2O_3 nanoparticles and their impact on system performance were assessed. The results of experiments indicated that the system with nanoparticles provided better absorption of heat from the generator and faster evaporation of the cooler from the cooling/absorption fluid. The connection units of the heat transfer in the system were investigated considering the effect of fluids containing nanoparticles. It was observed that the operation time of the system was reduced due to shorter heat transfer periods. Consequently, it resulted in obtaining desired temperature faster.

Amélioration de la performance thermique d'un système de froid à absorption par diffusion avec des nanofluides à l'alumine : une étude expérimentale

Mots clés : Diffusion ; Absorption ; Froid ; Alumine ; Nanofluide

* *Corresponding author*. Tel.: +90 312 2028607; fax: +90 312 2120059.
E-mail address: asozen@gazi.edu.tr (A. Sözen).
URL: http://websitem.gazi.edu.tr/asozen
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Nomenclature

h	Enthalpy (kJ kg^{-1})
m	Mass flow rate (kg s^{-1})
P_2	the rectifier outlet pressure (Bar)
Q	Heat load (W)
T_2	the rectifier outlet temperature (°C)
T_3	condenser outlet temperature (°C)
T_{4a}	the temperature of inlet point of liquid ammonia with low pressure to evaporator (°C)
T_{4c}	evaporator inlet temperature (°C)
T_5	absorber temperature (°C)
T_{7b}	boiler inlet temperature (°C)
U	Uncertainty

Abbreviation

COP	Coefficient of Performance
DARS	Diffusion Absorption Refrigeration System

Subscripts

evap	Evaporator
heater	Heater
m	Measurement
sf	Purifying
ky	Boiler
b	Vapor
s	Liquid
1–7	Point of measurement for DARS

1. Introduction

Von Platen and Munters invented the diffusion absorption refrigeration system, DARS, in the 1920s (Von Platen and Munters, 1928). In this study water & ammonia were used as the working fluids together with helium which was utilized as an auxiliary inert gas in the system. The DARS was based on the application of a limited amount of heat, and this system is commonly used in domestic refrigerators, caravans, recreational vehicles, camps, especially hotel rooms, and offices owing to its silent running system. The DARS operates in low efficiency, and capacity of the DARS is restricted to small values. In the literature, there exist a few studies done in order to improve performance of the DARS due to low performance of such systems (Zohar et al., 2007; Koyfman et al., 2003; Zohar et al., 2009; Sözen et al., 2012).

Three methods can improve the efficiency of heat and mass transfer in DARS.

i. The mechanical treatment: The bubble pump is an important component researched as a major part of the DARS in terms of energy efficiency of the system (Rodriguez-Munoz and Belman-Flores, 2014; Zohar et al., 2008). Other factors influencing efficiency of the DARS are geometric parameters and the characteristics of the flux regime according to some other studies (Rodriguez-Munoz and Belman-Flores, 2014; Zohar et al., 2008).
ii. Chemical treatment: There are studies, in which different cooling and absorbing fluids are used together with pressure regulating gases such as hydrogen and helium in order to enhance performance (Zohar et al., 2009). Mostly organic absorbents such as R32, R124, R125, and R134a are used to improve system performance.
iii. Nanotechnology: It has recently been seen that nanofluids, which are made of metal oxides added in certain size and ratio into working fluid, improve performance in terms of heat absorption and transfer. The literature review shows that fluids used in heat pipes and heat exchangers contain metal oxides in nano-size, which enhances system performance in heat transfer (Yang et al., 2012). This paper carried out an experimental study by considering that addition of nanoparticles into working fluid promotes separation of ammonia in vapor phase from ammonia/water mixture in a boiler where DARS turns electricity into heat. The electricity consumption of DARS is responsible for high expenses in operational cost of large building such as hotels, dormitories, etc. Nanofluid application can increase the disadvantages in terms of expenses that result from the usage of electricity in heat form.

As a result of studies which have been recently conducted on the application of nanofluid in ammonia/water, nanoparticles of alumina were used to make the binary nanofluids in ammonia/water solution (Yang et al., 2012; Kim et al., 2007) utilized n-octanol and 2-octanol as surfactants.

Usage of nanoparticles in absorption refrigeration system offers four main benefits (Kim et al., 2007):

i. The solubility between the refrigerant and the lubricant can be increased by addition of nanoparticles.
ii. Thermal conductivity and heat transfer characteristics of the refrigerant can be enhanced.
iii. The friction coefficient and wear rate might be reduced by nanoparticles dispersed in lubricant.
iv. In addition to larger surface area and higher heat capacity of the fluid, agitation and the rigor of turbulence scattering nanoparticles straightening the horizontal thermal gradient become larger owing to the fluid containing nanoparticles.

Therefore, it is known that nanorefrigerant made of metal oxides which are added into refrigerant/absorber mixture in certain amount and size can absorb heat more, and it can support faster separation of cooler from absorber in boiler. By this way, desired boiler temperature is reached more quickly by utilizing less electricity, and the system gets more energy saving (Mahbubal et al., 2013).

This study aims to achieve the design of refrigeration system with lower energy costs and increased thermal efficiency.