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Analysis of adiabatic heat and mass transfer of microporous hydrophobic hollow fiber membrane-based generator in vapor absorption refrigeration system

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Abstract

A microporous hydrophobic hollow fiber membrane-based generator (HFM-G) is expected to be an alternative type of generator in vapor absorption refrigeration system, which can be compact and lightweight with the enhanced heat and mass transfer. This paper pursues a comprehensive understanding of a detailed desorption mechanism of the proposed HFM-G, and suggests the feasible configuration for the practical use. A theoretical HFM-G mechanism is first introduced to gain an understanding of the adiabatic heat and mass transfer. A gas permeation test determines the nominal pore size of the membrane, which characterizes the mass transfer across the membrane. Transient experiments demonstrate the characteristics of the adiabatic desorption process on the HFM-G for wide range of feed solution concentrations under various practical operating conditions. A comparison shows that the experimental heat and mass transfer results are consistent with the theoretical values of adiabatic desorption heat and mass transfer on the HFM-G.

Keywords: Absorption refrigeration system, car air conditioner, desorber, generator, hollow fiber membrane, vacuum membrane distillation

1. Introduction

Vapor absorption refrigeration systems (VARs) are capable of utilizing low-grade thermal energy directly for the purpose of air conditioning. This heat-actuated absorption system is able to run without additional energy consumption by using waste heat obtained from the exhaust gas of an internal combustion engine. The absorbent and refrigerant in VARs, a lithium bromide (LiBr) and water pair, are eco-friendly, and therefore, VARs do not contribute to environmental problems, such as the greenhouse effect or ozone depletion. Certain challenges, however, must be overcome so that VARs can become more attractive for portable applications. VARs have a much more complex thermodynamic cycle compared to conventional automotive compression refrigeration systems, which allows them to achieve a high theoretical system performance. However, this higher performance demands a number of heat and mass exchangers and complex control systems. VARs are too heavy to be used in vehicle applications, as the major heat and mass exchangers are stainless steel-based structures due to the high corrosiveness of the LiBr solution [*Oleinik et al. (2003)*]. The system's large heat and mass exchangers are responsible for the high cost and volume required to attain the required cooling capacity. A LiBr-water absorption system runs at a static vacuum pressure associated with the large specific volume of water vapor, causing the large bulk and weight of the system. The generator and absorber are both major components that determine the system performance. The heat and mass transfer to volume ratio in a conventional generator is quite poor. In general, a heating tube bundle is installed in a conventional generator and is immersed in the LiBr solution, where the heat transfer occurs by boiling the solution. The inefficient use of space against the heat transfer surface leads to the inefficient desorption of water vapor. Desorption takes place only at the liquid-vapor interface, which also impedes mass transfer. Additionally, the liquid phase of the LiBr solution has a considerably large mass resistance. The absorption of water vapor takes place in a conventional falling film absorber, but the gravity-driven hydrodynamic formation of the LiBr falling film resists the water vapor absorption through the formation of a thick falling film produced over the cooling tube [*Behfar et al. (2014)*]. Mal-distribution of the sprayed LiBr solution also leads to a low heat and mass transfer to volume ratio [*Killion and Garimella (2004)*]. VARs have not been an attractive alternative for portable air conditioning systems as the unconstrained LiBr solution (i.e. liquid-vapor interface) exists in