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Comparative study on evaporator heat transfer characteristics of revolving heat pipes filled with R134a, R22 and R410A ☆

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ABSTRACT

Heat pipes are used extensively in various applications including the heating, ventilating and air conditioning (HVAC) systems. The high thermal conductivity of the device, attributed from the two-phase heat transfer processes within the heat pipe, made them superior heat exchanger devices. Heat pipes had been widely used in HVAC applications in energy conservation, dehumidification enhancement, heat dissipation, etc. A number of researches have been conducted to expand the applicability of heat pipes in HVAC in Malaysia, especially in air-to-air heat recovery using stationary heat pipes. However, the potential usage of rotating heat pipe in heat recovery in tropical countries like Malaysia was yet to be explored. Hence, the potential of rotating heat pipe in the HVAC systems used in tropics was explored through a parametric study that incorporates rotational speeds, off-axis displacements and varied refrigerants. The rotating heat pipes charged with R134a, R22 and R410A were tested with varied radial displacement from the rotational axis. The straight and leveled heat pipe with the furthest radial displacement yields the most significant heat transfer, which was attributed to the magnitude of the generated centrifugal force, and effective distribution of liquid in the evaporator.

1. Introduction

The need of reducing the consumption of the depleting energy resources and production of the greenhouse gasses that resulted in global climate change has been deemed necessary for a creating a sustainable future. Energy was extensively used in the heating, ventilating and air conditioning of a building to provide a comfortable environment for the occupants residing within it. Hence, the need of heat recovery devices, such as heat pipes, arises to reduce the energy consumption of the HVAC systems. Heat pipes are generally two phase heat transfer devices with very high thermal conductance. The heat pipe primarily consists of three main components; which are the container, working fluid and the wicking structure. Heat pipes transport heat by absorbing heat when the working fluid liquid evaporates at the evaporator and releasing the heat when the vapor condensates at the condenser as illustrated in Fig. 1(a).

The working fluid, which is the heat transport medium, is the most important component of the heat pipe. A good working fluid should be compatible with the heat pipe materials, have good thermal conductivity and stability, high latent heat of evaporation, high surface tension, low liquid and vapor viscosities, good wettability, reasonable vapor pressure over operating temperature range and suitable freezing point. Working fluids such as water, ammonia, methanol and ethanol have been proven useful in the comfort temperature range in the past. Refrigerant such as Freon was used in the heat pipe for air conditioning back in the 1980s [1]. However, the HCFC refrigerants replaced CFC refrigerants were subjected to phase-out under the Montreal Protocol due to its ozone-depleting potential.

Nowadays, refrigerants such as R22, R134a, R407C and R410A are common in the HVAC equipments and these refrigerants are readily available in the market for a reasonable price. Some of these refrigerants have been used in the heat pipe researches, such as the study of R22-charged thermosyphon solar collector done by Than et al. [2]. A performance study of R134a-filled thermosyphon was done by Ong and Haidar-E-Alahi [3]. An experimental investigation of convective heat transfer coefficient during downward laminar flow condensation of R134a in a vertical smooth tube has been conducted by Dalkilic et al. [4]. Esen and Esen [5] have conducted a study of R134a, R407C and R410A thermosyphon solar water heater. Akhavan-Behabadi et al. [6] have also studied the condensation heat transfer of R-134a inside a microfin tube with different tube inclinations. The results from their study revealed that the tube inclination angle affects the condensation heat transfer coefficient in a significant manner. Jung et al. [7] also have presented a comparative study they have conducted flow condensation heat transfer coefficients of R22, R134a, R407C, and R410A inside plain and microfin tubes. The results from their study show that the heat transfer coefficient of a microfin tube was 2–3 times higher than those of a plain tube and they show that the heat transfer enhancement factor decreased as the mass flux increased for all refrigerants tested. The advantage of using these refrigerants can be summarized by their suitable operating temperature in the comfort range, ease in charging heat pipe from pressurized cylinder, availability and cost.

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