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Experimental investigation of the heat transfer performance of capillary-assisted horizontal evaporator tubes with sintered porous hydrophilic copper-carbon nanotube-titanium dioxide (Cu-CNT-TiO_2) composite coatings for adsorption chiller

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ABSTRACT

A partially flooded evaporator is often used in adsorption chiller. This study explores the use of a ternary copper-carbon nanotube-titanium dioxide (Cu-CNT-TiO_2) composite coating on copper tubes with structured external surfaces for the enhancement of capillary-assisted water evaporation in semi-flooded evaporator. The composite coating, made from ball-milled composite powder, was deposited on the tube by electrostatic spraying and consolidated by sintering in an electric furnace. The coating samples were characterized by pore size, surface porosity, pore density and optical microscopy, scanning electron microscopy, and energy-dispersive X-ray spectroscopy. The wettability of the coated-surfaces with a droplet of refrigerant, i.e., water, was observed at atmospheric conditions by measuring the contact angle between water droplets and the surface. These characterizations showed that the Cu-CNT-TiO_2 coating had a porous surface structure and was more wettable than the pure copper coating. To investigate the influence of the applied coating and water level fraction on heat transfer, experiments for evaporation heat transfer were performed at a saturated water vapor pressure of 7.5 torr (~1 kPa) and a warm water inlet temperature of 12 °C with an evaporator with four serially connected tubes. Enhanced evaporation heat transfer was achieved when the heating tubes were partially immersed in water with level ratios of approximately 0.1 to 0.3 (i.e., 10 to 30% of the tube diameter). Furthermore, use of the Cu-CNT-TiO_2 coating improved the evaporation heat transfer, especially when applied to the finned tubes; a maximum enhancement ratio of 3.15 was obtained, comparing the Cu-CNT-TiO_2-coated finned tubes with the bare finned tubes.

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1. Introduction

Although the application of the capillary flow phenomenon in heat pipe technology has been well established [1], using capillary flow to aid liquid film evaporation in the evaporators of sorption (i.e., absorption and adsorption) cooling systems [2] is a relatively new concept. Applying this concept to a sorption cooling system could enhance the overall efficiency. Capillary-assisted evaporation from the outside surface of tubes has been investigated by a few recently published studies; researchers have investigated using finned evaporator tubes [3,4], tubes with porous coatings [5], and the effects of varied surface geometries [6,7]. Overall, these researchers have found that heat transfer performance is greatly influenced by the surface characteristics (e.g., geometry and hydrophilicity) of the tubes.

The chemical composition and physical structure or geometry of a solid surface affects the surface energy and thus the wettability. To promote the wicking of water through the surfaces of heating elements, the surfaces must be more porous with good wetting properties. Example of such surfaces have been reported by Tsai and Lee [8] and Lanzerath et al. [5]; Tsai and Lee [8] used flat and horizontal surfaces whereas Lanzerath et al. [5] used horizontal tubes as substrates for porous structures made of Cu powders by a thermal spray process. Their findings indicated that using smaller powder particles (Tsai and Lee [8]) or coated finned tubes (Lanzerath et al. [5]) exhibited the best heat transfer performance,

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