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Heat transfer characteristics of a two-phase closed thermosyphons using nanofluids

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ABSTRACT

The heat transfer characteristics of the heat transfer devices can be done by changing the fluid transport properties and flow features of working fluids. In the present study, therefore, the heat transfer characteristics of two-phase closed thermosyphon (TPCT) with iron oxide-nanofluids are presented. The TPCT is fabricated from the copper tube with the outer diameter and length of 15, 2000 mm, respectively. The TPCT with the de-ionic water and nanofluids (water and nanoparticles) are tested. The iron oxide nanoparticles with mean diameter of 4–5 nm were obtained by the laser pyrolysis technique and the mixtures of water and nanoparticles are prepared using an ultrasonic homogenizer. Effects of TPCT inclination angle, operating temperature and nanoparticles concentration levels on the heat transfer characteristics of TPCT are considered. The nanoparticles have a significant effect on the enhancement of heat transfer characteristics of TPCT. The heat transfer characteristics of TPCT with the nanofluids are compared with that the based fluid.

1. Introduction

The investigation of two-phase close thermosyphon and their applications into thermal engineering are known for years, being used in various applications, such as heat exchangers (air preheaters or systems that use economizers for waste heat recovery), cooling of electronic components, and solar heating systems. An operating TPCT may be divided into three distinct sections, namely the evaporator, adiabatic and condenser sections. Energy is added into the evaporator section where the working fluid reaches its boiling temperature and begins to boil. The buoyant vapor of working fluid rises through the adiabatic section to the condenser, where it condenses. The condensate then drains back into the evaporator section by gravitation. This process of evaporation and condensation of the working fluid repeats itself continuously, as long as heat is supplied to the evaporator and an opportunity for its removal from the condenser exists. Main factors which affecting on thermal performance of a TPCT are: inclination angle, operating temperature and pressure, filling ratio, aspect ratio and working fluid. Many researchers have studied these factors [1–6].

Numerous theoretical and experimental studies of suspensions containing solid particles have been conducted initiating Maxwell's theoretical work [7] published more than a century ago. However, due to high density and large sized particles used, it was a challenge to prevent particles from settling in the suspension. The lack of stability of such suspensions induced additional flow resistance and possible erosion. Consequently fluids with nanosized particles suspended in them which later called nanofluids has been proposed by Choi [8] from the Argonne National laboratory, USA. By suspending nanosized particles in a fluid, its heat transfer performance can be significantly improved with incurring either little or no penalty in pressure drop.

A considerable experimental and theoretical works have been done on the application and design modification for improving TPCT performance. Recent works have shown that the presence of the nanoparticles in TPCT or heat pipes causes an important enhancement of his thermal characteristics. Different nanoparticles such as silver [9–11], oxide copper [12–14], diamond [15,16], titanium [17,18], nickel oxide [19], gold [20], alumina [21,22], iron oxide [23,24] and laponite clay [21] have been utilized within TPCT and heat pipe working fluid. The improved thermal performance is observed through a reduction in thermal resistance [9,11,12,15–17,20,25], an increase in the TPCT and heat pipe efficiency [17,22], and an enhancement in the overall heat transfer coefficient [19]. In some studies [12,13], the existence of an optimum amount of nanoparticles has been established. Lin et al. [25] has shown that presence of the nanoparticles enhancement the thermal conductivity and convective heat transfer performance. In another study, Shafahi et al. [26] established an optimum mass concentration for nanoparticles in maximizing the heat transfer limit and Guo-Shan Wang [27] investigate the operation characteristics in steady operation process and the unsteady startup process.

Iron oxide nanoparticles are of considerable research interest as engineering applications, effective catalysts, magnetic recording media, and attractive materials for biological and medical applications. Researches concerning the use of the iron oxide nanoparticles in TPCT or heat pipe having a large ratio between length and

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