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A comprehensive study of the performance of a heat pipe by using of various nanofluids

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A B S T R A C T

In this paper, a two-dimensional numerical model is developed to simulate the performance of a heat pipe using various nanofluids. The effect of different nanofluids (prepared using alumina, copper oxide, and silver nanoparticles) at different concentrations and particle diameters on the performance of heat pipe is also studied by through finite volume method. The obtained results show that using a nanofluid instead of water leads to the increased thermal efficiency and reduction in heat at wall of the heat pipe. Also, the temperature difference between the evaporator and the condenser is a function of input power; this means that by an increase in the input capacity, the temperature difference between the evaporator and the condenser increases. It was observed that the use of nanofluid reduces the axial-flow pressure of the fluid inside the wick. As a result, the transmission of fluid flow inside the wick from the condenser to the evaporator is easily done with the cost of using a nanofluid. Moreover, with an increase in thermal capacity, fluid pressure drop becomes maximum and thus temperature difference between the evaporator and the condenser increases.

1. Introduction

Heat dissipation has become an important factor in the electronic devices designing. Heat pipes and thermosiphons are heat exchanger devices that have high efficiencies and performances in heat transfer between two points. Since invented by Grover (1963) many investigations have been performed to determine heat pipe's characteristics using thermosiphons [1]. Due to the evaporation and condensation of a working fluid, heat pipes can transfer thermal energy between two points [2–4]. Nanofluids are suspensions made from nanoparticles and base fluids. Many works have been performed on properties and characteristics of nanofluids. Nanofluids can have higher thermal conductivities and convective heat transfer coefficients compared to conventional base fluids such as water and oils [5–12]. Moreover, using them in heat pipes and thermosiphons we can promote the heat transfer rate from one point to another. During the last years, some investigations have been conducted on applications of nanofluids in heat pipes and thermosiphons. Almost, most of these studies are experimental.

Keblinski et al. [13] reviewed and discussed the use of nanofluids. Weerapun and Somchai [14] summarized investigations of convection of nanofluids. Bahrami et al. [15] reviewed the thermal conductivity of nanofluids. Cheng et al. [16] performed a study on the nanofluids flow. The first research about the application of nanofluids in heat pipes was published by Chien et al. [17]. Many papers and articles have been published since then, involving mesh wicked [18] and [19], micro-grooved [20], and sintered metal wicked heat pipes [21]. Tien and Rohani [22] analyzed the effects of vapor pressure on the vapor temperature, evaporation, and condensation rates and the performance of the heat pipe. Do and Jang [23] studied nanofluid enhancement in a flat micro heat pipe. Kang et al. [24] performed some experiments using Ag/water nanofluids. Huminic and Huminic [25] studied nanofluids implementation in heat transfer characteristics and thermal performances of heat pipes. Chen et al. [26] studied heat transfer characteristics of heat pipes using nanofluids. Alawi et al. [27] reviewed fluid flow and heat transfer characteristics of nanofluids in heat pipes and discussed the mechanism of heat transfer enhancement or degradation. Parametthanuwat et al. [28] studied heat transfer performance of nanofluid in a thermosiphon and showed that using a nanofluid it is possible to increase the thermosiphon efficiency. Some researchers [29–33] have reported an optimal concentration of nanoparticles in a nanofluid flow in the heat pipe.

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Nomenclature

v	radial velocity (m/s)	ϵ	porosity coefficient
u	Axial Velocity (m/s)	μ	dynamics viscosity (kg/s·m)
r	radial direction	φ	volume fraction
z	axial direction	nf	nanofluid
K	(m^2) permeability	eff	effective
k	thermal conductivity (W/m·k)	s	wick
P	pressure (Pa)	$solid$	solid
S	source (W/m^3)	bf	base fluid
T	temperature (K)	v	vapor
V	velocity vector (m/s)	e	evaporator
C_p	specific heat (kJ/kg·K)	a	adiabatic
L	length (m)	c	condenser
Q	heat power (W)	int	interface
h_{fg}	latent heat (J/kg)	v, sat	saturated vapor
R	radius (m)	l	liquid
Re	Reynolds Number	w	wall
ρ	density (kg/m^3)		

In this paper, a two-dimensional numerical model is developed to simulate the performance of a heat pipe using various nanofluids. The effect of different nanofluids (Alumina, Copper Oxide, and Silver nanoparticles) at different concentrations and particle diameters on the performance of heat pipe is also studied by using finite volume method. To the best of author's knowledge, there is no comprehensive and thorough investigation to predict the performance of heat pipes using different nanofluids at different concentrations and particle diameters.

2. Problem statement

2.1. Geometry

A schematic view of the heat pipe is shown in Fig. 1. The lengths of the evaporator (L_e), the adiabatic (L_a), and the condenser (L_c) sections are respectively 600 mm, 90 mm, and 200 mm. Also, the vapor chamber radius (R_v), the inner radius (R_w), and external radius (R_o) of walls are respectively 65.8 mm, 4.9 mm, and 55.9 mm. The heat pipe is made of copper and consists of a double layer copper grid used as the structure of the wicks. The porosity, permeability, and effective pore radius of the wick were respectively 0.9, 1.5×10^{-9} m^2, and 54 µm. Other features of the heat pipe are shown in Table 1 (See Fig. 2).

2.2. Governing equations [34]

Continuity equation:

For vapor Phase:

$$\frac{\partial u_v}{\partial z} + \frac{\partial v_v}{\partial r} + \frac{v_v}{r} = 0 \tag{1}$$

For liquid phase:

$$\frac{\partial u_l}{\partial z} + \frac{\partial v_l}{\partial r} + \frac{v_l}{r} = 0 \tag{2}$$

Momentum equations:

For vapor Phase:

$$\rho_v\left(u_v\frac{\partial u_v}{\partial z} + v_v\frac{\partial u_v}{\partial r}\right) = -\frac{\partial P_v}{\partial z} + \mu\left[\frac{4}{3}\frac{\partial^2 u_v}{\partial z^2} + \frac{1}{r}\frac{\partial}{\partial r}\left(\frac{r\partial u_v}{\partial r}\right) + \frac{1}{r}\frac{\partial}{\partial r}\left(\frac{r\partial v_v}{\partial r}\right) - \frac{2}{3}\frac{\partial}{\partial z}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_v)\right)\right] \tag{3}$$

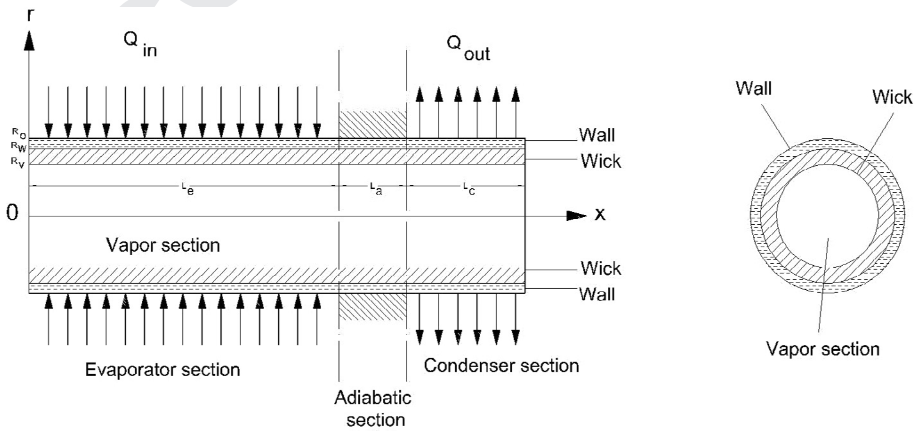

Fig. 1. A schematic view of heat pipe.

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