INFLUENCE OF LOW CONCENTRATION DIAMOND-WATER NANOFLUID ON HEAT TRANSFER IN LOOP HEAT PIPE

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by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CFD	Computation Fluid Dynamics
LHP	Loop Heat Pipe
CPU	Central Computer Unit of microprocessor
FEM	Finite Element Method
L	Length
W	Width
H	Height
vs	Versus

LIST OF SYMBOLS

A	Area
A_b	Area of base Plate
A_f	Surface area of aluminium rectangular fin
A_h	Cross-sectional area of LHP
c_p	Specific heat
h_{nf}	Heat transfer coefficient of nanofluid
h_{PW}	Heat transfer coefficient of pure water
ℓ	Volume
L_C	Condenser section length
L_e	Evaporator section length
L_l	Liquid line section length
L_V	Vapour line section length
Q	Heat input
q	Heat flux
Q^*	Coolant flow rate
R	Thermal resistance
R_b	Base thermal resistance
R_C	Convective thermal resistance
R_e	Evaporator thermal resistance
R_V	Vapor line thermal resistance

R_l	Liquid line thermal resistance
R_t	Total thermal resistance
T	Temperature
T_a	Ambient Temperature
T_b	Base plate Temperature
Tc	Condenser Temperature
Te	Evaporator Temperature
Tv	Vapor line Temperature
T_l	Liquid line Temperature
t	Time
m	mass
$\dot{m}$	Flow rate
μ	Dynamic viscosity
ρ	Density
s	Solid
w	Wall

PENGARUHAN CAMPURAN BERLIAN-AIR SEBAGAI NANOBENDALIR TERHADAP PERMINDAHAN HABA DALAM PENGELUNGAN PAIP HABA

ABSTRAK

Kajian secara eksperimen telah dibentangkan dalam thesis ini untuk menyiasat ciri pemindahan haba terhadap pengelungan pipe haba (LHP) dengan menggunakan kandungan air berlian yang rendah iaitu kurang daripada 1%. Kandungan bendalir yang akan dikaji adalah 0.3%, 0.6% dan 0.9%. Kajian terhadap pengunaan kandungan air berlian yang rendah dalam pergelungan haba dibahagikan kepada tiga perubahan keadaan dalam keseluruhan pengajian iaitu perubahan dari segi kadar pengaliran, beban haba dan kadungan nanobendalir yang berbeza. Untuk perubahan dari segi kadar aliran bendalir, kadar pengaliran optimum yang memberikan jumlah rintangan haba LHP yang rendah adalah 7.5mℓ/min selain daripada 5ml/min kepada 10/min. Untuk faktor beban haba yang beza daripada 20W hingga 60W, beban haba yang tinggi sebanyak 60W menberikan jumlah rintangan haba LHP yang rendah. Begitu juga dengan pekali permindahan haba menunjukan perningkatan sebanyak 10.95% dengan kandungan belian air sebanyak 0.9%. Untuk kesan kandungan nanobendalir yang berlainan terhadap jumlah rintangan haba, satu perbandingan diantara belian-air dengan silika-air pada kandungan yang sama sebanyak 0.6% akan diliputi dalam kajian ini. Keputusan menunjukkan berlian-air menpunyai rintangan haba yang rendah berbanding dengan silika-air. Pada masa yang sama, suhu LHP yang diperolehi secara experimen telah dibandingkan dengan simulasi ANSYS. Keputusan menunjukkan perbezaan diantara eksperimen dan simulasi berada dalam lingkungan yang baik. Dengan ini, pengunaan berlian air pada

kandungan yang rendah boleh dijadikan sebagai bendalir untuk LHP dari segi keupayan untuk memindah haba yang tinggi.

INFLUENCE OF LOW CONCERNTRATION DIAMOND-WATER NANOFLUID ON HEAT TRANSFER IN LOOP HEAT PIPE

ABSTRACT

An experimental works were conducted to investigate the heat transfer characteristics by using low concentrations of diamond-water, which was less than 1% in Loop Heat Pipe (LHP) in this thesis. The nanofluid consists of three types of mass concentration which is 0.3%, 0.6% and 0.9%. This study on LHP with low concentration of nanofluid were divided into three condition changes for the entire of study, which was flow rate changes, different heat load applied and different working fluid. For the effect of working fluid flow rate, the optimum flow rate to gain the lowest total thermal resistance of LHP was 7.5mℓ/min from the setting of 5mℓ/min to 10mℓ/min. The evaporator heat transfer coefficient also observes increase 16.7% for 0.9% diamond-water than pure water at flow rate 7.5mℓ/min. In term of influence of heat load to LHP, higher heat load 60W provides lower total thermal resistance of LHP. Same goes to heat transfer coefficient improve about 10.95% for mass concentration 0.9% diamond-water compared with water. On the effect of different nanofluid towards total thermal resistance, a comparison study between silica-water and diamond-water at mass concentration of 0.6% would be covered in the present experiment. Nevertheless, the diamond-water nanofluid has lower total thermal resistance of LHP than silica-water nanofluid. In the mean time, the experimental results were compared with ANSYS simulation and both were found to be in good agreement. Thus, there is a potential for low concentration of diamond-water nanofluid to be utilized as working fluid, in terms of high thermal conductivity.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The demand for heat pipe design optimization has increased rapidly in the recent years due to high heat dissipation in compact microelectronic systems. Heat removal becomes a vital consideration input while designing compact electronic components in order to prevent excessive heat reduce the electronic component lifetime itself. Among that, loop heat pipe (LHP) are popular for its quick cooling effect for high heat flux electronic device with flexible design. It is a device in which working fluid transport heat between the evaporator and condenser via heat pipes and uses capillary forces inside the wicked evaporator to circulate the working fluid inside a closed loop (Maydanik et al., 2005). The heat transfer device studied in this research will focus on a Loop Heat Pipe (LHP). The loop heat pipe system cooled with diamond-water nanofluid is experimentally investigated for thermal performance and feasibility. This chapter will go through a basic understanding of the fundamental of the heat pipe. Then the subsequent topics covered are divided in a few sections, which include the problem statement in a loop heat pipe. It is followed by the objective of study, scope of the thesis and thesis organization.

1.2 Fundamental of LHP

As illustrated in Figure 1.1, a heat pipe consists of four regions: an evaporator, a condenser, liquid line and a vapor line. The initial thermodynamic process in heat pipe begins with the base heater supply heat the heat pipe. The heater conducts heat to the evaporator and later to the working fluid. The heating effect throughout the time to working fluid would later change its phase from liquid phase to vapor phase and the vapor collected on vapor line. The high temperature in the evaporator and vapor line indirectly creating pressure difference cause the vapor to flow to the condenser region once the vapor flow along the condenser, the vapor changes its phase back to liquid phase due to the fins from condenser release the latent heat of vapor. These condensation processes in the heat pipe indirectly create a function of heat pipe as the cooling device in the thermal cooling application. The pressure difference between evaporator and liquid regions create the capillary force to continue to circulate the liquid back to evaporator. A steady state would reach once the heat load to the evaporator is maintained and the amount of vapor in heat pipe is directly depends on the heat load. The condensation process in the heat pipe indirectly creates a function of heat pipe as the cooling device in the thermal cooling application. (Chuang et al., 2003)

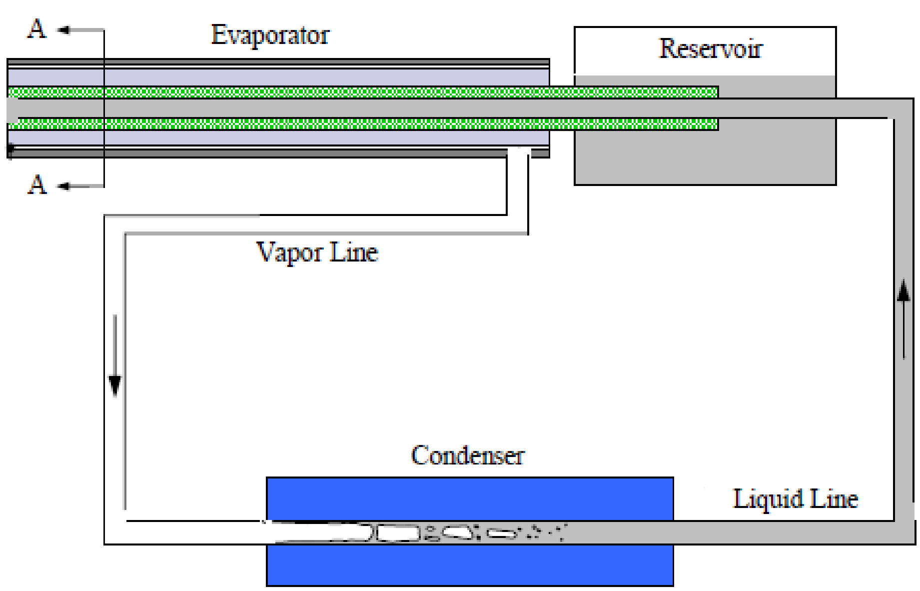

Figure 1.1: A schematic diagram of a conventional heat pipe (Chuang, 2003)

1.3 Problem statement

Conventional fluids such as water and glycol are often used as coolant for industries to maintain the temperature or cool the heat generated equipment. However, most of the heat transfer properties of traditional fluid are poor compared with conductive solid material. Nanofluid has gained a lot of attention from researchers and various industries to utilize its advantage for the thermal cooling application. There are several published studies have proven the suspending of metal or nonmetal nanoparticles into pure fluid can enhance the thermal conductivity than pure fluid itself. Nevertheless, out of the many types of nanoparticle as working fluid in previous publish literature, diamond nanoparticle still perform better thermal conductivity than other metal nanoparticle (Gunnasegaran, 2016). The diamond has an advantage of higher thermal conductivity (about 1000Wm K) than most metals except gold and silver according to thermal conductivity properties of material.

In term of mass concentration of nanofluid studies, although naofluids with higher heat conduction coefficients able to dissipate more heat. But the higher concentration will make the higher viscosity and will cause poor heat transfer due to the vapor bubble difficult to produce and increase obstruction of the liquid slug with tube wall (Lin et al., 2008). Thus, it is require to explore the ability of low mass concentration of nanoparticles to gain the maximum heat transfer of LHP system. Owing to this situation, the effect of low mass concentration nanofluid which is less than 1% on the LHPs has been investigated in present study, which is 0.3%, 0.6% and 0.9% mass concentration.

Most of heat pipe studies with nanofluid as working fluid are based on neither theoretical model nor experimental investigation. However, the study of modelling heat pipe characteristic to be compare with experimental results is less. Hence, a 3-D LHP assembly model with the nanofluid material properties input inside ANSYS-FLUENT is studied in the present study to give a picture into heat transfer and fluid flow mechanism in LHP.

1.4 Objective of study

In this research, three objectives are set to be studied:

i. Determine evaporator temperature, total thermal resistance of LHP, evaporator heat transfer coefficient with low concentrations of diamond-water and silica-water nanofluid for different heat load and flow rate.

ii. Study the transient temperature of LHP and find the flow pattern in vapor line for mass concentration of 0.3%, 0.6%, 0.9% diamond-water nanofluid

iii. Obtain the simulation temperature distribution and predicted transient temperature of LHP

1.5 Scope of thesis

An experiment is performed to investigate the heat transfer characteristics by using low concentrations of diamond-water and silica water, which is less than 1% in Loop Heat Pipe (LHP). The nanofluid consists of three types of mass concentration which are 0.3%, 0.6% and 0.9%. The nanofluid in current experiment was prepared by using two step methods and it will send to Transmission Electronic Microscopy (TEM) to check the agglomeration of nanoparticle in base fluid. Mean while, the experiment instrument consists of a loop heat pipe connect along with evaporator, vapour line, condenser and liquid line. The experiment is conducted under a heat input ranged from 20W to 60W and the flow rates of working fluid are set from 5 mℓ/min to 10 mℓ/min. The present experimental work require to measure the temperature of five locations in Loop Heat Pipe which consists of copper base plate (Tb), the evaporator (Te), the vapor line (Tv), the condenser section (Tc) and the liquid line (Tl) during steady condition. The temperature of each location will be taken to calculate the thermal resistance and heat transfer coefficient of each location in Loop Heat Pipe in order to justified cooling effectiveness with different types of working fluid in Loop heat pipe. Other than that, the transient temperature distribution of each region will include in current scope of studies in order to monitor the period to reach steady state with different type of nanofluid in LHP. The ANSYS-FLUENT simulation is conducted to determine the temperature of each region in LHP and the predicted transient temperature distribution of LHP. The results of simulation data will be compared with experimental data.

1.6 Thesis organization

There are five chapters in this thesis. In chapter one, a brief presentation about Loop Heat Pipe background, objectives of research are introduced. In chapter two, literature studies of LHP with nanofluid are presented. Methodology approach with experimental setup has been highlighted in chapter three. In chapter four, experimental results and result analysis are presented. The discussion also has been extended for comparison with different nanofluid in LHP. Finally, conclusion and recommendation for future works will be discussed in chapter five. The thesis ends up with reference.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical background

Over the past decade, nanofluids have been reported to poss substantially higher thermal conductivity than conventional water as coolant. However, the earliest approach to add metallic particles to base fluid to change the thermal properties of working fluid was proposed by Maxwell in 1873. (Choi and Eastman, 1995) The mixture thermal conductivity was found increase compared to the base fluid. Nanofluids word was then introduced by Choi in 1995, which prepared by dispersing nanometer-sized particles, generally less than 100 nm in a base fluid such as water. Then, the concept of nanofluid by applying nanotechnology to improved thermal conductivity was pioneered in Argonne National Laboratory Illinois, U.S.A. With addition of metallic nanoparticles copper, aluminum, silver, etc to the base fluid, it shows an increase in thermal conductivity of the mixtures and capable to enhance overall heat transfer capability.

In term of nanofluid working medium in heat pipe (HP), it was firstly created by Gaugler in the year 1944 which consists of a closed tube where the liquid can evaporate after absorb heat at heating location. However, Loop heat pipes (LHPs) were officially introduced at the Urals Technical University in Russia in 1971 (Maydanik et al., 2005). It is a particular kind of heat pipe in which the evaporator and condenser are separated, with the working fluid transported between the two components via tubing or pipes. Later in the year of 1985, Maidanik has file a patent for water based diamond nanofluid in loop heat pipe (LHP) experiments under various operating temperatures and heat powers (Maidanik et al., 1985) They