International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal
ISSN No: 2456 - 6470 | www.ijtsrd.com | Volume - 2 | Issue – 4

Experimental Enhancement of Heat Transfer Analysis on Heat Pipe using SiO2 and TiO2 Nano Fluid

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ABSTRACT

This paper describes the enhancement of thermal performance of heat pipe using SiO2 and TiO2 nano fliuds. The experimentation explains about the effects of heat pipe inclination and heat input on the thermal efficiency and thermal resistance. Heat pipe is an advance type of heat exchanger which transfers huge amount of heat due to the effect of capillary action and phase change heat transfer principle. Recent developments in the heat pipe with high thermal conductivity through nano fluids. This paper reviews, influence of various factors such as heat pipe tilt angle, charged amount of working fluid, nanoparticles type, size, mass/volume fraction and its effect on the improvement of thermal efficiency, heat transfer capacity and reduction in thermal resistance. The nano fluid preparation and the analysis of its thermal characteristics also have been reviewed.

Keywords: *Nano fluids; Heat pipe; Inclinations;Thermal resistance;Thermal efficency*

1 INTRODUCTION

A heat pipe is similar to a heat exchanger. It differs from a heat exchanger by virtue of its ability to transport heat against gravity by an evaporation-condensation cycle with the help of porous capillaries that form the wick. The wick provides the capillary driving force to return the condensate to the evaporator. The quality and type of wick usually determines the performance of the heat pipe, for this is the heart of the product. Different types of wicks are used depending on the application for which the heat pipe is being used.

This heat pipe concept was found especially for application in space during the 1960s by the NASA. One difficult problem in space was to transport the heat from the inner side to the outer side, because the heat transfer in vacuum is very low. So there is a unavoidable thing to create an effective and fast way to transport heat, without getting the effect of gravity action. The thing behind is to develop a flow fields that transport heat energy from one place to another through convection, because convective heat transfer is very much faster than heat transfer by conduction. Nowadays heat pipes are used in several applications, where one has limited space and the necessity of a high heat flux. Of course, it is still in use in space applications, but it is also used in heat transfer systems, cooling of computers, cell phones and cooling of solar collectors.

The nanofluids kept in the suspension of conventional fluids have the potential of superior heat transfer capability compared to the conventional fluids due to their improved thermal conductivity.

2. HEAT PIPE PRINCIPLE

Heat pipe is a heat transfer device which transports large quantities of heat with minimum temperature gradient without any additional power between the two temperature limits. It consists of three different sections namely evaporator, adiabatic section and condenser section. Figure.2.1 shows the schematic arrangement of a heat pipe. Heat pipes and their applications in thermal management have been studied for decades. They constitute an efficient, compact tool to dissipate substantial amount of heat from various engineering systems including electronic components. Heat pipe has ability to dissipate huge amount of heat with small temperature drop along the heat pipe while providing a self-pumping capable through a porous material in its structure. A limiting factor for the heat transfer potential of a heat pipe is depends working fluid properties. The thermophysical properties of the fluid can be improved. An innovative way to enhance liquid thermal conductivity is the dispersion of highly conductive solid nanoparticles within the base fluid. Copper heat pipe and stainless steel heat pipe as shown in figure 2.1from walunj A.A,pathan F.Z[1].

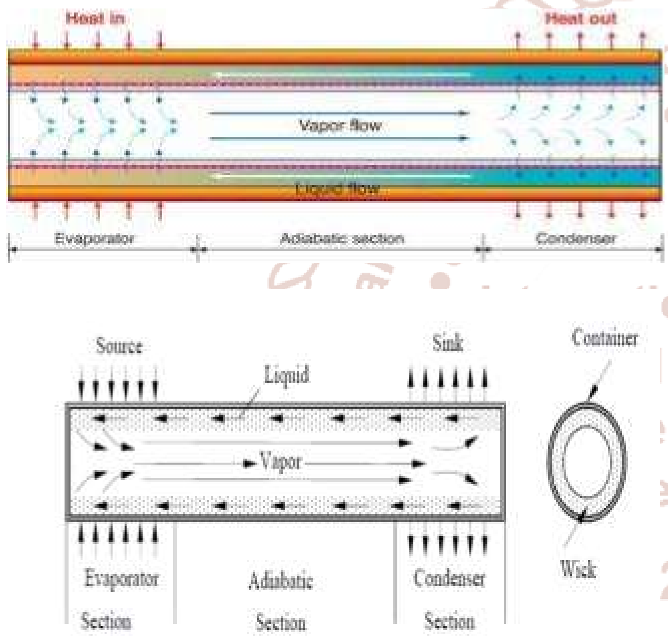

Figure 2.1 Simple Heat Pipe

Traveling through the adiabatic section the vapor reaches the condenser region where condensation rejects the latent heat of the fluid to the sink. The condensed liquid is pumped back against an adverse pressure gradient to the evaporator by a combination of the capillary pumping action and/or bulk forces. This fluid circuit is repeated during the normal operation of the heat pipe and can continue as long as there is sufficient vapor pressure and capillary pressure to support its operation. Simple heat pipe as shown Figure 2.1.

At the evaporator end the liquid recedes into the wick pores and hence the menisci in the pores at the vapor interface are highly curved. Whereas the liquid menisci at vapor interface in the condenser end are almost flat. This difference in the interface curvature of the menisci at the vapor interface coupled with the surface tension of the working fluid causes a capillary pressure gradient at the liquid-vapor interface along the length of the pipe. This capillary pressure gradient pumps the working fluid against various pressure losses such as friction, inertia and against bulk body forces. This axial variation of pressure is illustrated in Figure 2.2

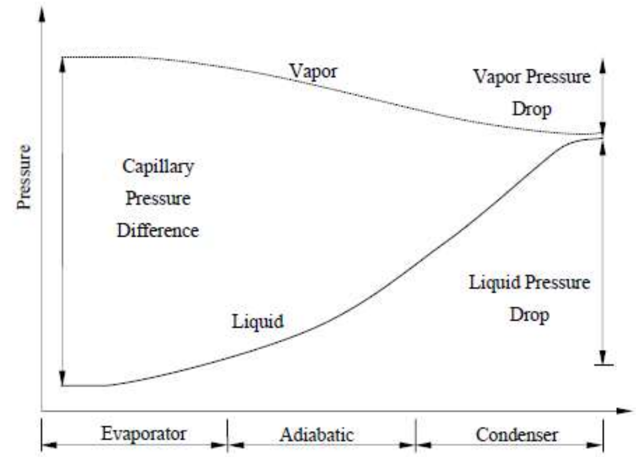

Figure 2.2 Pressure variation along a heat pipe

3. EXPERIMENTAL SETUP

A heat pipe is broadly divided in three sections namely, evaporator, adiabatic and condenser. A typical heat pipe as shown in Figure 3.1 has one evaporator section that takes heat from a source. The heat absorbed in the evaporator causes change of phase of the working fluid from liquid to vapor. The increased vapor pressure in the evaporator causes the vapor to exit from the evaporator section and travel through the adiabatic section.

The length of evaporation section is 300mm and adiabatic section is 400mm and condenser section is 300mm. A wire mesh made up of stainless steel material to place inside of the copper tube.There are three K type thermocouples fixed on the top surface of the stainless steel tube by using M-Seal.

The temperature values are displayed by temperature indicator. The temperature range of the thermocouple is -200°c to 1400°c.

A nichrome coil was wounded on the evaporator section only.

The evaporator and adiabatic sections are covered by Glass Wool.

Figure 3.1 Experimental Setup

The evaporator section was heated by a nichrome coil surrounding at its circumference and the power supply to the Nichrome coil was given by auto transformer. The condensation section cooled the nano fluid by temperature of atmospheric air. To minimize the heat loss the evaporator and adiabatic section was insulated by using glass wool. The heat pipe was arranged in different angles like 0o, 30o, 45o, 60o by using the wooden stand. Schematic diagram of heat pipe as shown in Figure 3.2.

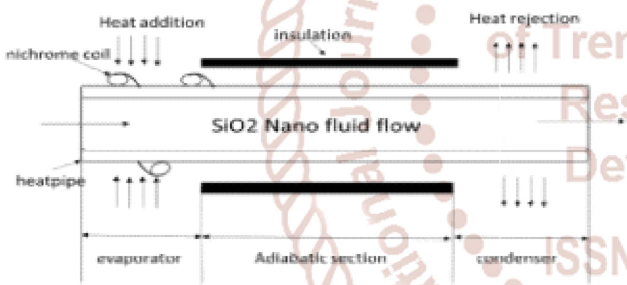

Figure 3.3 Schematic diagram of heat pipe

4. Preparation of nanofluids

The preparations of Nano fluid include as the production of Nano based particles and then blend into the base fluid. The two methods are used to prepare the Nano fluids are single-step method and two-step method. For the preparation of SiO_2 particles, two-step method is more suitable. In the two step method, initially nano–scale sized metals, metal oxides, fiber particles and carbon nanotubes (CNT/NCT) are prepared.

Then the dry powder is produced by various processes like chemical vapor condensation, mechanical alloying, etc. Thereafter, it is dispersed in the base fluids from Negin Monirimanesh[2]. The agglomeration is high in this method, because of its prolonged stages in the preparation. Magnetic Strier as shown Figure 4.1.

Figure 4.1 Magnetic Strier

In current experimental study, silicon dioxide of 0.1%,0.25%,0.50%,0.75% mass concentration is used and the reason for choosing silicon is due to its widely known thermal properties and easy to blend. The silicon dioxide Nano particles are purchased from a commercial trader. The properties of the Nano fluid are average particles size= 50 nm, Density=2650, Thermal conductivity= 1.38 W/m/K, specific heat= 703 J Kg-1 K-1, The required volume fraction of 0.1%, 0.25%, 0.50%, 0.75% was prepared by blending the specified quantity in distilled water from Kakaça S [3]. Table 4.1 shows the mass of SiO_2 and TiO_2 nanoparticles various volume concentration of nanofluid.

Table 4.1 Volume concentration of nanofluids

S.No	VOLUME CONCENTRATION OFNANOFLUIDS			
	Percentage of volume concentration	DI water quantity (ml)	Mass of SiO_2 nanoparticle (gram)	Mass of TiO_2 nanoparticle (gram)
1	0.1%	500	1.39	1.90
2.	0.25%	500	3.35	4.76
3.	0.5%	500	6.70	9.54
4.	0.75%	500	9.94	14.36

The above table 4.1 infers the volume concentrations for Sio2 and TiO2 nano fluids from LamasB[4].

5. CALCULATION

5.1 FORMULA

1. R= Te-Tc / Q (°C/W)

Where, R= Thermal Resistance (°C/W)
Q= Power (W)
Te= Evaporator Temperature (°C)
Tc= Condenser Temperature (°C)

2. Q= VxI in Watts

Where, V= voltage (V)
I =Current (A)

3. h= Q/A (Te-Tc) w/m2 °c

Where, h= Heat Transfer Co-Efficient
A= Area Of Heat Pipe

4. A = πdl in m2

Where, d= Diameter Of The Heat Pipe In m
l = Length Of The Heat Pipe In m

5.2 CALCULATION OF THERMAL RESISTANCE

For 0.1 Concentration At 0 Degree

1. Q = VxI

= 100x0.2

Q = 20 Watts

2. RSio2 = Te-Tc / Q

= (30-27) / 100

RSio2 = 0.15 °c/w

5.3 CALCULATION OF HEAT TRANSFER CO-EFFICIENT

For 0.1 Concentration At 0 Degree

1. $A = \pi$dl d = 12 mm = 0.012m l = 1000mm=1.0 m
= πx0.012x1
A = 0.0376 m2

2. h Sio2 = Q/A(Te-Tc) w/m2 °c
= 20 / 0.0376x3
h Sio2 = 177.39 w/m2 °c

6. RESULTS AND DISCUSSIONS:

FOR SILICON DI OXIDE (SiO_2)

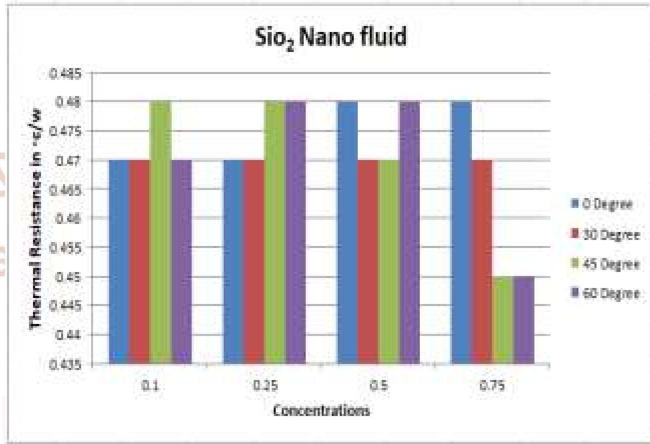

Figure 6.1 Experimental results for SiO_2 nano fluid

The above figure infers that the thermal resistance of Sio_2 nanofluid at 0^0, 30^0, 45^0 and 60^0 angle of inclination of heat pipe for various concentrations:For 0.10, minimum Thermal Resistance is 0.47. For 0.25, minimum Thermal Resistance is 0.47. For 0.50, minimum Thermal Resistance is 0.47. **For 0.75, minimum Thermal Resistance is 0.45.**

FOR TITANIUM OXIDE (TiO_2)

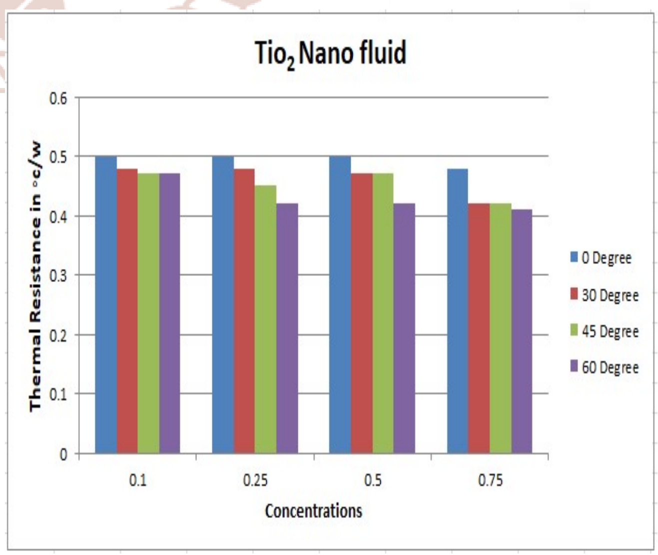

Figure 6.1 Experimental results for TiO_2 nano fluid

The above figure infers that the thermal resistance of Sio2 nanofluid at 0°, 30°, 45° and 60° angle of inclination of heat pipe for various concentrations: For 0.10, minimum Thermal Resistance is 0.47. For0.25, minimum Thermal Resistance is 0.42. For 0.50, minimum Thermal Resistance is 0.42**. For 0.75, minimum Thermal Resistance is 0.41.**

7. CONCLUSION:

This paper deals with the thermal analysis of this paper, the thermal performances of the heat pipe by using various nano fluids (SiO_2 and TiO_2) as the working fluid. A nano fluid is an innovative heat pipe working fluid with metal nanoparticles dispersed on it. In present case, the pure water with diluted nano particles, inside circular heat pipes, is experimentally tested, to study the thermal performance of the heat pipe. Cylindrical copper heat pipe under various operating parameters such as heat input, fill ratio and angle of inclination are experimentally investigated using the SiO2 and TiO_2 -DI water as a working fluid. The thermal resistance of TiO_2 nano fluid of 0.75 concentration at 60° angle of inclination is found to be the better nano fluid.

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