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Research Article

Thermal Performance Investigation of Heat Transfer Characteristics of a Two Phase Thermosyphon using Hybrid Nanofluid

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Abstract

It is very important to increase the rate of Heat transfer in many areas especially in heat exchangers, gas turbine, air coolers, different power plant, where transfer of heat Energy is an important factor. A tremendous amount of effort had taken to develop new methods to increase heat transfer. It demonstrated that nanofluid can have remarkable higher rate of heat transfer than those of the base fluid. In this paper a thermal performance of a circular heat pipe with hybrid nanofluid (i.e. copper oxide and carbon nanotube) is carried out at different heat input, at different angle of inclination and at different concentration of nanoparticle on two phase closed thermosyphon. Result of this experiment shows that efficiency of HP increases with use of nanofluid. Maximum efficiency observed at inclination angle 75^0 *and it is 33.24%.*

Keywords: *Thermal conductivity, nanofluid, Heat transfer enhancement, circular HP*

1. Introduction

The importance of heat transfer enhancement has gained greater significance in many areas. Due to limitation of fossil fuel in the world, subject of energy consumption optimization in various industrial processes becomes very important. There are different techniques to transfer heat. In this paper experiment is carried out to determine rate of heat transfer through heat pipe. Heat pipe it is an device used to transfer heat from one point to another point by using the principle of thermal conductivity and phase transition. Among all heat transfer technique heat pipe is the most appropriate technology and it is very cost effective and having excellent heat transfer capability, high efficiency and structural simplicity.

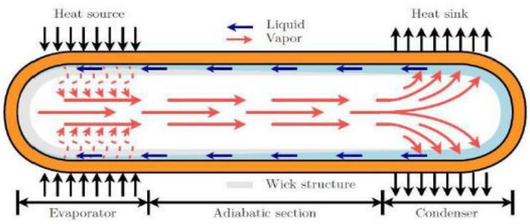

Fig.1: Technical description of HP

There are different type of Heat Pipe depends on the principle of coming back water from condenser to evaporator

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Two phase closed thermosyphon: A two phase closed thermosyphon is wickless. In this type condenser section is places above the evaporator section and whatever is the base fluid from condenser section that come back into evaporator section by the action of gravity.

Capillary-Driven Heat Pipe: It contains wick type structure. And wick is place on the inner radius of the pipe wall and base fluid return to evaporator through wick structure by the capillary action.

Annular Heat Pipe: It is similar to Capillary-Driven Heat pipe only difference is that cross section of the vapor space in annular heat pipe is annular instead of circular. So because of increasing surface area the capillary limit is higher in this case.

Vapour chamber: It is flat plate heat pipe in a rectangular or disked shape. In this basically additional block between evaporator and condenser section is provided. Used in special case when condenser is below the evaporator.

This Experiment is carried out to determine Heat Transfer characteristics of a two phase closed thermosyphon.

Nanoparticle is the very fine size metal or non-metal particle and when nanoparticle is associated with any base fluid is called nonofluid. Modern nanotechnology provides new opportunities to process and produce material with average crystallite sizes below 50 nm. They offer new possibilities to enhance heat transfer performance compared to pure fluid.

Because of larger surface area of nanoparticle not only heat transfer capability but also increases the stabilities. There are different nanofluid is been available like copper oxide (CuO), Aluminum oxide (AgO), Titanium oxide (TiO_2), Gold (Au), Silver (Ag), Copper (Cu) etc.

There is different pair of heat pipe material and nanofluid. Different researchers had been worked on it and finally they specified the pair like-copper envelope and water as a working fluid, copper-R134a, Aluminium-NH3, Super alloy-P etc. This experiment is carried out experiment on copper as an envelope and water as a working fluid.

Many researchers worked on different pair of heat pipe with different nanofluid.

Amir Faghri[2014] worked on, Heat pipe: Review, opportunities and Challenges. He studied various heat pipes, operation of HP, heat transport limitation. He also provided a self contained document to design and simulate various types of heat pipe under different operating condition.

M.G.Mausa[2011] carried out an experiment on, an Effect of nanofluid in circular heat pipe. The nanofluid consists of Al_2O_3 with a diameter of 100 nm. The experimental data of the nanofluid were compared with those of DI water. Experimental results showed that if the concentration of nanofluid increasing then thermal resistance of heat pipe decreasing.

Clement Kleinstreuer, Yu Feng[2011] worked on experimental and theoretical studies of nanofluid thermal conductivity enhancement. They foundthat metallic nanoparticle at low fractions in liquid, enhance the thermal conductivity over base fluid values and that's why they are potentially useful for advanced cooling of micro-system.

X.L.Shang, Z.H.Liu [2008] investigated the heat transfer characteristics of a closed loop heat pipe with copper as a nanoparticle and water as base fluid with different filling ratio. The results were compared with those of same heat pipe with distilled water as a base fluid. They found that by using Cu-water nanofluid in a heat pipe enhance the heat removal capacity by 83 %. It was stated that directly adding the nanoparticle into the distilled water without and stabilizing agent had greater heat transfer enhancement compared to case where stabilizing agent is added.

S.Kang, W.Wei, S.Tsai and S.Yang[2006] carried out an experiment on, Study of nanofluid is employed as theworking medium for a conventional grooved circular heat pipe. The nanofluid used in this case is an aqueous solution of 35 nm diameter silver nanoparticle. The experiment was performed to measure temperature distribution and to compare heat pipe thermal resistance using nanofluid with water. He demonstrated that the thermal resistance decreased 10-80% compared to water. Also he found that thermal resistance of heat pipe decreases as silver nanoparticle size and concentration increases.

Salma Halefadi, Patrices Estelle, Thierry Mare [2014] worked on heat transfer properties of aqueous carbon nanotube nanofluid in coaxial heat exchanger under laminar regime. He found that thermal conductivity of a based fluid significant effect on enhance by using nanofluid.

C.Y.Tasi [2004] worked on, experiment on cylindrical mesh wick heat pipe. The working fluid was aqueous solution of various size gold nanoparticle. The experimental results showed that total resistance of heat pipe reduced 20-37% due to the addition of nanoparticle.

Y.H.Lin [2008] investigated on the thermal performance of closed loop oscillating heat pipe using using nanofluid. They applied water based silver nanofluid in different volume fraction and various filling ratio(20%, 40%, 60%, and 80%). Results showed that the thermal performance of oscillating heat pipe using nanofluid was better than that of water. The best filling ratio was reported 60%.

Jung-Shun chen, Jung-Hua Chou [2014] worked on cooling performance of flat plate heat pipe with different liquid filling ratio. In their work the effects of different liquid filling ratio also studied on the performance of flat plate HP. He found that the optimal liquid fill ratio for the FPHP was 25% and maximum heat transport capacity reported 47 W. He also said thattoo much or insufficient filling ratio would reduce the effective thermal conductivity of FPHP.

C.Wilson [2006] worked on experimental investigation to study the nanofluid effect on heat transport ability in an oscillating heat pipe. Their results demonstrated that the thermal performance of heat pipe was significantly improve when charged with water based diamond nanofluid with the thermal resistance decreased to $0.03^0C/W$ at a power input 336 W.

H.B.Ma[2006] investigated experimentally and theoretically that heat transfer performance of flat plate oscillating heat pipe, which were created by machining grooved on both side of copper plate. Acetone, water, diamond-acetone, gold-water and diamond water nanofluid were tested as working fluid. The thermal resistance was further decreased by using the nanofluid. It was found that high volume fraction diamond-water was not stable but settled with time and reduces thermal performance. Gabriela Huminic [2011] worked on the heat transfer characteristics of two thermosyphon with iron oxide nanofluid. He found that heat transfer capacity increases with an inclination angle and also the thermal resistance decrease with increase in inclination angle and it also increase in volume concentration. The heat pipe filled with nanofluids has more thermal efficiency, it is more stable and lower thermal resistance than heat pipe filled with water suggested by Senthilkumar [2011].

The results displayed that aqueous solution of n-pentanol give better results than aqueous solution of n-butanol.

Wesley Williams [2008] worked on the turbulent convective heat transfer by using of alumina (Al_2O_3) and zirconia (ZrO_2) nanoparticle in water of horizontal

tube section at different flow rates. The results showed that there is an increase in heat transfer enhancement.
Ulzie Rea [2009] worked on the laminar convective heat transfer and various pressure losses for alumina-water and zirconia-water nanofluid in a vertical tube. The outcomes showed that by using these nanofluids, the heat transfer coefficient increases by approximately 3% in the developed region and 2% in the entry region at 1.32% vol.

Yu-Tang chen [2010] worked on Experimental study of silver nanofluid on flat plate HP thermal performance. He found from his experiment that the temperature difference and thermal resistance of FHP with silver nanoparticle solution were lower than that of with pure water.

TusharTiwantane, ShivprakashBarve [2015] worked on Experimental study of WHR using Heat Pipe Heat Exchanger with Hybrid nanofluid. In his experiment he work on heat exchanger which is made up of Heat Pipe as an WHR and used nanofluid as Al_2O_3, CuO, TiO_2. And he concluded that the average increase in Nussle number for hybrid nanofluid is 10.94% when compared to pure water.

Kamble D.P., Gadhave P.S., M.A. Anwar [2014] worked on Enhancement of Thermal Performance of HP using Hybrid nanofluid. He used Hybrid nanofluid Al_2O_3+CuO and water as a base fluid. He found that thermal resistance reduces by 32% with 2% volume concentration. For the variation of heat input between 25W to 100W with 2% volume concentration the thermal resistance decrease by 39.28% with pure water.

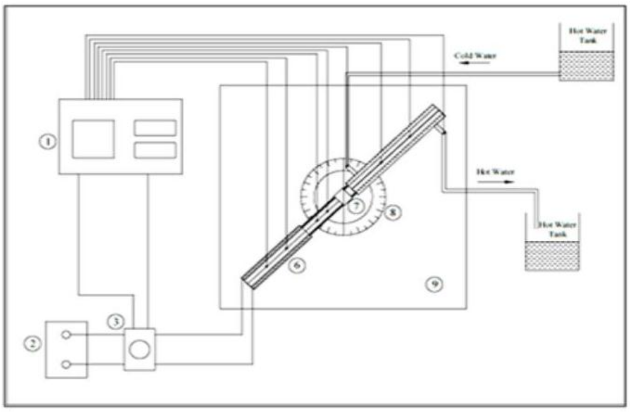
Research Gap: Most of the researcher worked to enhance heat transfer to using nanofluid. But very less work is available on the effect of thermal performance using mixture of two nanofluid on HP.

So following are the main objectives of this work:
1. To find the impact of various operating parameter like power input, concentration of nanofluid on rate of heat transfer of nanofluid in HP.
2. To find thermal performance of HP for different angle of inclination.
3. To find thermal resistance of HP for different angle of inclination and for various concentration of HP.

2. Experimental set up

In this work experimental set up is used to describe the thermal performance of hybrid nanofluid which is flowing inside the HP along the water. Heat Pipe can be design by considering the Capillary limit, Sonic Limit, Boiling Limit, Entrainment limit and Vapor pressure limit.

The schematic of experimental set up is shown in Fig.2. The band type heater is provided to supply heat at the evaporator section. A 230V AC power supply is given to heater. In the condenser section water jacket is provided. To determine the temperature at various location of heat pipe, J- type of thermocouples is provided. Here filling ratio is considered as 50%.In this experiment the amount of heat loss from evaporator and condenser section is assumed to be negligible.



(1. Control panel 2. Electric supply 3. Dimmerstat 4. Heat pipe 5. Angle variation arrangement 6. Angular scale 7. Water tank 8. Thermocouple)

Fig.2 Layout of Experimental set up

Table 1 Parameters of Heat Pipe

Sr.No.	Property	Value
1	Evaporator Length	0.1
2	Adiabatic Length	0.05
3	Condenser Length	0.45
4	Total Length	0.6
5	Effective Length	0.55
6	Outer Radius	0.01252
7	Inner Radius	0.011
8	Cross Section Area	0.000379
9	Axial Angle	90
10	Thermal Conductivity of Material (Copper)	385
11	Vapor Core Radius	0.011
12	Evaporative Section Radius	0.011
13	Condenser Section Radius	0.011

Here basically four Heat Pipe is manufactured of a same dimension, same material. One is of pure water, 2nd contain 1% hybrid nanofluid, 3rd contain 2% and

4th contain 3% of nanofluid. Power input to heat pipe is increased from a 25W. At a different tilt angle i.e.15^0, 30^0, 45^0, 60^0, 75^0 reading is taken. Mass flow rate, into water jacket is also gradually increased.

Fig.3 Experimental set up

3. Data reduction

Efficiency of HP given by:

$$\eta = \frac{mCp\Delta T}{Q} \quad (1)$$

Thermal Resistance of HP

$$R=\frac{Te-Tc}{Q} \quad (2)$$

Average Evaporative and condenser temperature is

$$Te= \frac{T1+T2}{2} \quad (3)$$

$$Tc= \frac{T5+T6}{2} \quad (4)$$

4. Results and Discussion

By doing the experiment we got following results:

1. HP with base fluid i.e. water at a 1 LPH mass flow rate with different inclination angle i.e. 15^0, 30^0, 45^0, 60^0, 75^0

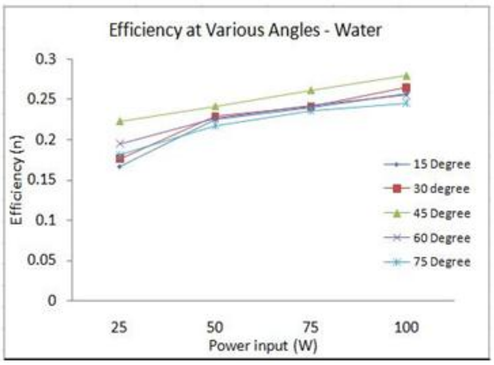


Fig.4 Effect of Angle of inclination on thermal efficiency

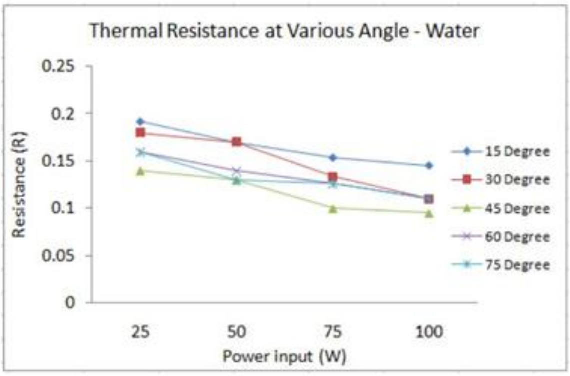


Fig.5 Effect of angle of inclination on thermal resistance

It is found that when HP is of water then at 15^0 we get thermal efficiency 22.22%, when angle is 30^0then 22.81%, at 45^0 25.119%, at 60^0efficiency is 23.02% and at 75^0efficiency is 22.03%. Also the thermal resistance reported at 15^0, 30^0, 45^0, 60^0, and 75^0 is to be 0.16, 0.14, 0.11, 0.13, and 0.13 respectively.

2. At a 1% concentration of nanofluid at 1 LPH with different angle i.e. 15^0, 30^0, 45^0, 60^0, 75^0

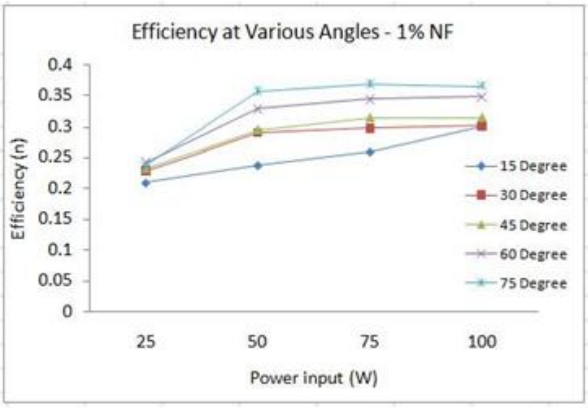


Fig.6 Effect of angle of inclination on thermal efficiency

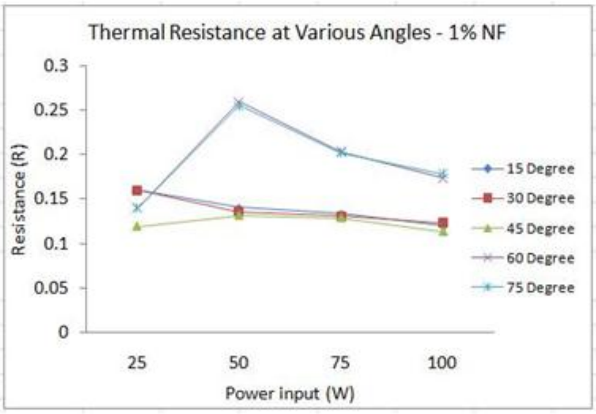


Fig.7 Effect of angle of inclination on thermal resistance

It is found that when HP is of 1% nanofluid then at 15^0 we get thermal efficiency 25.09%, when angle is 30^0 then 27.89%, at 45^0 28.86%, at 60^0 the efficiency is 31.61% and at 75^0 efficiency is 33.24%. Also the thermal resistance at 15^0, 30^0, 45^0, 60^0, and 750 found to be 0.138, 0.13, 0.123, 0.194, and 0.192 respectively.

Conclusion

1 From this experiment we found that thermal efficiency of HP increase with use of nanofluid.

In case of water as a base fluid thermal resistance get reduce as we increase angle of inclination.

We get maximum efficiency i.e. 33.24% when HP with nanofluid with orientation angle is 75^0.

Nomenclature

η= efficiency of heat pipe
R= thermal resistance of heat pipe
Te=Average temperature of evaporator
Tc= Average temperature of condenser
Q= Heat input
M=mass flow rete
Cp=specific heat of water
Δt= Temperature difference
HP= heat pipe.

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