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Research Article

Heat Transfer Enhancement of Circular Heat Pipe with Al_2O_3 BN/Water Hybrid Nanofluid

Kamthe Swapnil*, Pawar Dhananjay , Zurunge Gaurav, Ranade Anand and Kamble D.P.

Department of Mechanical Engineering, ZEAL (Dnyanganga) College Of Engineering &Research, Pune, India.

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Abstract

An experiment was performed to find out the effect of thermal efficiency of the heat pipe using Al2O3-BN/WATER hybrid nanofluid as a working fluid. We have taken the average size ofparticle Al2O3-BN as 40 nm and the concentration of Al2O3-BN nano particle in the fluid is 100 mg/lit. This research discusses about the different effect of heat pipe parameter like inclination angle effect, cooling water flow rate at condenser of heat pipe and heat given as input on the thermal efficiency and resistance. The aim of this paper is to experimentally find the behavior of nanofluid to improve the performance of a circular type of heat pipe. Pure water and Al2O3-BN water based nanofluid are used as working fluids in heat pipe. Thermal resistance decreases with increasing Al2O3-BN water based Nano fluid heat pipe compared to that of pure water based heat pipe.

Keywords: *heat pipe, nanofluids, thermal efficiency, heat input, heat pipe inclination.*

1. Introduction

Researches in the field of nano-material technology have led to meaningful results in the field of heat transfer enhancement. In 1995, given in Senthilkumar R *et al* (2011) first introduced "Nano fluid" concept which involved addition of Nano-metal or metal oxide particles in the liquid in a definite proportion leading to formation of a new type of cooling working and heat transfer fluid. Outstanding to its stability and high thermal conductivity, the nanofluid give a great deal of improvement in heat transfer. At present, researches on nano fluid heat transfer mainly working on forced convection in tube, heat transfer in pool boiling. Still the use of Nano fluid in thermal field is limited. As alternatives to the conventional heat sinks, two-phase cooling devices (Heat pipe) have been emerged as promising devices for heat transfer with effective thermal conductivity over 200 times higher compare to copper.

Heat pipes are passive type of devices that can transport heat from a one point (source) to a another point(heat sink) over relatively long distances by the latent heat of vaporization of a working fluid. It having three sections; evaporator, adiabatic section and condenser section. Heat absorbed by the working fluid in condenser is the amount of heat equivalent to the latent heat of vaporization. The working fluid vapor condenses in the condenser and then, returns back to the evaporator. Heat pipes are widely applied in various thermal systems because of its high-efficient heat transfer capability. Skilled designer have contributed to the improvement of the heat pipe by developing thermo syphon, pulsating type of heat pipe, capillary pumped loop (CPL), loop heat pipe (LHP), grooved type and micro type heat pipe. One of them is axial heat pipe with micro grooves. Many analytical and experimental researches have been done on the thermal performance of the axial micro-grooved heat pipe.

However, focus was kept on the heat pipes that are horizontal. Thus there is limited literature on inclined heat pipes. Heat transfer from working fluid takes place by phase change in a heat pipe. Hence, selection of working fluid is important in improving thermal performance of heat pipe. Previous results have shown that nanofluids can be helpful in heat transfer enhancement in the single and changingphase heat transfer. This has led to application of various nanofluids in heat pipes as the use of working fluid to improve their heat transfer characteristics.

Based on the experimental results inR. Manimaran *et al* (2010), this study is aimed at a fundamental understanding of the Nano fluid as working fluid on the thermal performance of a heat pipe. The inclination angle effects on the wall temperature distributions, heat transfer coefficient (HTC) of the evaporator and condenser section respectively, the total thermal resistance and the maximum heat flux under steady sub atmospheric pressures were investigated experimentally.

*Corresponding author: **Kamthe Swapnil**

2. Experimental Apparatus and Procedure

I. Objectives of Project

The objective of this work is to study the heat transfer enhancement of a circular heat pipe using Al2O3-BN/water hybrid nanofluid. The experimentation work is done using a circular heat pipe with the following objectives.
1. Effect of different concentration of hybrid nanofluids /water on thermal resistance of Heat Pipe.
2. Effect of inclination angle on thermal resistance of heat.
3. Effect of heat input on thermal resistance rate of heat pipe.

For achieving the objectives the experimental system designed with the following specifications, provision is made to vary the heater input by changing the voltage, arrangement is made to vary the inclination angle and to study the effect of volume concentration of hybrid nanofluid on thermal resistance of heat pipe three heat pipes with inner fluid as water, 1% volume fraction of hybrid nanofluid and 2 % volume fraction of hybrid nanofluid are prepared.

II. Specification of Experimental System

1. Three heat pipes of 600 mm length, one with inner fluid as water and two with 1% volume fraction of hybrid nanofluid and 2 % volume fraction of hybrid respectively.
2. Heater Capacity:-200 W with variation in 25W
3. Variation in inclination angle:-00 to 900
4. Rota meter:-0-10 LPM
5. RTD's:-8 Nos.3 for evaporator section, 2 for adiabatic section and 3 for condenser section.
6. Centrifugal Pump:-1/4 HP.

III. Experimental Setup

IV. Test Methodology

1. The body of heat pipe is made of copper having a length of 600 mm,25.4 mm is outside diameter and inside diameter of 25 mm.
2. It is filled with 400 ml of working fluid, approximately equal to the required amount to fill the evaporator. The section between the evaporator and the condenser is normally called as the adiabatic section. The 300 mm is the length of adiabatic section.
3. The temperature distribution on the wall at the adiabatic zone is measured using five evenly spaced thermocouple, at an equal distance from the evaporator.
4. Asbestos material layer is used to insulate the adiabatic section of heat pipe. The heat loss from the evaporator and condenser surface is negligible.
5. Aelectric heater having cylindrical shape is attached to the evaporator which supplies electrical power to it. Proper electrical insulation is provided. The heater is energized with 230V AC supply and measured using a voltmeter and ammeter connected in parallel and series connections respectively.
6. The evaporator and condenser having length of 150 mm. Two thermocouples are used along the length of evaporator to measure the temperature of evaporator.
7. Removal of heat from pipe has been done by using a water jacket at the condenser.
8. There is a possibility of a sudden rise in wall temperature due to ability to transfer the heat through the internal structure which could damage internal structure if heat is not released at the condenser section properly. Therefore, before supplying the heat to the evaporator, the cooling water is circulated first through the condenser jacket.
9. The cooling of condenser section is done using water flow through a jacket at the condenser section with an inner and outer diameter having size of 25.4 mm and 30 mm respectively. The flow of water rate is measured using a Rota meterat inlet to jacket; the flow rate is kept constant at 6.6 lpm. Three thermocouples are used which are spaced equally along the length of condenser to measure its average temperature.
10. Two thermocouple are placed at the inlet and outlet to measured temperatures.
11. Three heat pipes which are identical are manufactured as per mentioned dimensions are used for conducting the experiment. One of the heat pipes is filled with distilled water, second one with 1% aqueous solution of hybrid nano fluid (Al2O3-BN), third one with aqueous solution of 2% hybrid nano fluid.
12. The input power to the heat pipe is gradually increased to the desired level. The temperatures at five different locations on the surface along the adiabatic section of heat pipe are measured at regular time steps until steady state condition reaches. Simultaneously readings of the condenser and evaporator wall temperatures, water inlet and outlet temperatures at the condenser place are taken.

13. The input power is turned off and the cooling water is allowed to flow through the condenser to cool the heat pipe once the steady state is reached. The setup is than can kept ready for further experimental work.
14. The state in which the variation of temperature is within 10^0C for 10 min is defined as the steady state condition. The power is then increased to the next step and testing of heat pipe is done.
15. Experimental procedure is repeated for different heat inputs (25, 50, 75 and 100 W) and different inclinations of pipe (00, 150, 300, 450, 600, 750 and 900) to the horizontal position and observations are recorded. Energy balance to the condenser flow is applied to compute the heat transfer rate from the output of condenser.

3. Experimental Results and Discussions

The ultimate aim of the variation of inclination angle, heat input and volume concentration of hybrid nanofluid on circular heat pipe is to study its effect on thermal resistance.

The overall thermal resistance of circular heat pipe is calculated by equation

$$Rth = (Te-Tc)/Q \tag{1}$$

Where Te and Tc are the average wall temperatures of evaporator and condenser section and can be determined by following equations

$$Te = 1/n\sum_{i=1}^{n} Ti \tag{2}$$

$$Tc = 1/m\sum_{i=1}^{m} Ti \tag{3}$$

Q is heat at evaporator section and calculated by following equation

$$Q = VI \tag{4}$$

Where V and I are input voltage and current which is measured by digital voltmeter with resolution of 1 V and ammeter with resolution of 0.001 A respectively.

I. Sample Calculations

For 00 inclination with heat pipe containing water and for 25W heat input-
Te = ((T1+T2+T3))/3 ......(from equation 2)
Te=((45.1+45.1+56))/3
Te = 48.730C
Tc = ((41.1+40.2+40.1))/3 .....(From equation 3)
Tc =40.460C
Q = 25W
Therefore, thermal resistance Rth is
Rth =(Te-Tc)/Q ......(From equation 1)
Rth = ((48.73-40.46))/25
Rth = 0.3308.

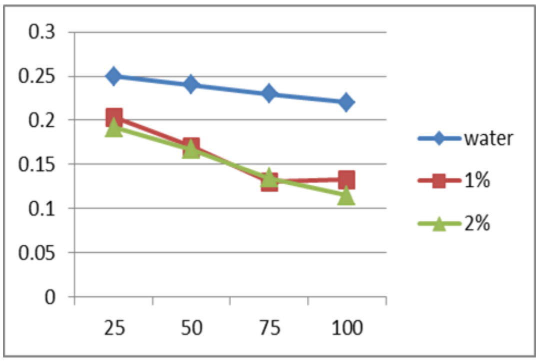

Fig 1.1 Graph of thermal resistance vs. power input for 0^0inclination for various concentrations of nanofluids w.r.t. water

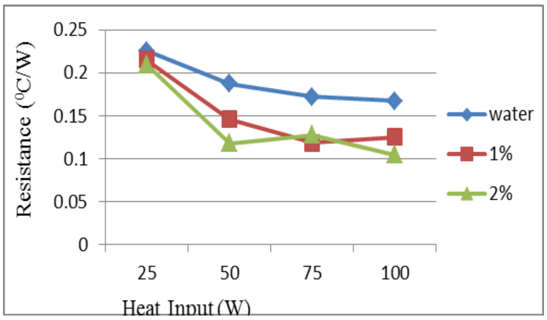

Fig 1.2 Graph of thermal resistance vs. power input for 15^0inclination for various concentrations of nanofluids w.r.t. water.

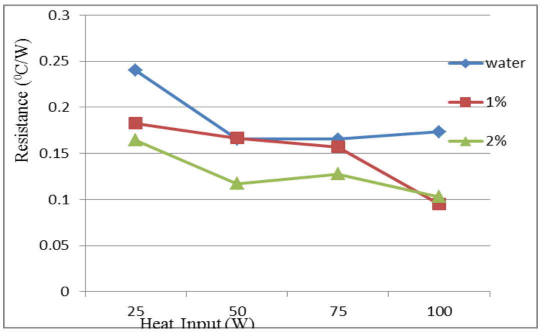

Fig 1.3 Graph of thermal resistance vs. power input for 30^0inclination for various concentrations of nanofluids w.r.t. water.

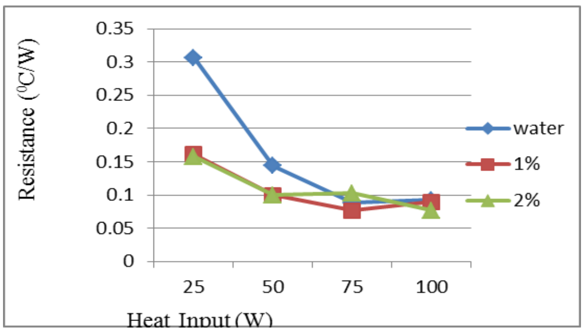

Fig 1.4 Graph of thermal resistance vs. power input for 45^0inclination for various concentrations of nanofluids w.r.t. water.

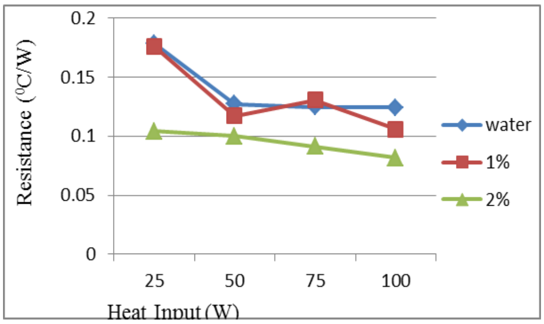

Fig 1.5 Graph of thermal resistance vs. power input for 60^{0}inclination for various concentrations of nanofluids w.r.t. water.

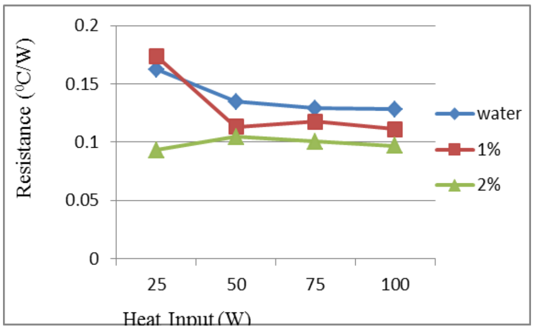

Fig 1.6 Graph of thermal resistance vs. power input for 75 inclination for various concentrations of nanofluids w.r.t. water.

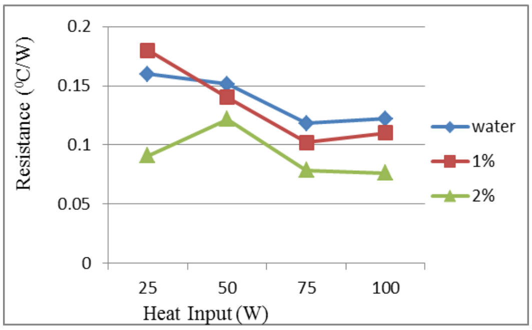

Fig 1.7 Graph of thermal resistance vs. power input for 90^{0}inclination for various concentrations of nanofluids w.r.t. water.

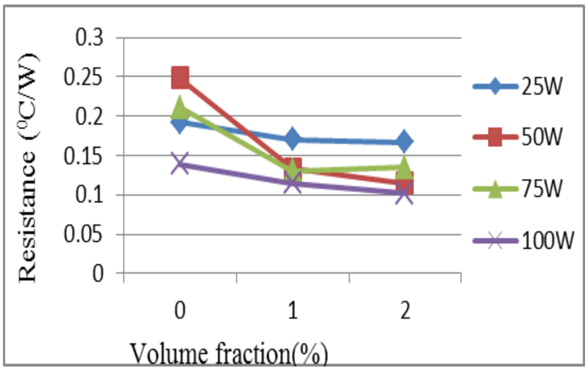

Fig.2.1 Graph of volume fraction vs. thermal resistance for 0^{0}inclination for various power input.

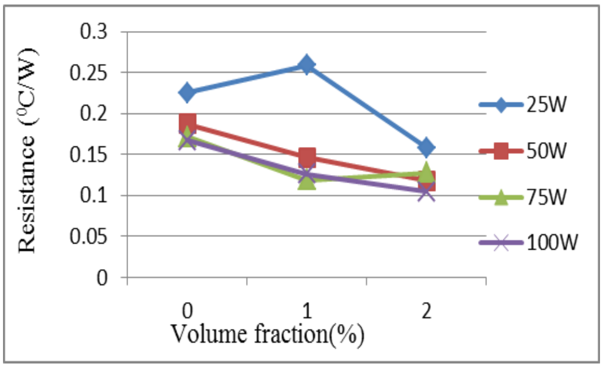

Fig.2.2 Graph of volume fraction vs. thermal resistance for 15^{0}inclination for various power input.

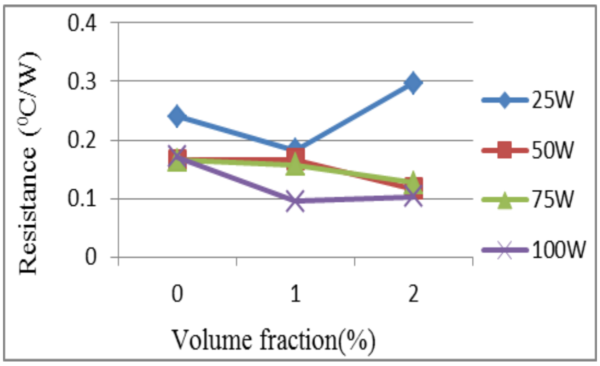

Fig.2.3 Graph of volume fraction vs. thermal resistance for 30 inclination for various power input.

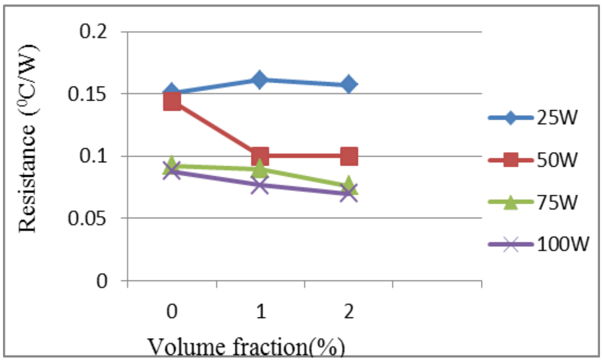

Fig.2.4 Graph of volume fraction vs. thermal resistance for 45^0 inclination for various power input.

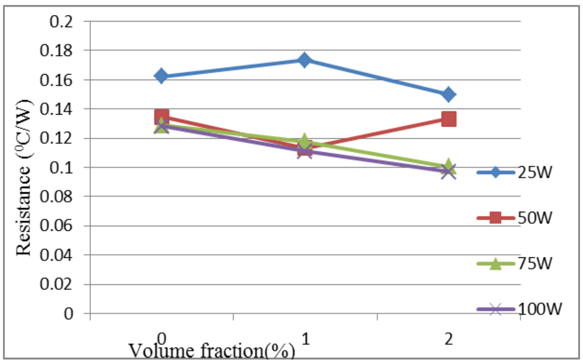

Fig.2.5 Graph of volume fraction vs. thermal resistance for 60^0 inclination for various power input.

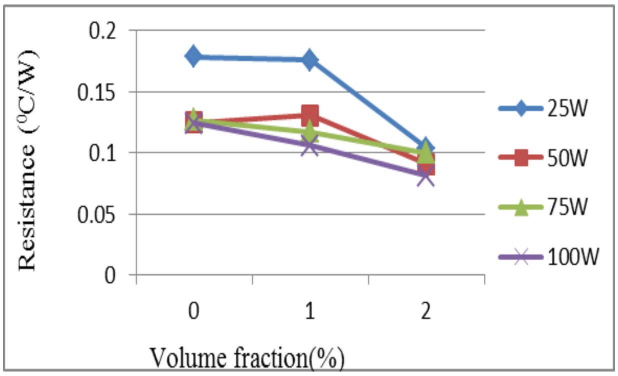

Fig.2.6 Graph of volume fraction vs. thermal resistance for 75^0 inclination for various power input.

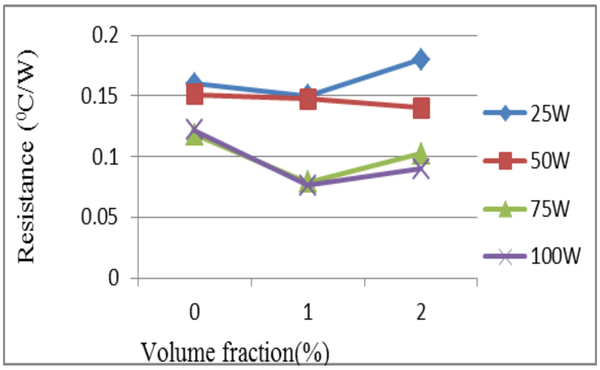

Fig.2.7 Graph of volume fraction vs. thermal resistance for 90^0 inclination for various power input.

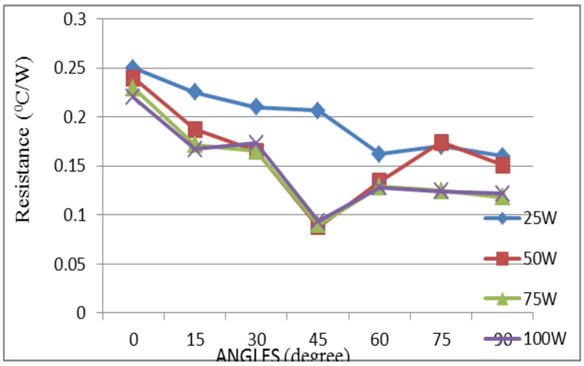

Fig.3.1 Graph of angle vs resistance of heat pipe where working fluid is water.

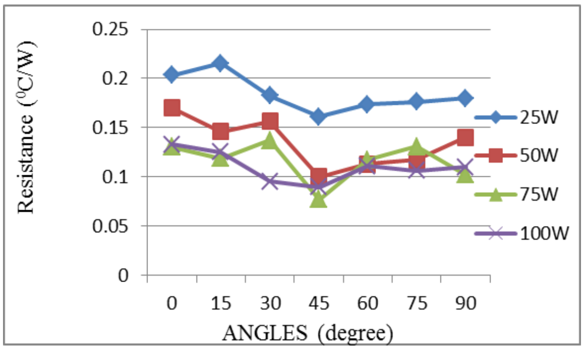

Fig.3.2 Gra ph of angle vs resistance of heat pipe where working fluid is 1% volume fraction nanofluid.

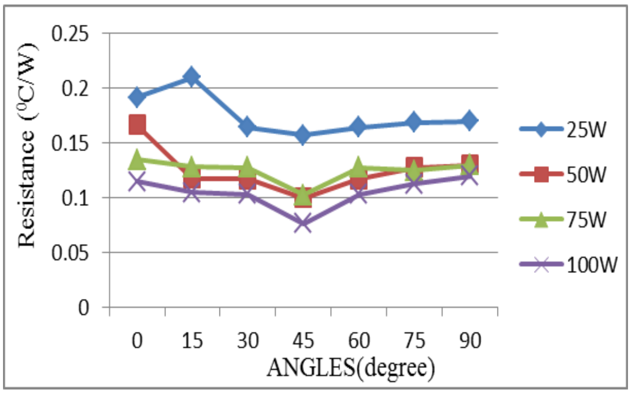

Fig.3.3 Graph of angle vs resistance of heat pipe where working fluid is2% volume fraction nanofluid.

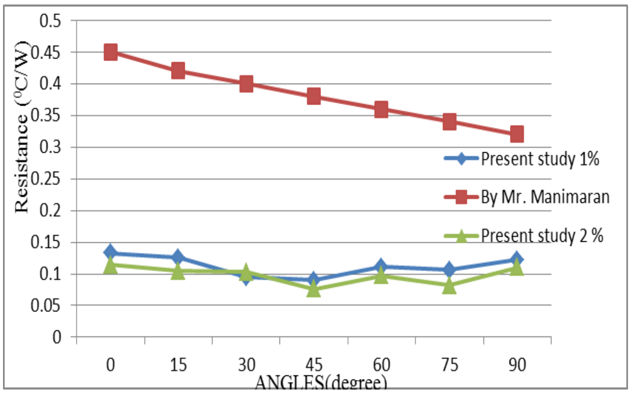

Fig 4 Comparison of the present results with available literature at different inclination angle.

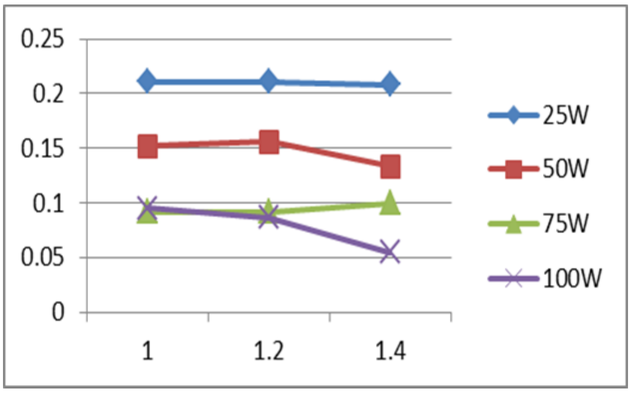

Fig.5 flow rate vs. resistance of heat pipe for inclination angle of 0^0 with heat pipe fluid as water.

Conclusions

This experimental research discusses the thermal properties of circular heat pipe performance using hybrid nanofluid (Al2O3-BN/Water) as working fluid. For that purpose the effect of different concentration of hybrid nanofluid, inclination angle, heat input on thermal resistance of circular heat pipe is studied. From the experimentation the following conclusions can be drawn

- There is a reduction in thermal resistance of circular heat pipe with increase in in volume concentration of hybrid nanofluid, increase in heat input and increase in inclination angle compared with distilled water as working fluid.
- With increase in the volume concentration of hybrid nanofluid the thermal resistance of circular heat pipe for 2% volume concentration of hybrid nanofluid as working fluid reduces by an amount of 39.92% compared with distilled water as working fluid.
- With increase in the inclination angle of circular heat pipe the thermal resistance reduces. For 2% volume concentration and variation in inclination angle from 300 to 900for hybrid nanofluid as working fluid thermal resistance reduces by an amount of 39.00 % compared with distilled water as working fluid.
- With increase in the heat input of hybrid nanofluid the thermal resistance of circular heat pipe reduces. For variation in heat input from 25W to 100W and inclination angle of 00for 2% volume concentration of hybrid nanofluid as working fluid it reduces by an amount of 40.62 % compared with distilled water as working fluid.
- Cooling water flow rate up to 2 lpm gives better performance.

From the above experimentation it is concluded that the circular heat pipe using hybrid nanofluid as working fluid can give the promising results compared with water as working fluid.

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