Experimental investigations on heat pipe performance by using different types of Nano fluid

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Abstract- In this study, the experimental compression of various types of Nano fluid was used to increase the performance of heat pipe in this experiment results showed that the rise in the input power of the heat pipe leads to increase the wall temperature of the pipe, whereas augmenting the thermal conductivity of nanoparticles leads to diminish the wall temperature and decrease the temperature difference between the evaporator and the condenser. Using the nanoparticles increases the thermal conductivity of the base fluid and minimizes the temperature gradient within it. Therefore, the thermal power of the heat pipe increases and its resistance drops. experiment results shows that the maximum value of heat transfer rate of heat pipe is obtained as 278.5 W at 100^0C with CuO Nano fluid which is 53.5% Higher than that of fluid concentration of silicon oxide Nano particle. And also conclude that the thermal efficiency of the heat pipe increases with thermal conducted of nanoparticle. The thermal performance of heat pipe is enhanced by alteration of different Nano particles in the working fluid.

Keywords- Nano fluid, Heat pipe, Inclination, Screen mesh, thermal performance.

1. **Introduction -** Heat pipe is a device that fluently carriages thermal energy from its one point to the other. It applies the implied heat of the vaporized working fluid instead of the reasonable heat. Nowadays, there is rapid development of practical engineering solutions to a multitude of heating problems. Heat generated in micro-devices used in manufacturing and electronics require special solutions. The closed-loop oscillating heat-pipe with check valves is a very effective heat transfer device. Heat is transported from an evaporator to the condenser by the oscillation of a functioning fluid moving in an axial track inside the tube. In this category of system the inside diameter of the pipe is important. It must be small enough so that under operation conditions liquid slugs and vapour plugs can be formed. If the diameter is too large, the liquid and vapour inside the tube will become stratified and operation cannot be established [1]. Choi et al. [2] put out the first paper in Nano fluid, numerous research papers have also been lead in which by using nanoparticles, a 20% increase in heat transfer can be attained. Other attempts have been made to better realize the changes in the heat transfer coefficient of heat exchangers [3,4]. The heat transfer coefficient in Nano fluids with a very low particle density is much higher than the base fluid. On the other hand, changes in the coefficient of friction and fluid viscosity have been reported to be very low. Harris et al. [5] founded the displacement heat transfer coefficient of CuO-water and Al_2O_3-water nanoparticles for laminar flow in a rounded tube under steady-state boundary conditions. These conditions were relatively different from the constant heat flux studied by other researchers. Mahendran et al. [6] prepared water-based TiO2 Nano fluid with a particle size of 30–50 nm to evaluate the effect of performance of the solar collector under various weather conditions. Hung et al. [7] described the effect of volume fraction of Al2O3 Nano fluid on heat pipe effectiveness at various concentrations (0.5, 1.0, and 3.0 wt%). The extreme heat flux increased as the volume fraction of Al2O3 reaches to less than 1.0 wt%. Then, additional rise in the mass concentration caused in its gradual loss. Shafahi et al.'s [8] worked a two-dimensional analysis is used to study the thermal performance of a cylindrical heat pipe utilizing Nano fluids. Three of the most common nanoparticles namely Al2O3, CuO, and TiO are considered as the working fluid. The existence of an optimum mass concentration for Nano-particles in maximizing the heat transfer limit is established. The effect of particle size on the thermal performance of the heat pipe is also inspected. It is establish that smaller particles have a more pronounced effect on the temperature gradient along the heat pipe. Do et al. [9] performed investigates to study the effect of water based Al_2O_3 Nano fluids on screen mesh heat pipe. A significant heat pipe wall temperature drop was observed for heat pipes with Nano fluid compared with that of the heat pipe with water and the reduction was reported as 27^0C for Al_2O_3 Nano fluids at volume concentration of 3%. Many studies reported the influence of Nano fluids on thermal performance of inclined heat pipes. Huminic and Huminic [10] performed experiments to investigate tilt angle effect on a two phase closed thermo syphon with iron oxide Nano fluid. Their experiments showed that the thermal resistance of heat pipe decreases with increasing tilt angle. They reported 39% reduction in

thermal resistance at inclination angle of 90^0Cand for Nano fluid at volume concentration of 5.3%. Liu et al. [11] studied the effect of tilt angle of a grooved heat pipe with water based CuO Nano fluid. Their experiments revealed that thermal resistance of heat pipe has been affected by tilt angle and the best performance obtained at inclination angle of 75^0C. Another experiment to investigate the effect of tilt angle on heat pipe using Nano fluids was performed by Naphon et al. [12]. They used TiO2/alcohol Nano fluid as a working fluid in heat pipe to study heat transfer performance. They found that the best performance obtained at tilt angle of 45^0C and for Nano fluid with volume concentration of 0.1%. Their experiments showed thermal efficiency enhancement by 10.60%. Entirely these features designate the potential of Nano fluids in applications involving heat removal. Issues, concerning stability of Nano fluids, have to be addressed before they can be put to use. Nano fluids of oxide particles are more stable but less effective in enhancing thermal conductivity in comparison with Nano fluids of metallic particles. The purpose of the present work is to investigate, experimentally, the performance of a heat pipe. The affecting parameters on performance of heat pipe are studied. The Different type of working fluid filling ratio of the working fluid, volume fraction of Nano-particles in the base fluid and heat input rate are considered as experimental parameters. Empirical correlation for heat pipe thermal performance taking into account the several operating parameters is obtainable.

2. Experimental setup and procedure

2.1. Preparation of Nano fluid

The C_uO, Al_2O_3 and SiO_2/water Nano fluid are used in this study contains commercial nanoparticles of purity of 98.0%. The Nanoparticles are in the size range of 30-50nm. The Nanoparticles with this size range is chosen for performance comparison with the heat pipe operated with Nano fluid prepared using the same size particles. The Nano fluid is prepared by mixing 1gm of each Nano particles with 1 L distilled water separately. Proper Mixing of Nanoparticles with distilled water is conceded out by direct synthesis method. The C_uO, Al_2O_3 and SiO_2/water Nano fluid produced direct synthesis method was then adopted as the experimental sample. The C_uO, Al_2O_3 and SiO_2/water Nano fluids were statically placed for one month to conform suspension performance. The thermo-physical properties of used Nano particles are shown below.

Table.1. Characteristics of CuO Nano particles

S.No.	Name of Properties of CuO nanoparticles	Range of values
1.	Colour and appearance	Black colour
2.	Size of particle in nm	30-50
3.	Thermal conductivity (W/mk)	36
4.	Purity (%)	98.0%
5.	Density(kg/m^3)	3950
6.	Specific heat(J/Kgk)	773

Table.2. Characteristics of Al_2O_3 Nano particles

S.No.	Name of Properties of Al2O3 nanoparticles	Range of values
1.	Colour and appearance	Grey colour
2.	Size of particle in nm	30-50
3.	Thermal conductivity (W/mk)	12
4.	Purity (%)	98.0%
5.	Density(kg/m^3)	3000
6.	Specific heat(J/Kgk)	451

Table.3. Characteristics of SiO_2 Nano particles

S.No.	Name of Properties of SiO2 nanoparticles	Range of values
1.	Colour and appearance	White
2.	Size of particle in nm	30-50
3.	Thermal conductivity (W/mk)	1.4
4.	Purity (%)	98.0%
5.	Density(kg/m^3)	2220 kg/m^3
6.	Specific heat(J/Kgk)	680

2.2. Set up details

The heat pipe in this experimental set up was made up of straight copper tube with an outer diameter of 18mm, thickness 3 mm and length 475 mm it is mainly divided into three sections namely evaporator, adiabatic and condensation Sections having length of 125mm, 200mm and 150mm respectively the experimental setup consist a

Resistance heater. The temperatures on the heat pipe were measured using a Digital temperature display with three thermocouples (J type) at different points. The accuracy of temperature measurements was ±0.50^0 C. The Digital temperature meter is used to record the thermocouple readings at unlike positions of the heat pipe. In total three thermocouples were devoted on the heat pipe wall, i.e. two at both the evaporation and condenser section, and one at the adiabatic section. The thermocouples are welded over the external of the heat pipe. The complete heat pipe is insulated by using glass wool powder to avoid heat loss from the system. A cooling jacket, which consists of inlet and outlet ports for cooling water, is fabricated using mild steel pipe. The temperature of cooling water at the inlet and outlet are measured using J-type thermocouples.

Table.3. configuration of heat pipe

Component	Dimensions
Heat Pipe	Length(L)= 475mm Do=18mm T= 3mm
Evaporator length	125mm
Adiabatic length	200mm
Condenser length	150mm
Insulating Material thickness	10mm
Cooling jacket length	150mm
Sintered wick thickness	4mm
Porosity of sintered wick	60 %

The heat pipe was charged with 20ml of different Nano fluid C_uO, Al_2O_3 and SiO_2/water Nano fluid respectively as a concentration 10 gm/L . An AC power supply is source of power for the cylindrical resistance heater, used for heating the resistance heater which is mounted over the evaporator section. The heating power of resistance heater is kept constant as 200W with an accuracy of ± 0.5W. The cooling jacket in the condensation section contained cooling water inside a mild steel pipe. This allowed the water tank to provide cooling water at a temperature of 35±0.5^0C. The flow rate of cooling water is measured when the heat pipe attains steady state conditions. It is adjusted to get the temperature difference of 3-4^0C. The test of heat pipe performance was with varying parameters such as Different Nano fluid and input temperature (T). The overall thermal Conductivity of the heat pipe was then calculated to evaluate its thermal performance. The accuracy of the power supply is ±0.5W. The accuracy of the steel ruler is ±1.0 mm. The accuracy of the thermocouples is ±0.50C.

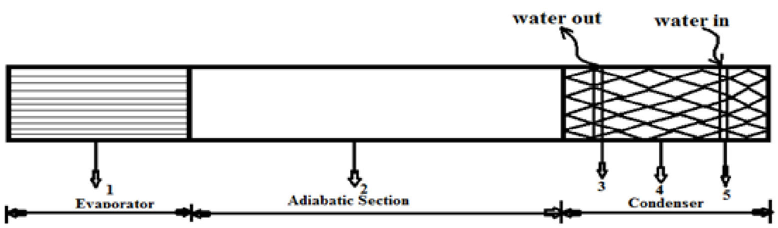

Fig.1. Schematic diagram of heat pipe

2.3. Experimental calculation

The rate of heat conduction in one dimensional path in hollow cylinder under a steady state complaint can be defined by Fourier's law which is communicated as,

$$Q=2\pi KL\frac{\Delta T}{\ln(r2/r1)}$$

The overall thermal conductivity of heat pipe is calculated by the formulation,

$$K_{HP}=\frac{Q}{Rth}$$

The overall thermal resistance (R_{HP}) is a measure of thermal performance of heat pipe,

$$R_{HP}=\frac{\Delta T}{Qout}, \quad \text{Where } \Delta T=T_e-T_c$$

The efficiency of heat pipe can be expressed as a ratio of the output heat by condensation to the inlet heat by Evaporation i.e.

$$\eta_{HP}=\frac{Qout}{Qin}$$

2.4. Results of experimental investigation

- Variation of Condenser Temperature with respect to Evaporator Temperature

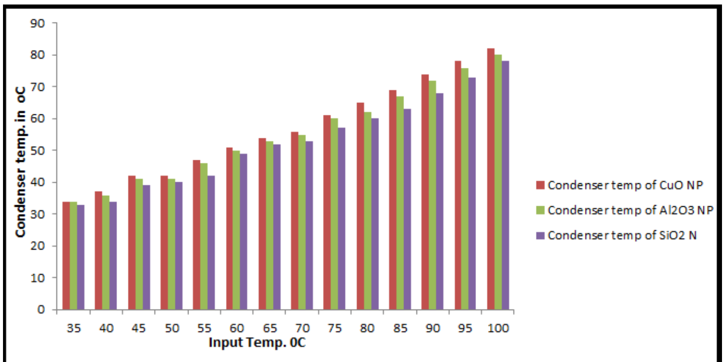

Fig.2. Variation of Condenser Temperature with respect to Evaporator Temperature

- Variation of Water Temperature with respect to Evaporator Temperature

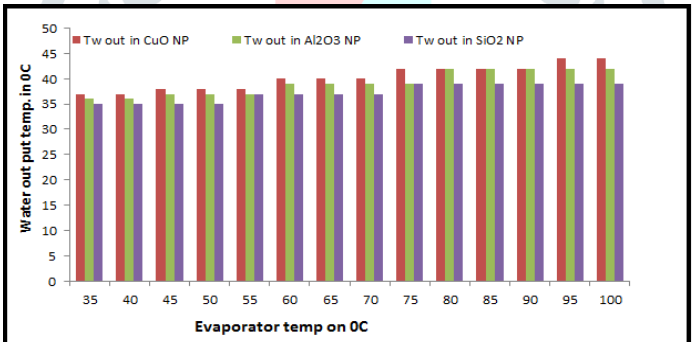

Fig.3. Variation of Water output Temperature with respect to EvaporatorTemperature

- Effect of input temperature on the heat transfer rate of heat pipe

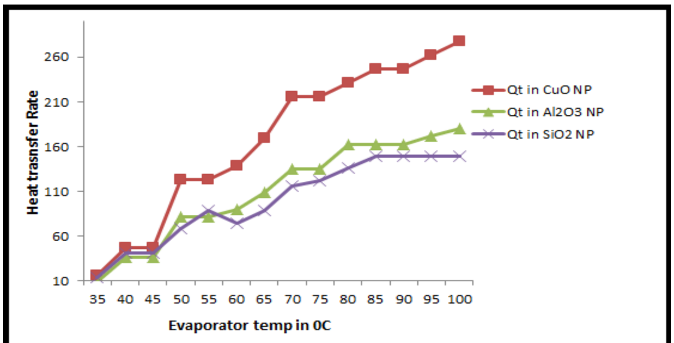

Fig.4.Effect of input temperature on the heat transfer rate of heat pipe

3. Conclusion

This investigation is concentrated on thermal conductivity and capacity of various types of Nano fluids in this experiment results shows that the maximum value of heat transfer rate of heat pipe is obtained as 278.5 W at 100^0C with CuO Nano fluid which is 53.5% Higher than that of fluid concentration of silicon oxide Nano particle. And also conclude that the thermal efficiency of the heat pipe increases with thermal conducted of nanoparticle. The thermal performance of heat pipe is enhanced by alteration of different Nano particles in the working fluid.

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