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Experimental Investigation of Heat Transfer Augmentation on Heat pipe with Nano materials

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ABSTRACT

An experiment was carried out to study the thermal efficiency enhancement of the heat pipe using Zinc oxide nanofluid as the working fluid. The zinc oxide nanoparticles are uniformly suspended with the de-ionized water using homogenizer and sonicator to prepare the zinc oxide nanofluid. The average particle size of the copper is 35-45 nm and the concentration of copper nanoparticle in the nanofluid is 1%,2%,3%,4% & 5% of weight. The study discusses about the effect of heat pipe inclination, type of working fluid and heat input on the thermal efficiency and thermal resistance. The experimental results are evaluated in terms of its performance metrics and are compared with that of DI water.

Keywords— Heat transfer, Nanofluid concentration, Inclination angle. Heat input.

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I. INTRODUCTION

Heat pipe are high-efficient heat transfer devices and have been widely applied in various thermal systems. Since heat pipes utilize the phase change of the working fluid to transport heat, the selection of working fluid is of essential importance to promote the thermal performance of heat pipe. Owing to the heat transfer enhancement effects of nanofluids in single phase and phase change heat transfer, some researchers have applied various nanofluids in heat pipes as the working fluid to enhance their heat transfer performance.

In this work, experimental investigation of heat pipe with nanofluid is carried out. The heat pipe is made of straight copper tube of total length 600mm. (Evaporator length=150 mm, adiabatic length=300 mm, condenser length=150 mm), outer diameter 20mm and inner diameter 17.6mm. DI water and nanofluids (ZnO) with water are used as working fluids. An experimental setup is constructed to study the performance under different operation conditions. This study presents a discussion on effect of variation of concentration of nanomaterials (1%wt,2%wt,3%wt,4%wt and 5%wt), effects of variation in tilt angle (0^0,15^0, 30^0,45^0,60^0,90^0) and effect of variation of heat input(30W,40W,50W and 60W) on the heat pipe performance.

II. LITERATURE REVIEW

Number of researchers worked in this field and there obtained results and conclusion were discussed briefly below.

Heat transfer enhancement in heat pipe with nanofluid investigated by several investigators. Also the performance of heat pipe with nanofluid is improvement as compare with pure DI water.

Weia et al. [1] has employed Nanofluid is as working medium for conventional 200 µm wide grooved circular heat pipe. The nanofluid used in an aqueous solution of various-solution sliver (Ag) nanoparticles. The average diameter of Ag nanoparticles is 10 nm. The experiment was performed to measure and compare thermal resistance of pure water and nanofluid filled heat pipes. At the same charge volume of 0.45mL, test result showed the average decrease of 30%-70% in thermal resistance of heat pipe with nanofluid as compared with pure water.

Heris et al [2] studied laminar flow forced convection heat transfer of Al_2O_3/water nanofluid inside a circular tube with constant wall temperature was investigated experimentally. The Nusselt numbers of nanofluids were obtained for different nanoparticle concentrations as well as various Peclet and Reynolds numbers. Experimental results emphasize the enhancement of heat transfer due to the nanoparticles presence in the fluid. Heat transfer coefficient increases by increasing the concentration of nanoparticles in nanofluid. The increase in heat transfer coefficient due to presence of nanoparticles is much higher than the prediction of single phase heat transfer correlation used with nanofluid properties.

Naphon et al [3] studied experimentally the effects of %charge amount of working fluid, heat pipe tilt angle and %nanoparticles volume concentrations on the thermal efficiency of heat pipe are considered. The nanoparticles have a significant effect on the enhancement of thermal efficiency of heat pipe. The thermal efficiency of heat pipe with the nanofluids is compared with that the based fluid. the % change amount of working fluid increases more than 66% by heat pipe volume, the heat pipe thermal efficiency tends to decrease, the heat pipe thermal efficiency decreases as heat pipe tilt angle >60° for de-ionic water and >45° for alcohol. Then nanofluids with 0.10% nanoparticles volume concentration, the thermal efficiency of heat pipe increases as much as 10.60%compared to that of the based working fluid.

Mousa et al [4] designed and studied experimentally the effect of filling ratio, volume fraction of nanoparticles in the base fluid, and heat input rate on the thermal resistance is investigated. Total thermal resistance of the heat pipe for pure water and Al_2O_3-water based nanofluid is also predicted. He found that the optimum filling ratio of charged fluid in the tested heat pipe was about 0.45–0.50 for both pure water and Al_2O_3 water based nanofluid, respectively.

Liu et al [5] reviews and summarizes the research done on heat pipes using nanofluids as working fluids. The effect of characteristics and mass concentrations of nanoparticles on the thermal performance in various kinds of heat pipes with different base fluids under various operating conditions. The majority of micro-grooved heat pipes, mesh wick heat pipes, oscillating heat pipes and most closed two-phase thermosyphon, adding nanoparticles to the working liquid can significantly enhance the heat transfer, reduce the total heat resistance and increase the maximum heat removal capacity.

Moraveji et al [6] investigated the effect of using aluminum oxide nanofluid (pure water mixed with Al_2O_3 nanoparticle with 35 nm diameter) on the thermal efficiency enhancement of a heat pipe on the different operating state. The heat pipe was made of a straight copper tube with an outer length of 8 and 190 mm and a 1 mm wick-thickness sintered circular heat pipe. In the heat pipe tube, there is a 90° curve between the evaporator and condenser sections. The tested concentration levels of nanofluid are 0%, 1% and 3%wt. Results show that by charging the nanofluid to the heat pipe, thermal performance is enhanced by reducing the thermal resistance and wall temperature difference.

Park et al [7] studied the enhancing the heat-transfer utility of the heat pipe in a solar collector, the work attempted to improve nanoparticle dispersion stability by means of a chemical reformation process wherein nanofluid is formulated with hydroxyl radicals combined with oxidized multi-walled CNTs (MWCNTs). The rate of thermal conductivity increase of oxidized MWCNT nanofluids is higher than that of MWCNT nanofluids.

Gunnasegaran et al [8] investigate heat transfer characteristics of using nanofluid in a Loop Heat Pipe (LHP) as a working medium for heat input range from 20 W to 100 W. the LHP performance using silica (SiO_2–H_2O) nanofluid with particle volume fraction of 3% which was used as a coolant is examined. The LHP using SiO_2–H_2O nanofluid yields lower temperature and reaches its steady state faster than LHP using pure water

Albadr et al [9] studied experimentally on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al_2O_3 nanofluid (0.3–2) %. The results show that the convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid at same mass flow rate and at same inlet temperature.

Senthilkumar et al [10] studied experimentally Effect of Inclination Angle in Heat Pipe Performance Using Copper nanofluid the thermal efficiency enhancement as the working fluid. The average particle size of the copper is 40 nm and the concentration of copper nanoparticle in the nanofluid is 100 mg/lit. The study discusses about the effect of heat pipe inclination, type of working fluid and heat input on the thermal efficiency and thermal resistance. The experimental results are evaluated in terms of its performance metrics and are compared with that of DI water. The result show that if inclination angle increase then thermal efficiency increase and thermal resistance decrease.

III.EXPERIMENTAL TEST RIG

This apparatus consists of a screen mesh wick straight heat pipe with one side having evaporator and other having condenser. The heat pipe is made up of copper material. Wick is made up of stainless steel having 60 mesh per inch. Heat pipe having inner diameter 17.6mm and outer diameter is 20mm,600mm in length, 150mm evaporator,150mm condenser and 300mm adiabatic section. The evaporator section is heated by an electrical heater surrounding at its circumferences. The condenser section is cooled by cooling water circulating in a constant-temperature thermal bath. The cooling water is supplied with the help of hydraulic pump. Also the flow meter is attached to measure the flow of cooling water. The flow rate of the cooling water were fixed at constant values for keeping steady cooling conditions in the condenser section for varying heat fluxes. The insulation is provided on the adiabatic section to minimize the convective losses.

IV. NANOFLUID PREPARATION AND STABILITY EXPERIMENT AND STABILITY FOR EXPERIMENTATION

In this work two step methods is use for preparation of Nano fluid. Powder ZnO of 35-45 nm size and 99.9+% pure particles were purchased from a nanoshel (Haryana) company. . It can be seen that the primary ZnO nanoparticles are spherical and their size is widely distributed in a range of 35-45 nm. The specific surface area of the powder is found to be (>110) m^2/g, Distilled water was used as the host liquid and SLS (sodium laurel sulphate) was used as dispersant to inhibit ZnO nanoparticles aggregation and break up clusters.

Figure No. 1. Photographic view of Experimental setup

SLS concentration use for stability is 0.1%. Required Powder nanoparticle is mixed with distilled water and 0.1% SLS is added in mixture. The Zno- H_2 O nanofluids suspension was vibrated for 1 hour at 5500 rpm in an Overhead stirrer. After stirring mixture is kept in sonicator for one hour. It shows that the stabilization of the suspension with dispersant can last about 1 week in the stationary state and no sediment was found.

Figure No.2 Overhead stirring of ZnO Nanofluid

Figure No. 3 Ultra-sonication of ZnO Nanofluids

The procedure is used to take the reading on setup includes

1. The heat pipe is charged with 40 ml of working fluid, which approximately corresponds to the amount required to fill the evaporator.
2. Make ON motor the cooling water is circulated first through the condenser jacket, before the heat is supplied to the evaporator.
3. Make ON heater Keep temperature at 30 watt and 0^0 after steady state is reached note all temperatures reading, inlet and outlet also noted.
4. Experimental procedure is repeated for 1%,2%,3%,4% and 5% by weight of ZnO nanofluid, heat inputs (30, 40, 50 and 60 W) and different inclinations of pipe (0^0, 15^0, 30^0, 45^0, 60^0, 75^0 and 90^0) to the horizontal position and observations are recorded

V.DATA REDUCTION

The overall thermal resistance of circular heat pipe is calculate by equation-

$$R_{th} = \frac{Te - Tc}{Q} \qquad \ldots\ldots (1)$$

Where T_e and T_c are the average wall temperatures of evaporator and condenser section and can be determined by following equations-

$$T_e = \frac{1}{n}\sum_{i=0}^{n} Ti \qquad \ldots\ldots (2)$$

$$T_c = \frac{1}{m}\sum_{i=0}^{m} Ti \qquad \ldots\ldots (3)$$

Q is heat at evaporator section and calculated by following equation-

$$Q = VI \qquad \ldots\ldots (4)$$

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.

VI. RESULTS AND DISSCUSSION

A number of experimental runs are carried out on the setup with different concentration of ZnO nanofluid,by changing the wattage input and inclination angle the obtained result shown in following section.

Graph of Heat input vs. Thermal resistance for different angle of inclination and volume fraction of nanofluid.

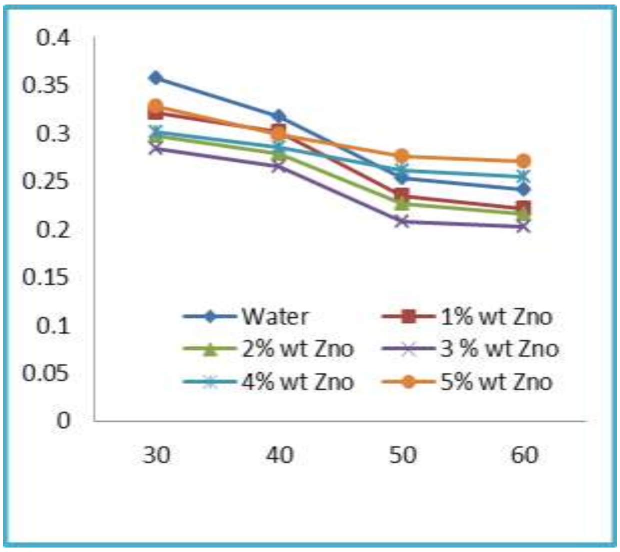

Fig No.4 Thermal resistance of heat pipe for 0^0 inclination.

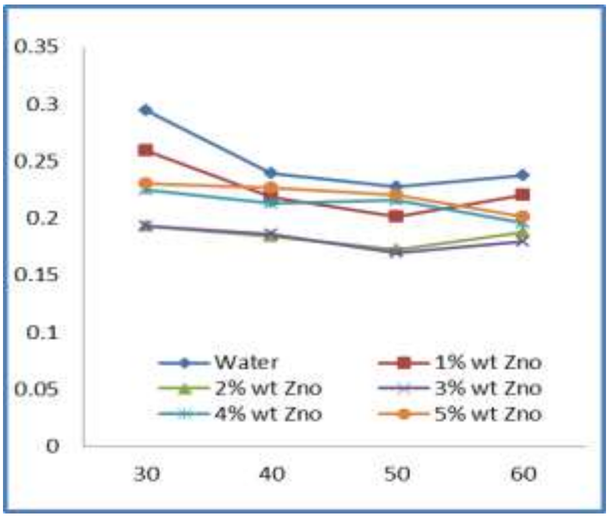

Fig. No.5 Thermal resistance of heat pipe for 15^0 inclination.

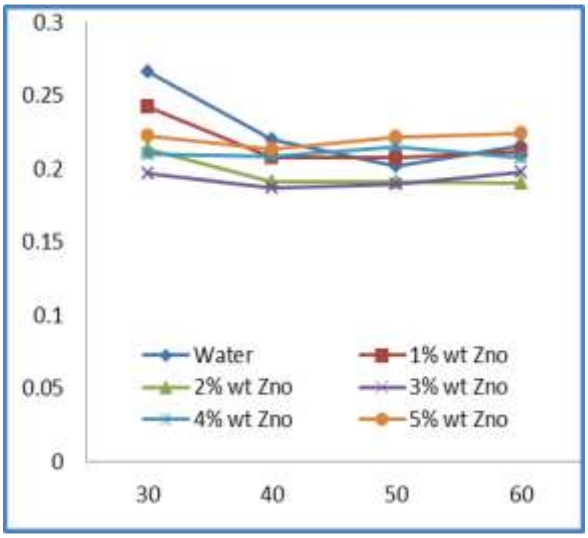

Fig. No.06 Thermal resistance of heat pipe for 30^0 inclination.

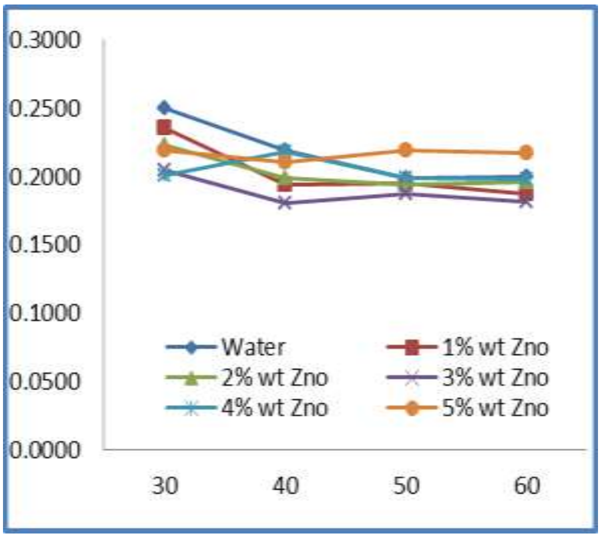

Fig. No.07 Thermal resistance of heat pipe for 45^0 inclination.

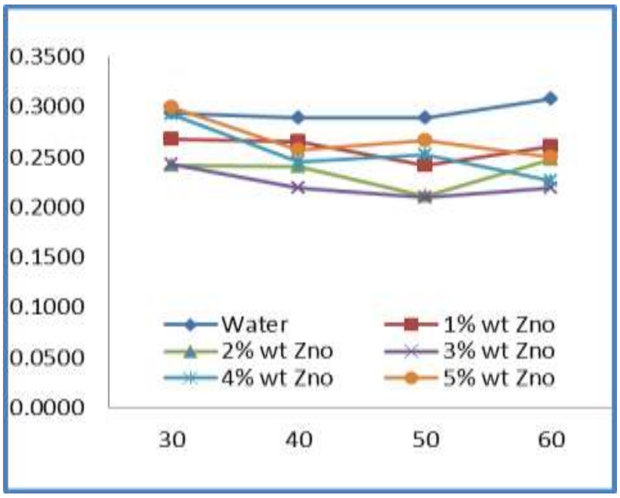

Fig No. 08 Thermal resistance of heat pipe for 60^0 inclination.

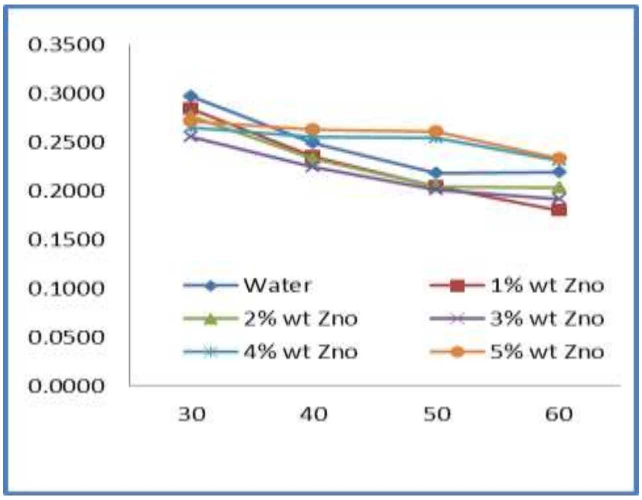

Fig No.09 Thermal resistance of heat pipe for 75^0 inclination.

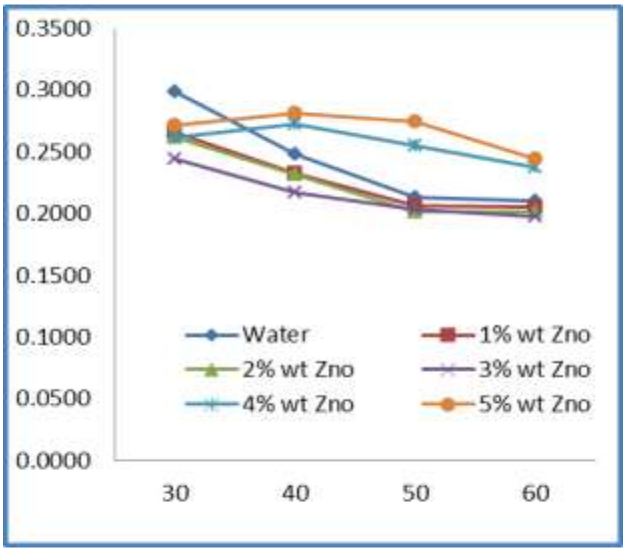

Fig No.10 Thermal resistance of heat pipe for 90^0 inclination.

Graph No 05-10 shows the comparison of thermal resistance of heat pipe with DI water as a working fluid to ZnO nanofluid as a working fluid for different heat input. From this figure it is clear that the thermal resistance of heat pipe decreases with increasing concentration of nanoparticals but upto 3%wt of ZnO and after that it decreases. Thermal resistance of the nanofluids is always less than DI water.

Graph of Inclination vs. thermal resistance for different heat input and volume fraction of nanofluid.

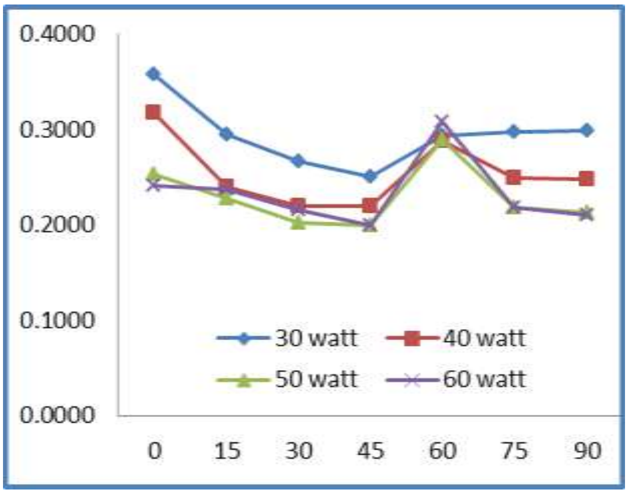

Fig No.11 Thermal resistance of heat pipe for water.

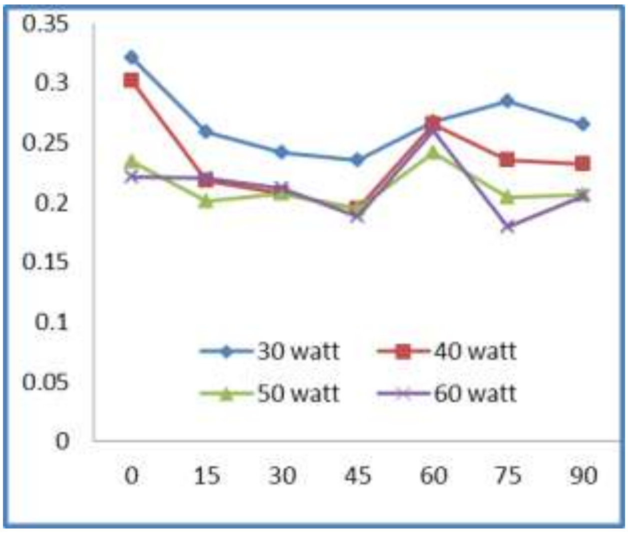

Fig No.12 Thermal resistance of heat pipe for 1% wt ZnO.

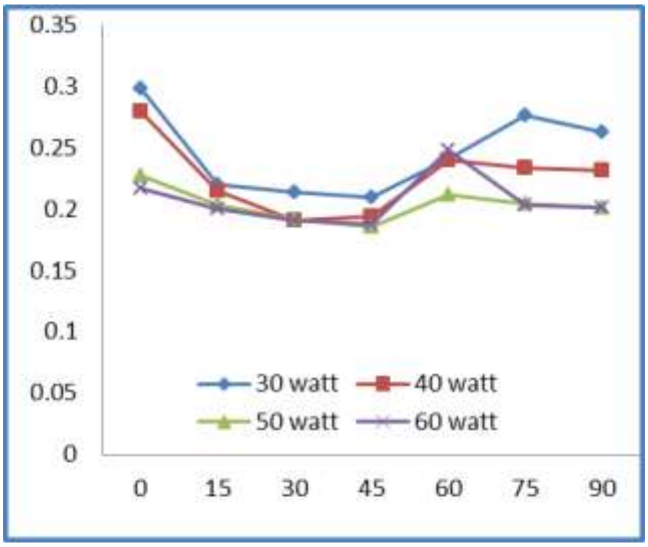

Fig No.13 Thermal resistance of heat pipe for 2% wt ZnO.

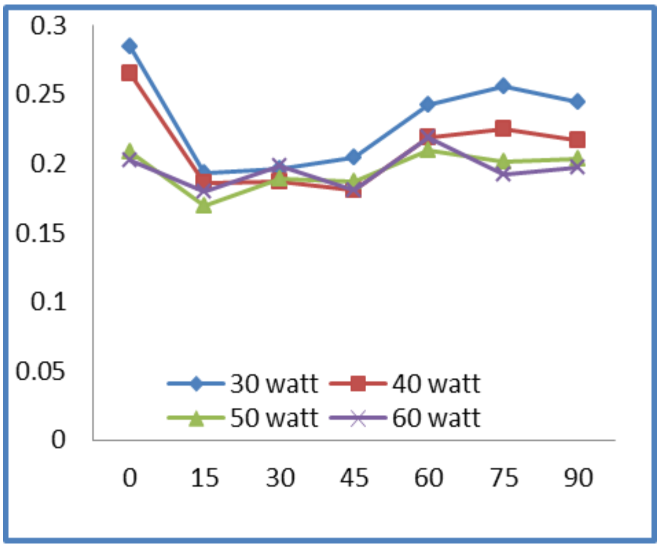

Fig No.14 Thermal resistance of heat pipe for 3% wt ZnO.

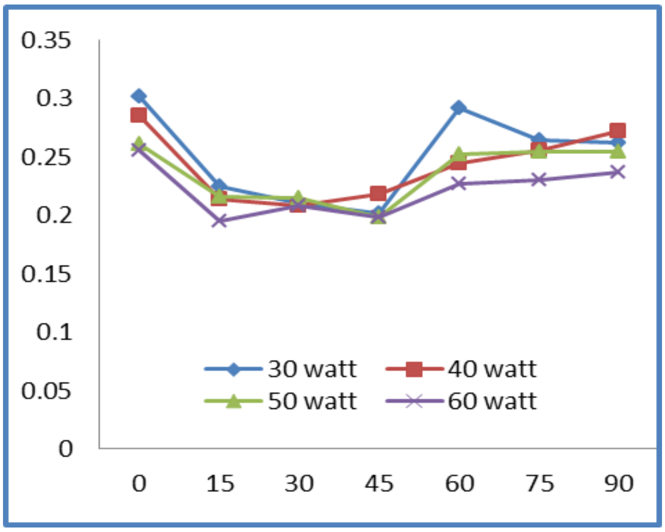

Fig. No.15 Thermal resistance of heat pipe for 4% wt ZnO.

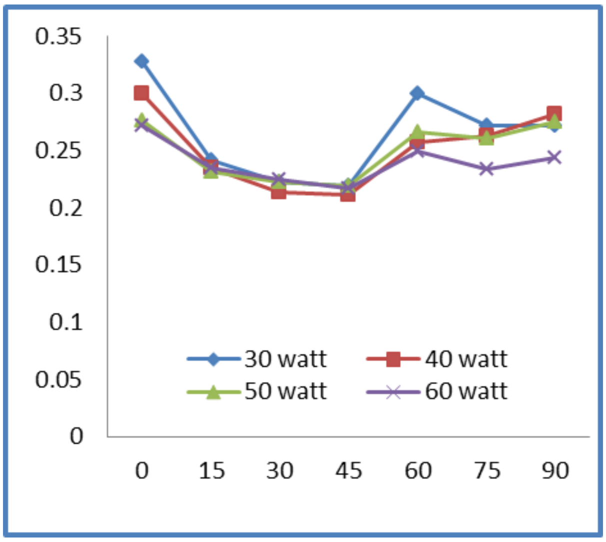

Fig. No.16 Thermal resistance of heat pipe for 5% wt ZnO.

Graph No 11-16 shows the comparison of thermal resistance of heat pipe with DI water as a working fluid to ZnO nanofluid as a working fluid for different heat input. From this figure it is clear that the thermal resistance of heat pipe decreases with increasing heat input. At low heat input, the thermal resistance of both the working fluid is high because of the relatively solid liquid film that resides in the evaporator section. When the heat load increases, these thermal resistances condense quickly to their minimum value. It also shows that thermal resistance of heat pipe decreases from 0^0 inclinations to 45^0 inclination and then it increases.

VII.CONCLUSION

1. Thermal resistance of straight heat pipe decreases with increase in concentration of nanofluid upto 3% weight of ZnO nanofluid and afterwards it increases.
2. Heat pipe shows better performance in the range of angle of inclination between 30^0-60^0. Maximum performance is observed at 45^0 angle of inclination.
3. Thermal resistance of straight heat pipe decreases with increase in heat input.
4. Better performance is observed for ZnO nanofluid with 3% weight concentration, 15^0 of angle of inclination and 60 watt heat input

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

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