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Comparative Study of Al_2O_3 Nanofluid Heat Pipes Using Various Inclinations with Water Based Heat Pipes

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Abstract - **An experimental study is carried out in order to quantify the net heat transfer from evaporator region of a heat pipe to the cold water poured inside cooling water pot mounted on the condenser end of the heat pipe. For this purpose a setup is designed in order to accommodate five heat pipes out of which four of them are charged with nanofluid in the increasing order such that the concentrations by the total volume of working fluid were 0.1%, 0.3%, 0.6% and 1% respectively and remaining one consisting pure water. For preparation of nanofluids water is used as the base fluid because of its reliability to high temperature and ease of availability. Nanoparticles of the size of 100nm were manufactured in nanolabs and TEM (Transmission Electron Microscopy) analysis is carried out. 20 RTDs (4 RTDs for each heat pipe) were used to measure the local wall temperature; five heaters are mounted at the bottom of heat pipe to heat the evaporator region of heat pipe, and a control panel consisting of temperature indicator, voltmeter and ammeter. A heat input in the steps of 25W is given to the evaporator and the performance is monitored for various concentrations by varying inclinations of heat pipes with respect to horizontal. The tests are stopped after a heat input of 100W. All the tried inclinations (30^0,45^0,60^0,90^0) proved that there is increase in the net heat transfer rate when heat pipes are charged with nanofluids than that of water.**

Keywords: **Inclination angles, nanoparticles, nanofluids, thermal resistance.**

I. INTRODUCTION

As the traditional sources of energy generation are depleting day by day and on the other hand while opting to the non-conventional sources of energy like solar energy generation or any other means such as biomass, biofuels geothermal, hydropower, sea wave energy leads involvement of high capital. Hence it is necessary to minimize the loss of useful energy, more likely heat. Thus net saving in energy and the demand of transferring unnecessary heat to the surroundings is a bottleneck problem. With the growth of electronic industries, the size of components associated with the specific electronic part is getting smaller and smaller. Thus the heat generated by processors needs to be dissipated. But because of tiny space in the cabinet where the components are located there is no significant space for the heat to be dissipated. Because of which the heat gets trapped inside the component and hence leads to the decreased life and performance of the component as well. Heat pipes are found to be very effective in order to dissipate heat over long distances. The main beauty associated with this is there is very low temperature loss between the two end of heat pipe viz. evaporator at which heat is supplied and condenser at which the heat gets rejected to the atmosphere. Thus a large bulk of heat flux can be fetched over a long distance; the main beauty in this is temperature gradient associated with this heat transfer is the least and there is no any need of extra power between these two temperature limits. Minimum temperature drop can be maintained between evaporator end and condenser end by incorporating latent heat of evaporation at evaporator section. Provided that an equal importance should be given while designing evaporator, adiabatic and condenser sections so that to obtain constructive thermal conductivity between two ends. The working fluid inside the heat pipe vaporizes because of high temperature and pressure that is gained by latent heat of vaporization from a heat source, say heater. Thus it flows towards the other end i.e. at the condenser section, at that instant the latent heat of vaporization gets released and the working fluid is again sucked back to the evaporator by the action of capillary. Hence it can be stated that capillary pressure plays an important role and hence the capillary limit should be satisfied. It can be stated that within a same body structure the working of both the evaporator and condenser is different provided that the working fluid be the same. Here in this experiment filling ratio for working fluid is kept 50% of the total volume of the heat pipe. But in most of the cases the thermal conductivity of these liquids is poor than that of the solids, thus an unusual idea of suspending solid particles which are as fine as possible, preferably nanometer sized; ranging between 10nm to 100nm into a base liquid are called nanofluids. The reason behind going for a nanoparticle is that they cannot get settled at the bottom and remain suspended for a long duration of time, also they do not form any slurry at the bottom as that of the micro sized particles. Hence issues related to clogging of the wick structure of heat pipe are minimized. And a combined benefits of properties of both the solid particles and base fluid can be taken for enhancing the overall thermal conductivity of working fluid (behi and mirmohadi,)[1] thus the costs associated with this are also gets minimized along with the compact heat exchanger structure. i.e. Heat pipe. These nanofluids have good thermal conductivity because of the

combined properties of solid particles as well as base liquids; thermal conductivity of these fluids is directly proportional to the temperature, hence at high temperature they show a good productive approach towards enhancing the heat transfer. However there is increase in the performance while using nanofluids but the morphology again plays a vital role in synthesis and it's a parameter which should be taken into consideration in order to have a good thermal performance, for this purpose Li. *et al*.[2] carried out one experiment where two different sizes of Al_2O_3 nanoparticles were taken into consideration viz. 36nm and 47nm. Thus the results obtained with least sized particles were higher than that of the greater sized particles; an increase in the thermal conductivity was obtained ranging between 7% to 9%. Hence it can be said that the morphological parameters such as shape, size and structure of a particle should be taken into account while preparing nanofluids (sankar, 2012)[3].

To validate the importance of shape consideration this falls under category of morphology, Xie. *et al* [4] carried out an experiment in those respects. In his research he used spherical shaped SiC nanoparticles. Another experiment was carried out for the same morphological consideration by Murshad *et al*.[5] in which TiO_2 of rod shaped were used. Kang *et. al*[6]showed in his experiment that there is decreased thermal resistance with heat pipe containing nanofluid than that of those containing water.For this purpose he used silver nanofluid as working fluid in grooved heat pipe, thus he concluded that nanofluids are the best substitute for cooling purposes for the components which have bulk power density over the conventional fluids, such as water. But while using nanofluids, one must go for the appropriate concentration as the percentage concentration within the total volume of the base fluid is an important parameter to be considered. Hence to evaluate the net increase in thermal conductivity an experiment was carried out by Eastman et. al[7], where base fluid was taken to be ethyl glycol and nanoparticles that were used was made up of copper, the concentration by the total volume of fluid was near about 3%. Results obtained shown net increase of 40% thermal conductivity than that of the conventional fluids. Along with morphology, temperature and concentration; motion of the particles also plays an important role while evaluating thermal conductivity of nanoparticles. Because the motion is highly responsible for setting up a temperature gradient (behi, mirmohmadi, 2012).A motion is caused because of the collision between base fluid molecules and the nano sized particles thereby suspended into them; called as Brownian motion. It can be said that temperature, concentration and motion of a nanoparticle is directly proportional to thermal conductivity while on the other hand size of the particles is inversely proportional to thermal conductivity. To examine the effect of $Al2O3$ nanofluid Moraveji *et al*.[8] conducted an experiment on sintered circular heat pipe curved at 90^{0}. One length of the pipe is 190 mm while the other is 8mm. Heat input provided for evaporator was from 5W to 60W. thus from the findings of the experimentation it was concluded that on increasing heat input there is decrease in thermal resistance along with this it has also been evaluated that if the concentration goes on increasing there is increase in thermal efficiency of the performance of the heat pipe. The overall temperature difference between evaporator and condenser regions having water as working fluid was higher than that of the temperature difference noted for the case of heat pipes having nanofluid as working fluid. However there was a decrease in thermal resistance for the heat loads between 5W to 40W. But there was no significant decrease for heat inputs more than 40 Watts. As the nanofluid and researches related to them are a new era in engineering P. keblinski *et. al* [9] in his review paper discussed the challenges associated regarding synthesis of nanoparticles, controversies related to nanofluid properties taking into account their thermo-physical properties. Riehl[10] carried out experiment to examine the wettability of nanofluids on about two to three wick structures that were made up of different materials, wick materials used for the experiments were copper, nickel (sintered), hydrophilic polyethylene, positive effects were seen in the case of sintered nickel regarding the wettability but on the other hand there was a diminution in its thermal performance. Some of the possible reasons of this reduction as mentioned by Riehl were drag force caused due to the viscosity of the nanoparticles and thereby reducing the capillary potency of the wick structure to drive back the condensate towards evaporator. M. G. Mousa [11] in his experimental study over circular heat pipe using nanofluids; drawn a correlation for prandtl number to prophesy its dominance. In his study he compared performance of nanofluid heat pipes with one that was carrying water as a working fluid, the comparison with the theoretical model found within satisfactory limits. A trial was carried out by Lips *et al*.[12] in which the temperature of the flat plate heat pipe wall surface was measured at various locations. The parameters that are varied are unlike filling ratios, power input so that to vary for different heat inputs and the vapour region diameter under the wick structure loops. Conclusions drawn were regarding optimum vapour thickness and filling ratios.

II. EXPERIMENTAL SETUP

Below is figure describing the schematic of heat pipe setup, the temperature sensors are mounted from bottom to the top i.e. from evaporator to the condenser region for first three heat pipes and for rest of the two; arrangement of sensors is from top to the bottom.

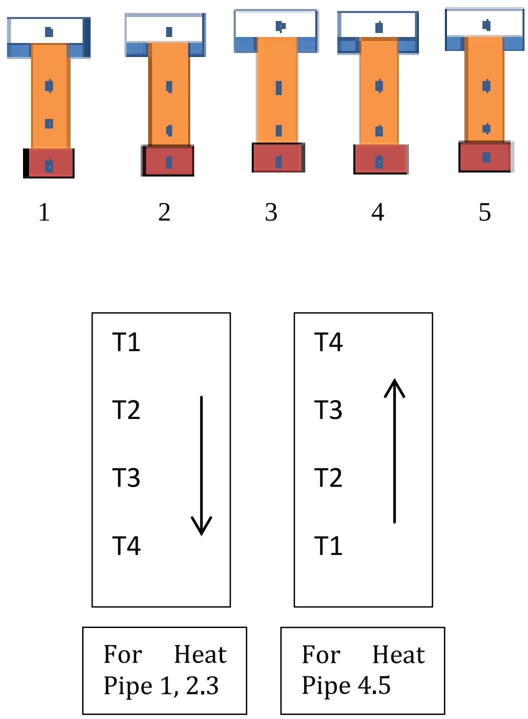

Fig.1 Block Diagram of Heat Pipe setup

The specifications of 5 specimen of heat pipe are as shown in table.

TABLE 1 CONFIGURATION OF HEAT PIPE

Heat pipe wall material	**Copper**
Material used for wick structure	Phosphorous Bronze
Length of evaporator	0.06m
Length of condenser	0.06m
Length of adiabatic section	0.06m
Heat pipe outer diameter	0.012m
Heat pipe inner diameter	0.010m
Mesh size per inch	180

Filling ratio used for the working fluid is 50% of the total inner volume of heat pipe. A band heater having a capacity of 100W is used to deliver heat to the evaporator end. The distribution of the thermocouples over the length of heat pipe is made in such a way that two corresponding thermocouples are equidistant from each other; the thermocouple at the condenser end is suspended in the water jacket using a concept of thermo well. These thermocouples are insulated from outside to avoid short circuiting. Voltmeter used was having a capacity of 500V, connected in parallel. Ammeter used was connected in series of the capacity of maximum 5 amps. A provision was made to vary the voltage from zero to maximum through a variable frequency drive switch, A rotary On/Off switch was mounted to turn On or Shut Down the whole setup from mains supply, A toggle type heater switch was used in order to turn On or Off the heat input that is being provided from a heat source. Two temperature indicators of select type were used to note down the temperature readings at various locations along the length of heat pipe wall in such a way that first temperature indicator indicates the temperature of twelve thermocouples for first three heat pipes, and the second temperature indicator for showing the temperature of rest of the eight thermocouples. The experimentation is carried out such that the heat was provided in a gradual way and the heat pipe wall exterior temperatures were noted down at specific time interval and by varying the orientation with different inclinations with respect to the horizontal. The first heat input provided was 30 W, the moment the heat pipe gained a steady state; the supply from heat source was turned off. Now water was allowed to be poured into the water jacket for cooling purposes. And the local temperatures were noted down. Same procedure was repeated for different powers up to 70 W. and at six different inclinations staring from 15^0 to 90^0 with a step size of 15. Thus the experimentation was carried out for six different orientations.

Fig.1 Actual setup of heat pipe unit.

III. RESULTS AND DISCUSSIONS

In the following graphs, a difference between evaporator and condenser temperature is taken and the outcome so obtained is then divided by the heat supplied in W. Suitably defined as the thermal resistance of heat pipe. It is found experimentally that the heat pipe having water as a working fluid has more resistance to pass the heat from evaporator to condenser than that of those who carry nanofluid within them as a working fluid. It can also be stated that when the orientations are considered from 30^0 to 90^0 it has been found that there is increase in the effectiveness in the heat pipe as thermal resistance goes on decreasing because of the nanoparticle inhabits at the evaporator end, thereby leading to effective boiling of working fluid as the heat input is increased step by step. The main responsible things for enhancing the heat transfer rate are thermo-physical behavior and when suspended into the base fluid they form a covering over wick structure, therefore a rough exterior is formed at the evaporator side that is passively responsible for heat transfer augmentation.Also wetting ability of the wick structure gets increased. Hence these are some of the possible reasons for decrease in thermal resistance of heat pipe.

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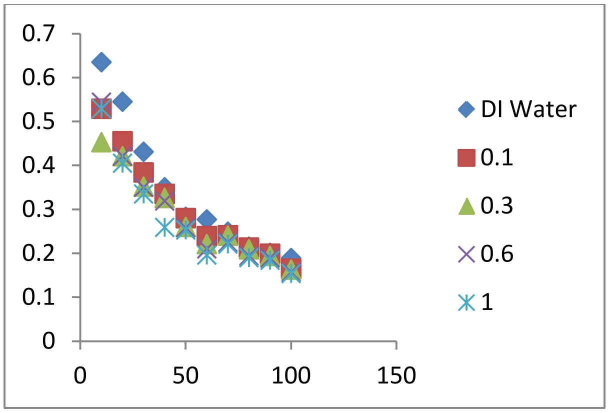

Fig.2Heat i/p vs. thermal resistance for 30^0 inclination

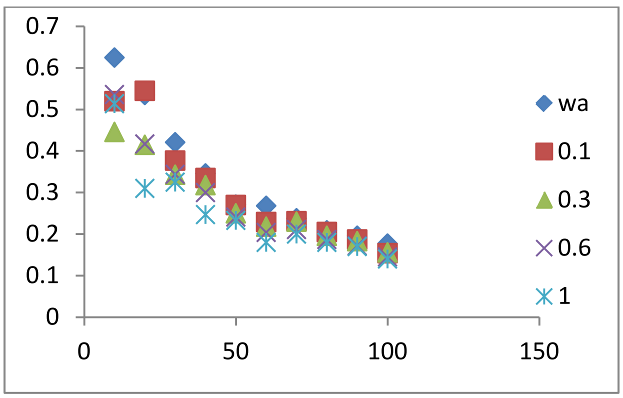

Fig.3 Heat i/p vs. thermal resistance for 45^0 inclination

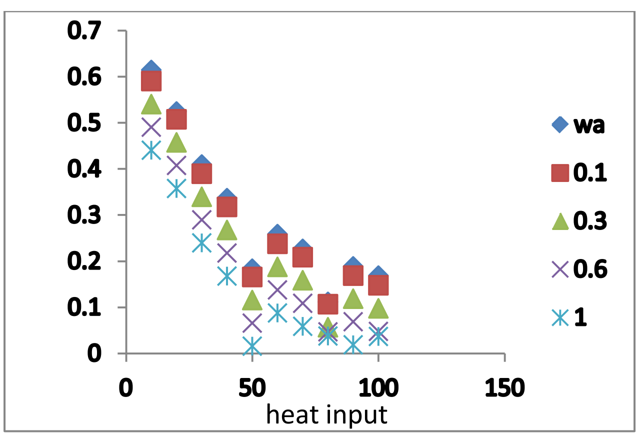

Fig.4 Heat i/p vs. thermal resistance for 60^0 inclination

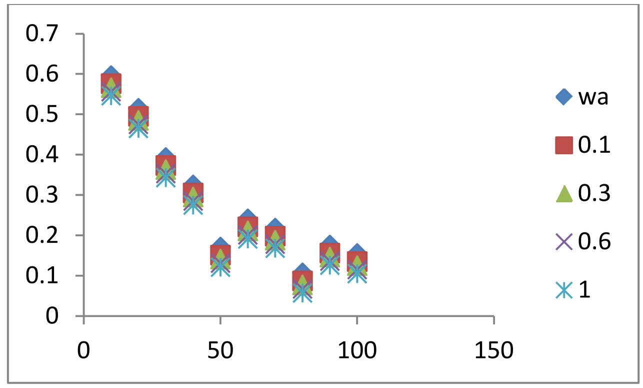

Fig.5 Heat i/p vs. thermal resistance for 90^0 inclination

IV. CONCLUSION

Experimental outcomes are drawn using Al_2O_3 nanofluid within heat pipe as a working media. Inclination angles at which the heat pipe orientations are changed are 30^0,45^0,60^0,90^0. It is clear from the tests carried out that nanofluids have ability to convey heat more rapidly than that of the water or other conventional base fluids. Thus where high heat dissipation is a problem statement; nanofluids can be effectively worked out over there and more preferable than that of the usual cooling medias. Along with this one should also think for ecofriendly solutions for disposing the nanofluids, as they contain many toxic ingredients within them, and also a cost reduction approach to use it with as effective budget as possible.

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