ENHANCEMENT OF THERMAL PERFORMANCE OF A SCREEN MESH WICK HEAT PIPE USING (Al_2O_3) NANO FLUID

S.M.Channa Basava[1], P.Lakshmi Reddy[2],

*[1]Department of Mechanical Engineering, G.Pulla Reddy Engineering College, Kurnnol, Andhra Pradesh

[2]Department of Mechanical Engineering, G.Pulla Reddy Engineering College, Kurnnol, Andhra Pradesh

ABSTRACT: The thermal performance of a cylindrical screen mesh wick heat pipe with Al_2O_3 nanofluid was experimentally investigated. The heat pipe was fabricated with straight copper tube of dimensions 300 mm length, 12.5 mm outer diameter and 1mm thickness. The heat input to the heat pipe was varied from 50 W to 250 W in five equal steps. The heat pipe was tested with two concentrations of nanofluid (0.1% and 0.2%). The results of the investigation showed that for the maximum heat load of 250 W considered in this work, the thermal resistance of the nanofluid with combination, Al2O3 17.3% showed 32.9% reduction compared to deionised water.

Keywords: Heat Pipe, Thermal Resistance, Copper Mesh, Al_2O_3 Nanofluid.

I.INTRODUCTION

With the increase of work frequency and heat flux of electronic components, the dissipation problem of the high heat flux components becomes one of the key technologies of the electronic device design. Up to now, heat pipe technology has been widely applied in the field of micro electronics cooling, as the improved construction of the general heat pipes, screen mesh wick heat pipe has now become a hotspot technology of heat pipe research and development and has been widely applied in many fields, such as spacecraft thermal control, high heat flux electronic equipment cooling, medical and health undertakings, and household appliances. Heat pipe is a device used to transfer the heat from one place to the other. The heat pipe consists of evaporator section, adiabatic section and condenser section. Heat absorption takes place in the evaporator section and heat rejection at the condenser section. Adiabatic section is fully insulated. The heat pipe is evacuated using a vacuum pump and is filled up with the working fluid. The working fluid absorbs the heat at one end of the heat pipe called evaporator and releases the heat at the other end called condenser. Due to the capillary action, the condensed working fluid through the mesh wick structure returns to the evaporator, on the inside wall of the pipe. Normally conventional fluids are used in heat pipes to remove the heat.

For the time being, nanofluids play an important role in heat pipes to increase the heat transfer compared to conventional fluids. Many researchers have presented the heat transfer characteristics of heat pipe using nanofluids. The concept of "nanofluid" has firstly proposed by Choi and Eastman. That is, adding nanoscale metal or metal oxide particles in the liquid with a certain way and proportion, which forms a new class of heat transfer and cooling working fluid.

II. PREPARATION OF NANO-FLUID

Two different concentrations of Al_2O_3 nanoparticles were used in the present experimental work. Al_2O_3 nanoparticles were purchased from Reinste nano ventures, New Delhi, India. The size of nano particles are less than 50 nm. The first key step in the experimental work is the preparation of nanofluid. In the present investigation, the nanofluid was prepared by mixing Al2O3 nanoparticles of volume concentration 0.1% and 0.2% mixed with deionised water as the base fluid. In order to get a uniform and stable nanofluid, it is then sonicated for 30 min in an ultrasonic vibrator. Two different combinations of nanofluid such as having a total 0.1% and 0.2% of volume concentration were used for the study.

III.EXPERIMENTAL SETUP

Heat pipes were fabricated by using commercially available straight copper tubes. The outer diameter, inner diameter and length of the heat pipes are 12.5 mm, 11.5 mm and 300 mm respectively. The evaporator, adiabatic and condenser sections were maintained each of 100 mm length respectively. Fig.(1) shows the schematic of the experimental setup. Copper screen mesh was used as the porous medium for the construction of the heat pipe wick. Three layers of 100 mesh screen copper wick were scrolled into the inner surface of the tube and tightly affixed by a spring mechanism. The heat pipe was evacuated by vacuum pumping system. The wick was completely saturated by filling the heat pipe with 6.5 ml of two different concentrations of Al2O3 /DI water nanofluid and DI water. Both ends of the copper tube were closed by end caps. The outer surface of the evaporator was circumferentially wound by a 350 Watt Nichrome wire heater. The power supply to the electric heater was controlled by an autotransformer and the power input was measured by a digital multimeter.

The condenser section was covered with an acrylic tube of 35 mm diameter and coolant (water) was admitted to the acrylic tube to cool the condenser. The inlet coolant temperature was maintained at a specified value of 25°C by a chiller unit and the flow rate through the condenser section was maintained at 20 l/h. The evaporator and adiabatic sections of the heat pipe were perfectly insulated by glass wool to minimize the heat loss to the surroundings. Twelve T type thermo couples were employed at different locations of the heat pipe to measure the surface and vapour temperatures. Among these, six were placed at the surface of the heat pipe and remaining six inside the heat pipe (vapour core). These thermocouples were located such that they cover the entire length of the heat pipe. To measure the temperature in the vapour core, holes were drilled on the surface of the copper tube at the evaporator, condenser and the adiabatic section . One side sealed short copper tubes of internal diameter 2 mm were inserted into these holes so that these tubes extended into the vapour core at the different sections of the heat pipe. These copper tubes act as thermometer wells and the thermocouples were inserted in these copper tubes to measure the temperature at the vapour core. Additional two thermo-couples were also placed at the inlet and outlet of the cooling water jacket in the condenser region to measure the inlet and outlet coolant temperatures.

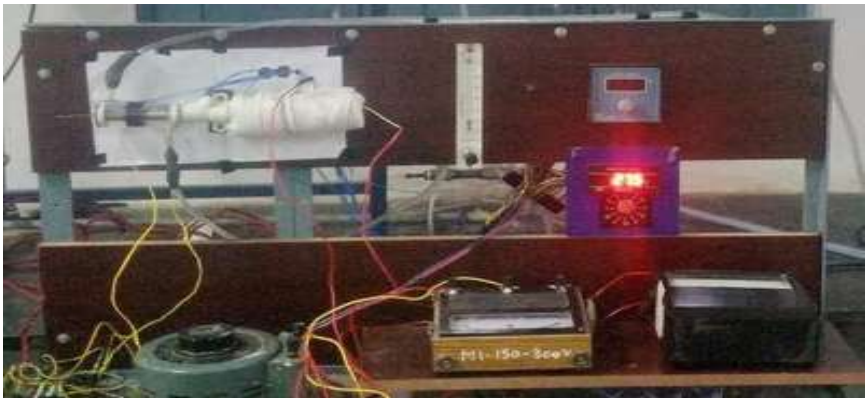

Fig.(1) Heat pipe experimental setup

IV.RESULTS AND DISCUSSIONS

Experiments were conducted for deionised water and two different concentrations of Al_2O_3 nano-particle/DI water heat pipes, three different heat pipes were fabricated for this purpose. The orientation for all the heat pipes was kept horizontal throughout the experiment. The heat pipe was kept in operation for sufficient period of time till the temperature recorded by thermocouples showed a steady value. Experimental study was conducted on three different heat pipes. The heat inputs were varied from 50 to 250 W in equal intervals of 50 W. DI water and nanofluid were used as the working fluid. An important characteristic of any heat pipe used in many heat dis-sipating components is its ability have a faster cooling rate. A lower vapour temperature along the length of the heat pipe indicates that the heat pipe can work under higher heat loads. To illustrate this, the vapour temperature distribution along the axial length of the heat pipe for a heat load of 200 W has been plotted in fig.(2).

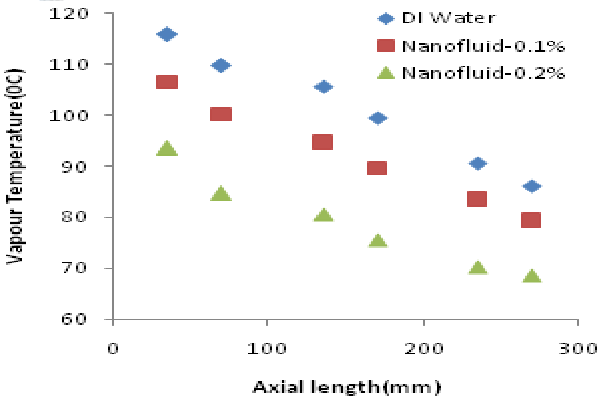

Fig.(2). Distribistion of Vapour temperature along the axial

Length (Q=200W)

As seen in the figure, the heat pipe with working fluid 0.2% of nanofluid showed a maximum drop in temperature of 23.7^0 C and 18.4^0 C respectively in the evaporator and adiabatic region compared with DI water. The maximum drop in temeperature is because nanofluid contains maximum total mass of nanoparticle.

The adiabatic vapour temperature has a significant influence on the operating characteristics of a heat pipe. The influence of heat load on the adiabatic vapour temperature of the heat pipe working under different nanofluids is shown in fig.(3). From the figure it is seen that the adiabatic vapour temperature increases with the increase in heat load on the evaporator region and for a particular heat load it decreases as the total weight of nanoparticle in the base fluid increases.

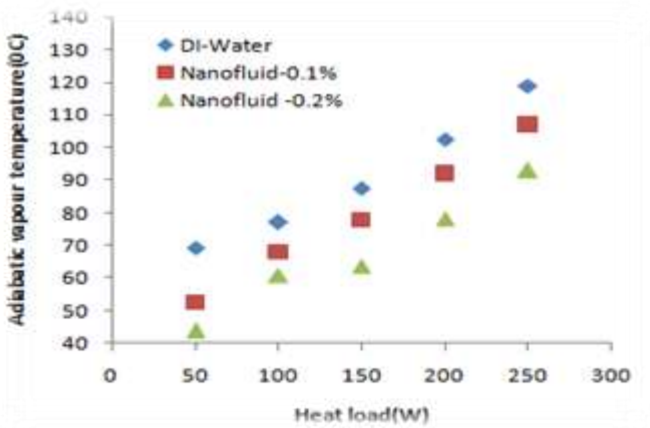

Fig.(3). Variation of adiabatic vapour temperature with heat load

At a maximum heat load of 250W, considered in the present study, the adiabatic vapour temperature shows a reduction of 10.12% and 21.93% respectively for 0.1 and 0.2 vol% concentration compared with DI water.

The ability of the heat pipe to operate at a larger heat load depends upon the vapour temperature difference between the evaporator and the condenser. It is observed from fig.(4)., that the temperature difference between the evaporator and the condenser decreases with increase in total mass of nanoparticle for a given heat load. This reduction in temperature difference is largest for 0.2vol% and therefore the heat pipe working with 0.2vol% nanofluid has a greater heat transport capability.

Another performance parameter which shows the ability of a heat pipe to work at a higher heat load is its evaporator and condenser wall temperature difference which is expressed as thermal resistance and defined as the difference of wall temperature of evaporator section and condenser section to the heat load given at evaporator section. The variation of thermal resistance against heat load is plotted in fig.(5).

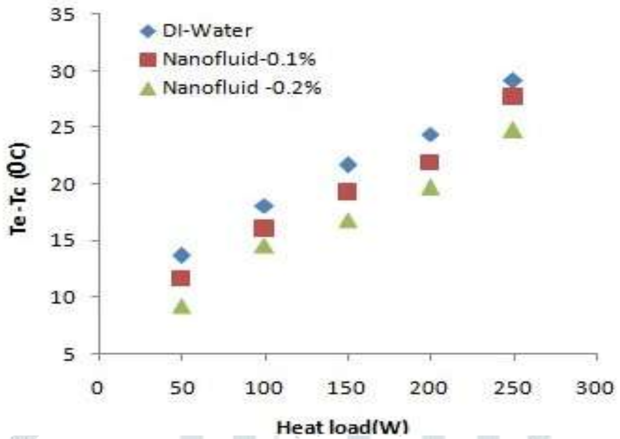

Fig.(4) Evaporator and Condenser vapour temperature difference as a function of heat load

It can be inferred from the figure that the thermal resistance of all the two concentrations of nanofluids is lower at all heat loads compared to the heat pipe operating with base fluid (DI water). It is seen that as the heat load increases the thermal resistance decreases. The reduction in thermal resistance is found to be more while using nanofluid compared to heat pipe operating with DI water. At 250 W reduction in thermal resistance is ob-served for nanofluid-0.1% is 17.32 and nanofluid-0.2% is 32.92% compared to that of DI water.

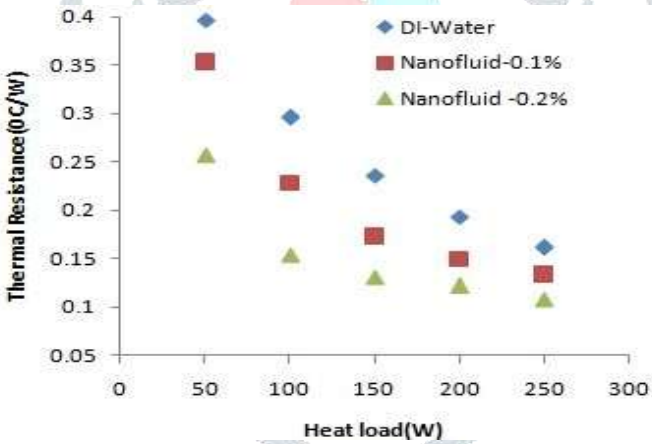

Fig.(5) Thermal resistance of heat pipe as a function of heat load

V.CONCLUSION

In this work, experimental investigations were carried out to study the performance of a heat pipe using two different proportions of Al2O3 nanoparticles of 0.1% and 0.2% volume concentration that were added in deionised water and used to form nanofluid. From the experimental investigation it was ob-served that the operating temperature of the heat pipe reduces as the total weight of nanoparticle in the base fluid increases and there-fore nanofluid can increase the operating range of heat pipe above 250 W, which is the maximum heat load considered in the study. The thermal resistance of the heat pipe has decreased by 17.32% for nanofluid-0.1%, 32.92% for nanofluid-0.2% compared with deionised water. Based on the results obtained in the investigation, it is concluded that the performance of nanofluid-0.2% is better than the DI water.

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