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EXPERIMENTAL STUDY ON BEHAVIOUR OF SINTERED COPPER WICK HEAT PIPE AT DIFFERENT ORIENTATIONS

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ABSTRACT-- A Heat Pipe is a closed system generally in the form of a simple cylindrical pipe sealed at both sides and partially filled with a working fluid (water) that transfers heat as latent heat of evaporation. The main components of heat pipe are container, wick structure and small amount of working fluid in liquid state. The heat pipe is divided into three segments: evaporator section, adiabatic section and condenser section. Now a day's heat pipes are extensively as a heat transmission device because of the following advantages like constructional simplicity, exceptional flexibility, accessibility to control and ability to transport heat at high rate over considerable distance with extremely small temperature drop and also it doesn't require any external pumping work. Some of the main applications of heat pipes are space crafts, computer systems, permafrost cooling, heat exchangers and thermal storage sub systems. In this work we are going to do the experiment on sintered copper wicked heat pipe placed at different orientations and note the heat transfer rates of the heat pipes at each position. The temperature at evaporation section and condensation section of the heat pipe is measured using K type thermocouple. From this experimentation we here by conclude that sintered copper wicked heat pipe thermal performance is very less affected by gravity and angle of orientation because of high capillary action of the wick.

Keywords— heat pipe, wick structure, working fluid, capillary action, water, thermal performance.

I. INTRODUCTION

The interest in the use of heat pipes for thermal management is recognized in many industrial applications. For example the thermal management of electronic equipment has become an important issue because of increasing power levels along with the miniaturization of the devices. With the advent of denser device packaging and faster intrinsic speeds, cost, reliability and size have been improved, but it requires new cooling solutions often based on liquid/vapor phase change systems. As a first approach, the thermal performance of a heat pipe can be characterized by both its overall thermal resistance and its maximum power in horizontal and vertical positions. These characteristics depend mainly on the capillary structure, which is usually made of grooves, meshes, sintered powder or a combination of them. In many applications, heat pipes are circular and are used to transport heat from one heat source to one heat sink, which can be any cooling system. Planar heat pipes, also called flat plate heat pipes have the same components, but offer a wide cross- section, which allows reducing their thickness without reducing their thermal performance. Furthermore, several heat sources can be located on them, which is interesting to cool electronic cards, with many electronic components. The interest in the use of heat pipes for thermal management is recognized in many industrial applications. For example the thermal management of electronic equipments has become an important issue because of increasing power levels along with the miniaturization of the devices.

II. LITERATURE SURVEY

Experimental study on sintered copper heat pipe with two different working fluids namely ethanol and pure water which is done by R.Obaid et al .2011 [1]. In his study he had studied the behavior of heat pipe placed in horizontal by varying the heat inputs and concluded that the performance of heat pipe with water as working fluid is more efficient than ethanol as working fluid when both operated at same conditions. K.C Leong et al. (1997) [2] has conducted a study on wick structures based on porosity and permeability of wick. In his study he compared sintered copper wick with mesh wick and found that performance of sintered copper wick is optimum than mesh wick because of the presence of smaller pores. Nattawut et al.(2013) [3] has conducted experiments on sintered copper heat pipe with two heat sources and established a mathematical model using Finite element method (F.E.M.) to calculate temperature and thermal resistance. Therefore, from this study, we are able to design an effective heat pipe for double heat source applications which is very useful for the electronic industry. Ashvini rana, et. al. (2014) [4] have done experimentation on heat pipes with nanofluids as working fluids. Their result shows improvement in thermal efficiency, heat transfer capacity and reduction in thermal resistance higher using nanofluid than the base fluid and thermal performance of sintered wick heat pipe was better than that of the mesh wick heat pipe. Ck Loh, et. al. (2011) [6] has done research on heat pipes with different wick structures placed at different orientations. They found out that the sintered copper wick structure has less effect on gravity and inclinations because of strong capillary action. Experimentation on effect of thickness of wick structure on heat transfer performance of heat pipe done by Hanlon, (2009) [7], A theoretical analysis has been done with mathematical model and results are compared with experimental values. He had concluded that the thinner is the wick structure more is the heat transfer performance.

III. EXPERIMENTAL STUDY

The experiment is conducted on sintered copper wick structured heat pipe by varying the heat input and angle of inclination (ɵ), Powder particles are diffused together and to the tube wall to form a sintered wick structure. Copper powder is the most common material used in heat pipes. Copper powder is dendritic structure nature and is filled with a 50 to 55% porosity level. **Specifications:** Outer diameter of pipe: 15.88 mm, Length of the pipe : 565 mm, Length of evaporator section : 200 mm,Length of condensation section : 200 mm, Working fluid : Deionised water, Fill ratio : 50%

Figure 1. Experimental Test Bed

Thermocouple: A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. Here we have used K-TYPE thermocouple for measuring temperature of condenser and evaporator. Type K (chromel– alumel) is the most common general purpose thermocouple. It is inexpensive, and a wide variety of probes are available in its −200 °C to +1350 °C range. Water sink/tank: Water required for circulation is taken from the bottom tank and is passed over the condenser region with help of water pump supplied with 2 valves, where it absorbs heat and thus the heated water is brought out from the pipe coming out from the condenser section. Measuring jars: to measure the mass flow rate of circulating water. Control unit: For varying the power input as and when required. Stop watch: to measure the flow rate time.

Experimental Procedure:

The heat pipe is placed in the position as shown in the experimental setup. The degree of inclination is then set by moving the water jacket in an inclined way. The angle is measured by using angle measuring device. The two thermocouples are fixed to the two ends of the heat pipe (i.e. one at evaporator section and other at condenser section) with the help of locking screw. The heater is placed at evaporator section and the heat input is given by switch on in the heater. The amount of heat input can be varied the varied provided on the setup. Water is being pumped continuously at condenser section through a water jacket to take away the heat from condenser.

The temperatures at evaporator and condenser sections are measured using thermocouple which is displayed on the setup. The temperatures are noted once the system reaches the steady state. The mass of water flow is calculated by taking the time required to fill certain amount say 200 ml in the measuring jar. The same procedure is conducted by varying the inclination and readings are noted

Mathematical Formulation & Observations

The amount of heat supplied at the evaporator section is absorbed by the working fluid and it is released as latent heat of evaporation at condenser section. The amount of heat dissipated by the condenser is equal to that of heat absorbed by the circulating water in the jacket. Experiments are conducted from 0^0-50^0 inclinations shown in tables.

Let m be mass of circulating water in (kg/sec), C_p be the specific heat of water = 4.18 kJ/kg*K, T_{OUT} be temperature of outlet circulating water in ^{0}C, T_{IN} be temperature of inlet circulating water in ^{0}C, T_E be evaporator temperature in ^{0}C, T_C be condenser temperature in ^{0}C, Q_{IN} be amount of heat supplied at evaporator =V*I in watts (w) Q_{OUT} be amount of heat gained by circulating water = $m*C_p*(T_{OUT}-T_{IN})$, Efficiency of heat pipe == $(Q_{OUT} \div Q_{IN})$ %ŋ = $(Q_{OUT} \div Q_{IN})*100$, Thermal resistance $(R_{TH}) = ((T_E - T_C) \div Q_{IN})$ in (^{0}C / W). Experimental values as follows.

TABULATIONS:

Table I Behaviour of heat pipe at inclination $\theta = 0^0$

Mass flow rate (kg/sec)	Power Input Q_{IN} in W	Evaporator Temperature T_E in ^{0}c	Condenser temperature T_C in ^{0}c	Water inlet temp T_{IN} in ^{0}c	Water outlet temp T_{OUT} in ^{0}C	Q_{OUT} in w	Thermal resistance R_{TH} in ^{0}c/w	Efficiency η in %
0.0148	107.8	39	35	25	26	61.864	0.0371	57.38
0.0148	150.8	42	38	27	29	123.728	0.0265	82.047
0.0148	204	43	37	27	30	185.592	0.0196	90.97
0.0148	255.5	45	40	28	31	185.592	0.01956	72.638
0.0148	290	47	44	29	32	185.592	0.01034	63.997

Sample Calculation: Mass flow rate =0.0148 kg/sec, Specific heat of water =4180 J/kg*k, Q_{IN} =107.8 W, $T_E = 39^0$C, $T_C = 35^0$C, $T_{IN} = 25^0$C, T_{OUT} = 26 ^{0}C, $Q_{OUT} = m*c_p*(T_{OUT}-T_{IN})$ = 0.0148*4180*(26-21) = 61.864 W, %η = $Q_{OUT} \div Q_{IN}$ = (61.864 ÷ 107.8) , Thermal resistance $R_{TH} = ((T_E - T_C) \div Q_{IN})$ in (^{0}C / W) = ((39-35) ÷ 107.8) = 0.0371^{0}C / W

Table II Behaviour of heat pipe at inclination $\theta = 30^0$

Mass flow rate (kg/sec)	Power Input Q_{IN} in W	Evaporator Temperature T_E in ^{0}c	Condenser temperature T_C in ^{0}c	Water inlet temp T_{IN} in ^{0}c	Water outlet temp T_{OUT} in ^{0}C	Q_{OUT} in w	Thermal resistance R_{TH} in ^{0}c/w	Efficiency η in %
0.0148	98.7	41	34	31	32	61.864	0.07246	62.678
0.0148	153.9	43	37	32	33	123.728	0.04048	80.935
0.0148	204.6	45	39	31	33	185.592	0.03030	90.709
0.0148	250.8	48	42	32	34	185.592	0.02384	74.00
0.0148	301	50	45	34	35	185.592	0.01073	61.758

Table III Behaviour of heat pipe at inclination $\theta = 50^0$

Mass flow rate (kg/sec)	Power Input Q_{IN} in W	Evaporator Temperature T_E in ^{0}c	Condenser temperature T_C in ^{0}c	Water inlet temp T_{IN} in ^{0}c	Water outlet temp T_{OUT} in ^{0}C	Q_{OUT} in w	Thermal resistance R_{TH} in ^{0}c/w	Efficiency η in %
0.0148	107.8	41	36	32	33	61.864	0.05175	57.387
0.0148	153.4	43	37	32	34	123.728	0.04048	80.657
0.0148	201	46	40	34	35	185.592	0.03030	92.334
0.0148	248.2	49	43	32	35	185.592	0.02384	74.775
0.0148	291.6	51	45	32	35	185.592	0.02083	63.646

Graphs:

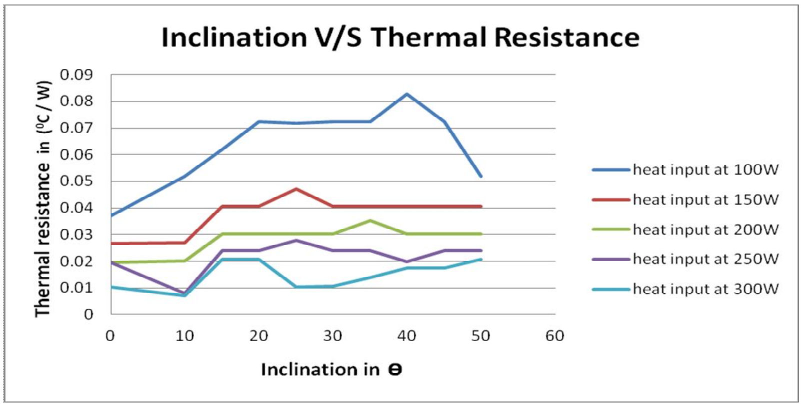

Figure 2 Variation of thermal resistance with inclination

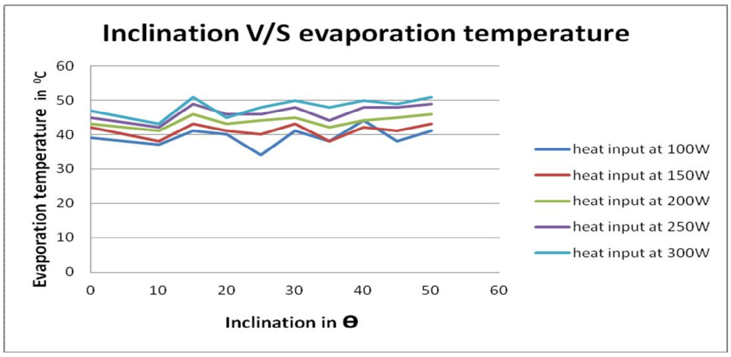

Figure 3. Variation of evaporation temperature with inclination

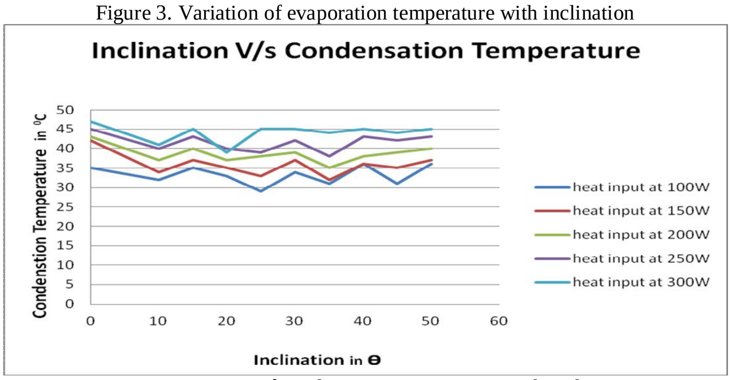

Figure. 4 Variation of condensation temperature with inclination

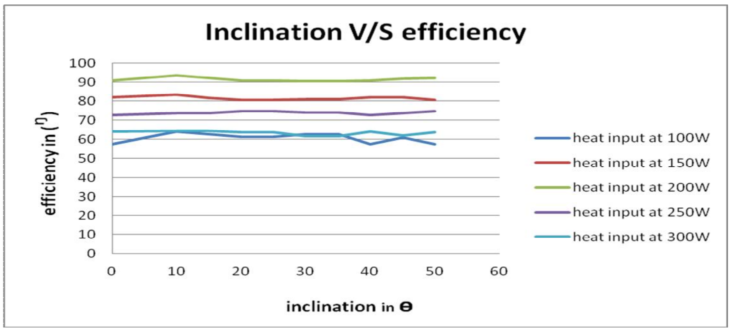

Figure .5 Variation of efficiency with inclination

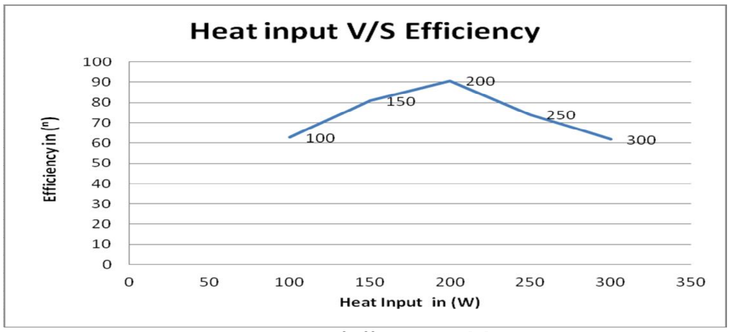

Figure .6 Variation of efficiency with heat input

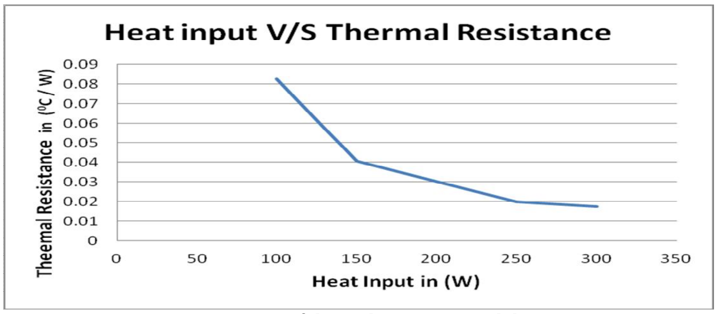

Figure .7 Variation of thermal resistance with heat input

IV.RESULTS AND CONCLUSONS

A study on performance of sintered copper wicked heat pipe is done by varying heat input and angle of inclination which is applicable in Laptops having capacity Heat load of 250 Watts Maximum. From this experiment we conclude:

1. *The efficiency of heat pipe is decreasing after crossing 250W of input because the working fluid (water) is crossing its burn out temperature and the working fluid capacity to absorb latent heat of vaporization decreases.*
2. *The variation of efficiency of heat pipe with angle of orientation is very less because of the strong capillary action of sintered copper wick.*
3. *The increase in the condensation temperature and evaporation temperature is due to increase in latent heat of vaporization as the heat input increases.*
4. *The average efficiency if sintered copper heat pipe is 74.28% when worked at a heat input range of 100W -300W.*

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