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Effect of Inclination on Efficiency of Heat Pipe

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Abstract **- Heat pipes are used in several applications, where one has limited space and the necessity of a high heat flux. Of course it is still in use in space applications, but it is also used in heat transfer systems, cooling of computers, cell phones and cooling of solar collectors. Especially for micro applications there is micro heat pipes developed as for cooling the kernel of a cell phone down. Due to limited space in personal computers and the growing computational power it was necessary to find a new way to cool the processors down. By means of a heat pipe it is possible to connect the processor cooling unit to a bigger cooling unit fixed at the outside to cart of the energy.**

In this paper, different tests were carried out at the different angle of inclination of heat pipe having same current and voltage. The efficiencies at each angle of inclination are calculated from the obtained data.

Keywords: **Heat pipe, Effectiveness of heat pipe, Inclination Angle, Mass flow rate.**

I. INTRODUCTION

Heat pipes were developed especially for space applications during the early 1960´ by the NASA. One main problem in space applications was to transport the temperature from the inside to the outside, because the heat conduction in a vacuum is very limited. Hence there was a necessity to develop a fast and effective way to transport heat, without having the effect of gravity force. The idea behind is to create a flow field which transports heat energy from one spot to another by means of convection, because convective heat transfer is much faster than heat transfer due to conduction.

The heat pipe is a device for transferring heat from a source to sink by means of evaporation and condensation of fluid in a sealed system. A heat pipe is a device of very high conductance .It transfers heat by oiling a fluid at one end and condensing at another. The evaporation and condensation process are responsible for nearly isothermal working of the heat pipe .The condensed liquid is transferred back to the boiling area by the capillary action through a wick structure in the heat pipe. It is the use of capillary action for pumping the liquid back, which is the unique characteristic of the heat pipe .The thermo siphon in many ways resembles a heat pipe, except that the return of the liquid to the evaporator is due to gravity. The working of heat pipe is as shown in figure 1.

The effective thermal conductivity of device is found to be greater than that of solid material of similar mass. The transfer of the thermal energy by conduction using solid material essentially limited by the thermal conductivity of the material structure .Because the thermal energy being transferred by evaporation condensation process rather than by a conduction, The heat pipe can transfer heat much more effectively than solid conductor of the same cross-section .Heat pipe has no moving parts, require no external energy, is reversible in operation and completely silent.

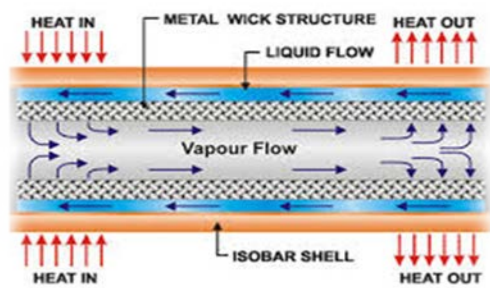

Fig.1 Working of heat pipe.

II. TEST PROCEDURE

1. First the heat pipe is fully instrumented and set up in the instrument.
2. The evaporator section was fitted into the 100 mm long heater block in the test rig. And condenser section covered by 100 mm long water jacket. Whole system was then packed into the single cover.
3. Initially check all the electrical connections are to the mark. And autotransformer is set to be zero.
4. Then supply the electrical power to the autotransformer.
5. Mass flow rate in the condenser unit is kept constant at some specific required value.
6. Adjust the current and the voltage required supplied to the heater.
7. Preferably that, input should be applied at first in steps, building up to design capability and allowing the temperature along the heat pipe to achieve a steady state.
8. Different tests were carried out at the different angle of inclination of heat pipe having same current and voltage.
9. Calculate the efficiencies at each angle of inclination from the obtained data.
10. Compare the efficiencies and discuss the results.

III. OBSERVATIONS AND CALCULATIONS

Observations

1. Internal Diameter Of Heat pipe : 22mm
2. Outer Diameter Of Heat Pipe : 25mm
3. Thickness of Pipe : 3 mm.
4. Length Of Heat pipe :400mm
5. Volume of liquid in the cooling Jacket At the condenser section : 500ml

Fig.2 Image at 0^0 angle

Observation Tables

A. For Angle 0^0

TABLE 1 OBSERVATION TABLE FOR 0^0 ANGLE

Time interval	Voltage	Current	T1	T2	T3	T4	Tin	Tout
1	78	0.267	30.2	29.1	29.0	28.6	26.1	26.2
2	78	0.267	35.1	31.5	31.3	29.8	26.1	26.4
3	78	0.267	39.5	33.2	32.9	31.2	26.2	26.9
4	78	0.267	44.4	37.6	37.3	32.8	26.2	27.3
5	78	0.267	48.6	39.4	39.3	33.9	26.2	27.6
6	78	0.267	51.4	42.7	42.4	35.1	26.2	27.9
7	78	0.267	53.1	44.9	44.8	36.6	26.1	28.1
8	78	0.267	54.7	46.2	46.1	37.4	26.2	28.3
9	78	0.267	54.7	46.2	48.1	37.4	26.2	28.4

Calculations for Angle 0^0

1. Mass of Liquid in Jacket (m_1) = Quantity of cooling water circulated through condenser unit.

=100 ml. per min.
=0.001/60 lit/sec.
=0.00167 kg/sec (1litre=1 kg)

2. Heat Input (Q_{in}) = V * I
= 78 * 0.267
= 20.826 watts.

Where, V= Voltage Maintained in Volts, I= Current In ampere

3. Heat Output (Q_{out}): = m_1*Cp*(T_{out}-T_{in})

= $(1.670*10^{-3})*(4.187*10^3)*(29.5^0- 26.2^0)$
=15.3830 watts.

Where,
m_1= mass flow rate
C_p= specific heat of water
T_{out}= outlet temperature
T_{in}=Inlet temperature

4. Cross sectional area = $\frac{\pi}{4} d^2$

= $(3.14/4)*(0.025)^2$

= $0.49 * 10^{-3}$ m^2.

5. Effectiveness of the Heat Pipe (η):

= Q_{out}/Q_{in}

= 15.3830 /20.826

= 0.4028

= 73.86 %.

B. For Angle 45^0

TABLE 2 OBSERVATION TABLE FOR 45^0 ANGLE

S. No.	Voltage	Current	T1	T2	T3	T4	Tin	Tout
1	78	0.269	37.7	34.4	31.6	29.9	27.9	28.0
2	78	0.269	42.7	37.7	33.6	30.7	27.8	28.2
3	78	0.269	54.8	50.2	43.9	35.9	30.0	28.4
4	78	0.269	55.6	52.6	50.2	39.9	27.9	28.7
5	78	0.269	57.6	53.7	50.4	41.1	27.9	28.9
6	78	0.269	57.6	55.4	55.3	44.4	30.1	29.1
7	78	0.269	57.7	55.6	55.5	44.6	27.9	29.3
8	78	0.269	57.6	55.6	55.6	44.6	27.9	29.3

Fig.3 Image at 45^0 angle

Calculations for 45^0

1. Mass of Liquid in Jacket (m_1) = Quantity of cooling water circulated through condenser unit.

=95 ml. per min.
=0.095/60 lit/sec.
=0.00158 kg/sec (1litre=1 kg)

2. Heat Input (Q_{in}) =V * I
= 78 * 0.269
= 20.982 watts.

Where,

V=Voltage Maintained In Volts.

I= Current In ampere.

3. Heat Output (Q_{out}): $= m_1 * Cp * (T_{out} - T_{in})$

$= (1.670*10^{-3})*(4.187*10^3)*(29.3^0-27.9^0)$
=9.7892 watt

Where,

$m_{1=}$mass flow rate
$C_{p=}$specific heat of water
T_{out}=outlet temperature
T_{in}=Inlet temperature

4. Cross sectional area $= \frac{\pi}{4} d^2$

$= (3.14/4)*(0.025)^2$

$= 0.49 * 10^{-3}\ m^2$.

5. Effectiveness of the Heat Pipe (η):

$= Q_{out}/Q_{in.}$

= 9.7892/20.982.

= 0.4665

= 46.65%.

C. For Angle 65^0

TABLE 3 OBSERVATION TABLE FOR 65^0 ANGLE

Time interval (minute)	Voltage	Current	T1	T2	T3	T4	Tin	Tout
1	78	0.274	27.7	27.5	27.3	27.1	26.8	26.9
2	78	0.274	43.7	38.1	37.4	31.8	27.0	27.0
3	78	0.274	55.5	50.9	45.3	36.5	27.2	27.4
4	78	0.274	56.6	52.6	47.1	38.9	27.4	27.6
5	78	0.274	56.9	53.1	48.7	39.2	27.5	27.9
6	78	0.274	57.0	53.1	48.8	39.2	27.4	28.1
7	78	0.274	57.0	53.0	48.8	39.3	27.4	28.2
8	78	0274	57.0	53.0	48.8	39.3	27.4	28.2

Fig.4 Image at 65^0 angle

Calculations for 65^0

1. Mass of Liquid in Jacket (m_1) = Quantity of cooling water circulated through condenser unit.

=95 ml. per min.
=0.095/60 lit/sec.
=0.00158 kg/sec (1litre=1 kg)

2. Heat Input (Q_{in}) =V * I
= 78 * 0.274
= 21.372 watts

Where,

V=Voltage Maintained in Volts;
I= Current In ampere

Heat Output(Q_{out}): = m_1*Cp*(T_{out}-T_{in})

= $(1.670*10^{-3})*(4.187*10^{3})*(28.2^0-27.4^0)$.
=5.5938 watts.

Where

m_1 = mass flow rate
Cp = specific heat of water
T_{out}= outlet temperature
T_{in} = Inlet temperature

3. Cross sectional area = $\frac{\pi}{4} d^2$

= $(3.14/4)*(0.025)^2$

= $0.49 * 10^{-3}$ m^2.

4. Effectiveness of the Heat Pipe (η):

= Q_{out}/Q_{in}

= 5.5938/21.372

= 0.2617

=26.17 %.

IV. RESULTS AND DISCUSSION

After experimentation at different inclination angles of heat pipe, following results are obtained,

a. The efficiency of heat pipe for angle 0^0 is - 73.86 %.
b. The efficiency of heat pipe for angle 45^0 is -46.65 %.
c. The efficiency of heat pipe for angle 65^0 is - 26.17 %.

The table 1 shows the temperature distribution along the length of heat pipe with 200 size mesh at a time interval of 10 minutes, with a heater input of 400 watt. An every stage take variable time to attain the steady state. The vertical position require minimum time to attain the steady state as compared to at other angle.

Hence, the efficiency of heat pipe is changed as the inclination angle increases and when it goes more than 50^0 the efficiency is changed dramatically.

V. CONCLUSION

The heat transfer rate for the same period of time at the different angles of heat pipe varies continuously. The result shows that, the heat transfer rate is maximum when the heat pipe is at vertical position and the heat transfer rate will go on decreasing at the different angles with respect to the vertical.

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