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Performance and Analysis of Thermosyphon with Refrigerant R-134a

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Abstract

Heat pipe is a device that can transfer heat energy from one point to another point without using any external power source. It is very reliable and has very low cost. Refrigerant R- 134a is the better substitution for the refrigerants R-11, R-12 and R- 22 because it is reliable and echo friendly as it doesn't get involve in to effect ozone depletion. The analysis of temperature difference between constant mass flow rate and fill ratio, condenser section and bath on the thermosyphon R-134a were determined. The following experiment comes with the outcome of increase in fill ratio, coolant mass flow rate and temperature difference between condenser section and bath give rise to heat flux.

Keywords*:fill ratio,thermosyphon,thermalcharacteristics*

1. Introduction

The demand of heat pipe heat exchanger is increase in the market as it is most reliable, low cost and echo friendly. It is used in many applications such as in HVAC system as energy recovery, in boiler as preheater and in many heat transfer applications.

Nomenclature

mcoolant water mass flow rate (kg/s)
C specific heat of water (J/kg K)
Q heat transfer rate (W)
F_R Fill ratio
T_i Inlet temperature of water jacket (°C)
T_0 Outlet temperature of water jacket (°C)
T_b Bath temperature (°C)
T_c Condenser temperature (°C)
T_e Evaporator temperature (°C)
T_{sat} Saturation temperature of refrigerant (°C)
U_e Overall heat transfer coefficient ($Wm^{-2}K^{-1}$)

Lots of study has been done in thermal performance of the heat pipe or thermosyphon [1-9]. Because of ozone depletion potential R-11, R-12 and R-22 are substituted with R- 134a. Refrigerant R134a is most echo friendly. Some investigation has been done on R-134a filled heat pipes [10-11]. Thermal performance of R-134a filled thermosyphons was examined in present investigation.

2. Literature review:

1) S.H.Noie, Heat transfer characteristic of a two phase closed thermosyphon:

He gives heat transfer performance of thermosyphon. In his paper he gives the effect of three parameters: input heat transfer rates (100 < Q < 900W), the working fluid filling ratios (30% ≤ FR ≤ 90%), and the evaporator lengths on the thermosyphon with water as working refrigerant.

I investigate the same experiments at different filling ratios, different heat transfer rate and length of thermosyphon with working refrigerant R-134a. After investigation it found that the thermal performance of thermosyphon with R-134a is better than water.

2)PatilAniket, Factors Affecting the Thermal Performance of Two Phase Closed Thermosyphon:
He studied lots of investigations on the performance of thermosyphon. According to his investigation the thermal performance of thermosyphon is dependent on pipe material, fill ratio, coolant flow rate, coolant temperature, properties of fluid, heat load etc.
He resulted the conclusion with theoretical study but I investigated same conclusion with experimental study.

3)Thanaphol Sukchana,Effect of Filling Ratios and Adiabatic Length on Thermal Efficiency of Long Heat Pipe Filled with R-134a:

He gives the comparison study between filling ratio and adiabatic length on the performance of thermosyphon with constant inlet water temperature. He found that the thermal performance is dependent on the length of adiabatic section as well as fill ratio.

I investigate the experiment with different fill ratio, heat load, coolant mass flow rate and bath temperature. After investigation I conclude that performance of thermosyphon mostly depend upon the fill ratio and coolant mass flow rate.

4)Mr. Faddas Nikhil Ashok,Thermal Performance of Thermosyphon Heat Pipe Charged with Binary Mixture:

He performs the same experiment but with binary mixture(ethanol and methanol) as working fluid. He concluded that performance of the thermosyphon is greater for binary fluid. I performed experiment with R-134a as working fluid with different parameters.

3. Experimental Setup

The experimental setup is mainly divided in to three parts as evaporation section, adiabatic section and condensation section. There used 720 mm long, 28 mm O/D and 25.3 mm I/D copper tube single thermosyphon as shown in fig 1.

A condenser section of thermosyphon was surrounded by water cooled jacket which is 300 mm long along the thermosyphon. The water jacket has 40 mm I/D throughout its length. It has two openings named as inlet and outlet. Each opening has 10 mm diameter as shown in fig 1.

For evaporation section water bath used which heated by water heater at different power. Stirrer used to stir bath water for steady temperature. The evaporation section is 300 mm long. The adiabatic section was 120 mm long and well insulated by the insulating material to prevent the heat loss by convection and radiation.

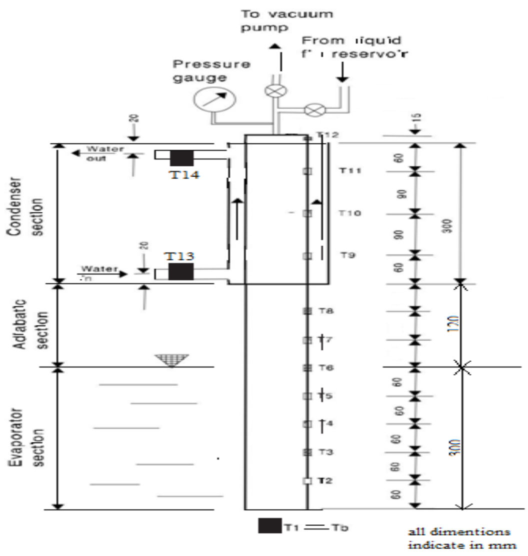

fig.1 A thermosyphon

4. Working

The evaporation section of the thermosyphon was dipped in to the water bath. The water bath is heated by using heater with different power. The water bath is stirred by stirrer to get steady temperature throughout the bath water. Coolant water was supply to the water jacket by using coolant tank as shown in fig 2. Flow meter used to measure the flow rate of coolant water. To run the experiment there used various water flow rates of coolant water.

In every experiment, maintain the bath temperature equal to ambient temperature and then raise the bath temperature step by step until desired steady state. Steady state of bath water conformed when all the thermocouples inside the evaporation section shows the equal or slightly different readings or temperatures. According to this next experiments proceed.

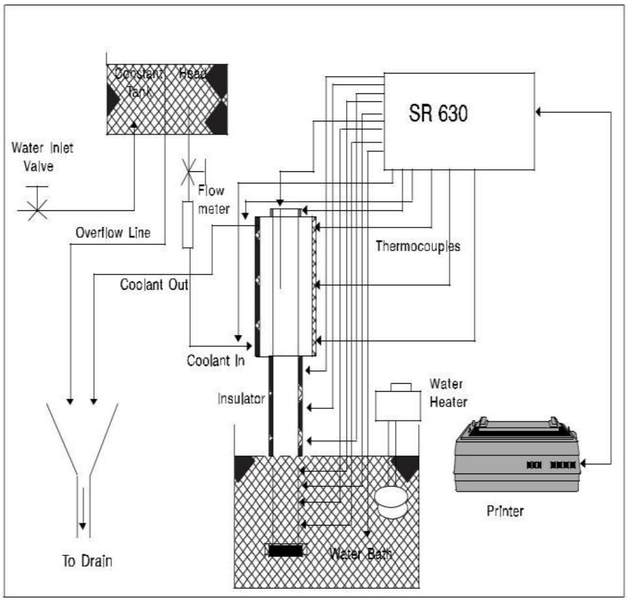

Fig2. Experimental set up

5. Mathematics

Heat absorbed by the refrigerant in evaporation section is equal to heat rejected by the same refrigerant in condensation section.

The condenser temperature (T_c) is arithmetic mean of inlet temperature (T_i) and outlet temperature (T_o) of the water jacket.

$$T_c = (T_i + T_o)/2$$

Heat rejected to water jacket is equal to heat transmitted from thermosyphon.

Q = mC$(T_o - T_i)$

General heat transfer equation

Q = $U_e A_e (T_b - T_c)$

6. Result and discussion

At filling ratio 0.7 with coolant flow 0.0100 kgs^{-1}. Fig 3 shows temperature distribution along the length of heat pipe. There shown saturation temperature (T_s), coolant water temperature (T_c) from graph it was calculated that at low bath temperature, the temperature difference throughout the pipe is same or there was no any fluctuation in evaporator, in adiabatic and condenser section. But as the bath temperature rises there was little fall in temperature towards adiabatic section.

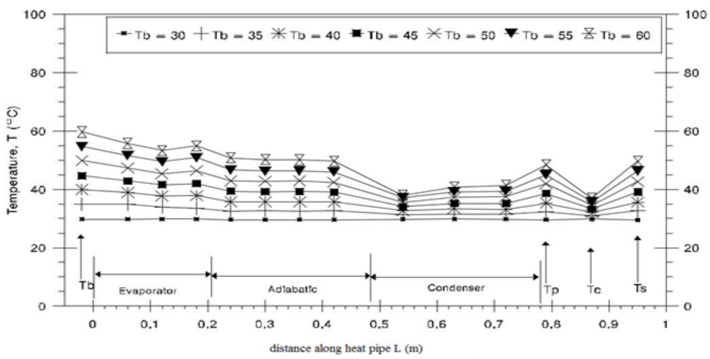

Fig. 3 [Working fluid = R-134a, fill ratio = 0.7 , m = 0.0100 kg/sec

For fill ratio 0.7 and for various coolant mass flow rates fig 4 shows the graph between bath temperature vs difference in bath and evaporator temperature. Temperature difference nothing exceeds than 1^0 to 4^0C.

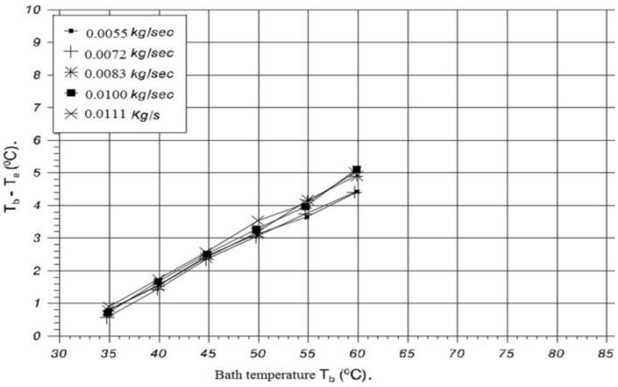

Fig.4 [working fluid R-134a, fill ratio = 0.7]

In fig.5 shows the graph of difference between bath and mean condenser water temperature vs overall heat transfer coefficient U_e at coolant flow rate 0.0100 kg/s for various fill ratios it was concluded that as the fill ratio increases it increase the overall heat transfer coefficient U_e. With temperature difference$(T_b - T_c)$, heat transfer coefficient was seemed to be increased.

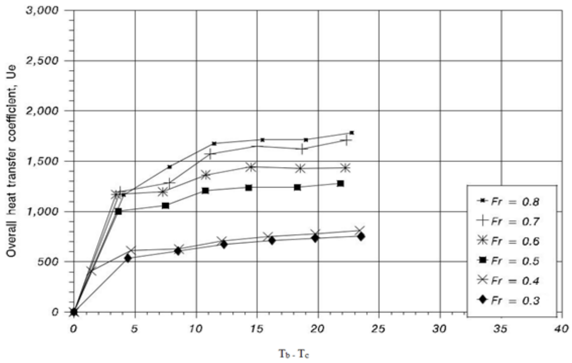

Fig.5 [working fluid R-134a ; m = 0.0111]

For various coolants mass flow rate there plotted graph of highest $U_e$vs fill ratio. It indicated that as mass flow rate increase it increased overall heat transfer coefficientU_e.
As fill ratio increased it increased overall heat transfer coefficient $U_e$linearly. But as fill ratio increased than fill ratio 0.8 it decreases overall heat transfer coefficient U_e heat pipe. Hence for higher fill ratio beyond certain limit heat transfer performance of thermosyphon decreased.

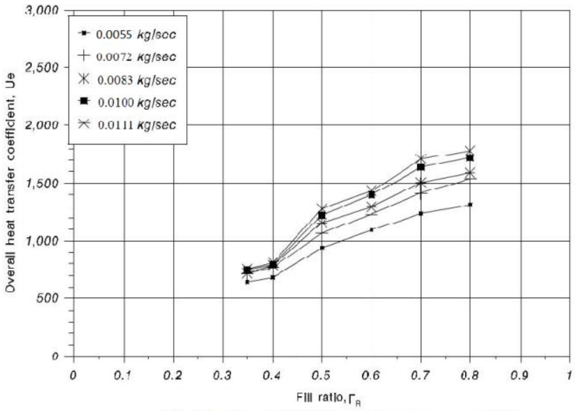

Fig.6 (working fluid R-134a, Bath temperature- 328 k)

Fig.7 shows the plots of condenser water flow to the calculated heat transfer rate from hot water in water bath for coolant mass flow rate of 0.0072kg/s and fill ratio 0.7. It's shows that was came within 1min.

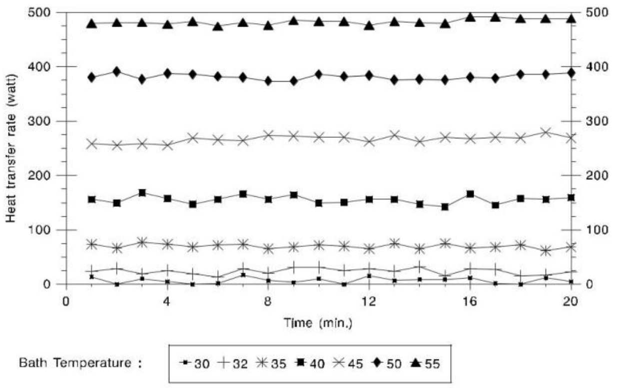

Fig7 Heat transfer rate vs Time(m=0.0072 kg/s, fill ratio=0.8, working fluid=R-134a)

The graph of bath temperature vs heat transfer rate shown in fig.8 for coolant mass flow rate 0.0072kg/s and fill ratio 0.7. the result shows that with increase in bath temperature heat transfer rate increases. During the measurements, fluctuations occurred in heat transfer rate from 12 to 26 W

Conclusions

Analysis resulted that performance of the thermosyphon with refrigerant R-134a was better with high fill ratios, maximum temperature difference between bath and condenser temperature and at high coolant mass flow rate.

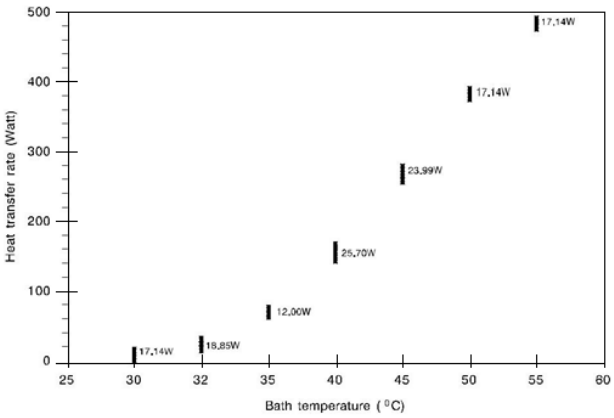

Fig.8. variations of heat trancefer rate at different bath temperature(m=0.0072kg/s, fill ratio= 0.8,working fluid=R-134a)

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