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Experimental Study And CFD Based Simulation of Closed Loop Pulsating Heat Pipe Using of Refrigerants (R-134a)

Monika Tiwari[1], Dr. Nilesh Diwakar,[Hod2]
[1]*Research Scholar , M.E.(Thermal Engg.) Department Of Mechanical Engineering*
Truba Institute Of Engineering & Information Technology, Bhopal, (M.P.)
[2]*Department of Mechanical Engineering*
Truba Institute Of Engineering & Information Technology, Bhopal, (M.P.)

ABSTRACT
Experimentally investigated the performance of closed loop pulsating heat pipe using a single turn pipe to demonstrate the complex hydrodynamics. Optimum filling ratio and optimum inclined angle were found on the basis of best performance of CLPHP. There is great effect of gravity and number of turns on the performance of closed loop pulsating heat pipe by experimentation of closed loop heat pipe of different number of turns. CLPHP was made up of copper tubes of 1.0 and 2.0 m internal diameter. The fluids employed are ethanol, water and R-123. The behavior of wall temperature oscillations in a closed-loop pulsating heat pipe using non-linear analyses on temperature data. The tests were performed with heat pipe consisting of five turns and made of copper capillary tube which had an internal diameter of 2 mm. After this the experimental result and simulation result some different because of some error during operation of experimental process.
Keywords: *Experimental approach, simulation, Cooling fluid, Heat pipe*

I. INTRODUCTION

The effect of inclination angle and working fluid on the heat transfer characteristics and performance of CLPHP. The experiments were performed using two different working fluids water and ethanol with inclination angle of 0° (vertical). The evaporator section is heated by electrical heat input, while the condenser section is cooled by atmospheric air flow[2]. The experimental results indicate a strong influence of gravity and thermo physical properties of the working fluid on the performance of the CLPHP. The results demonstrate the effect of the input heat flux, inclination angle and physiochemical properties of the working fluid on the thermal performance of the device,[6].

II. METHODOLOGY

The first step of a Computational fluid analysis is geometry creation. Analysis of the performance of CLPHPs is done using computational fluid dynamics method. For this geometry is modeled in 2D in Gambit 2.2.30. A schematic diagram of the geometry is shown in figure 1.

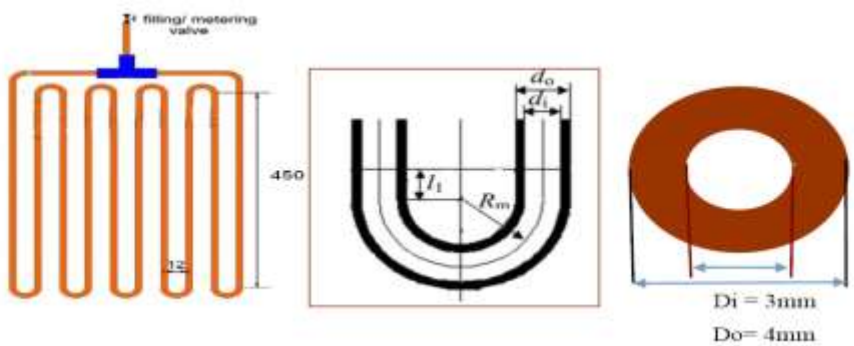

Figure. 1 Closed loop het pipe

Number of turns is taken as 10. Inside and Outside diameter of pipe are 3 mm and 4 mm respectively. Length of pipe is 450 mm and 12 mm is the gap between the pipes. Total length of the pipe is taken as 6 m. For achieve better results grid independent study is done, element size.5 mm, 2 mm and 3 mm are selected.

Different kind of mesh has been checked for simulations and 0.5 mm element size mesh is found optimum and selected for further analysis in figure .2.

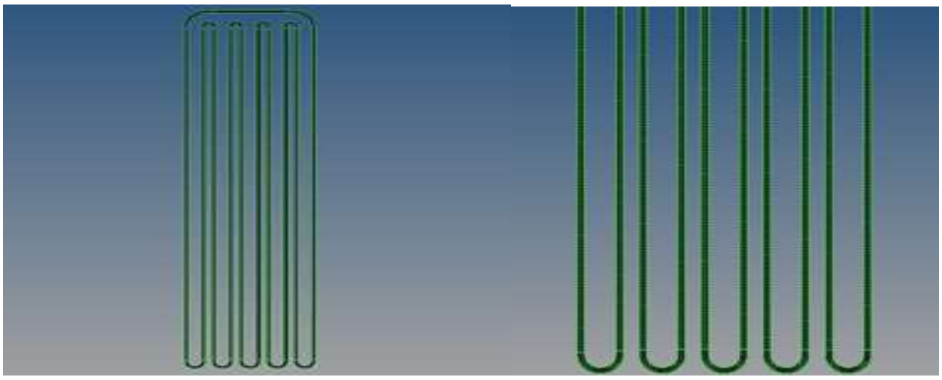

Figure. 2. 0.5 mm Mesh closed loop heat pipe

It is found that the 0.5 mm mesh has 13279 elements, 2 mm mesh has 7495 elements and 3 mm mesh has 3852 elementsin figure.3. Since the number of elements in 1 mm mesh is more so it will provide us better results. in figure .4.

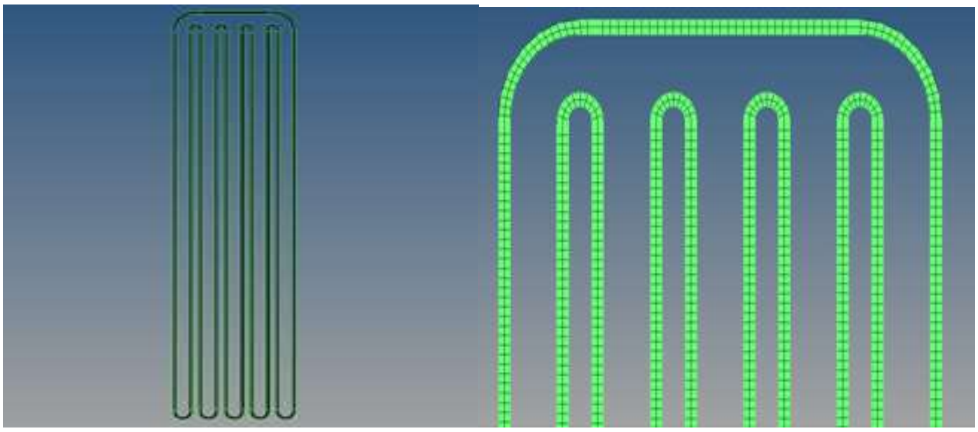

Figure. 3. 2 mm Mesh closed loop heat pipe

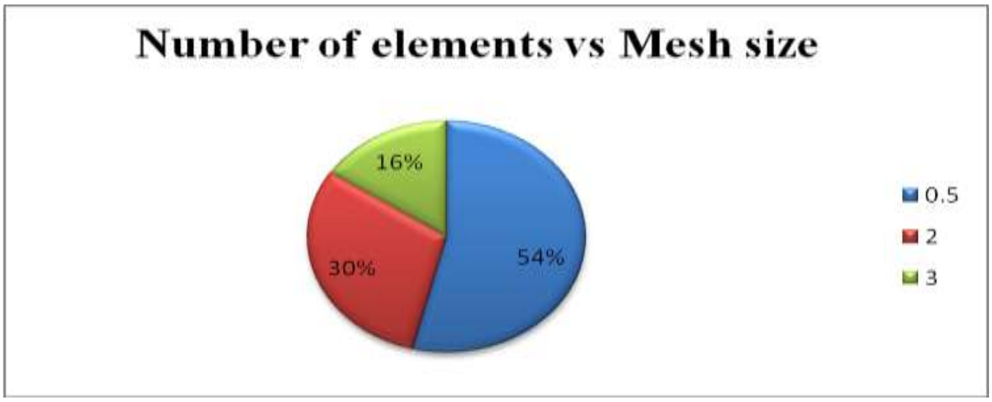

Figure. 4. Number of elements ratio vs Mesh size

III. EXPERIMENTAL SET UP

An experimental set up of closed loop pulsating heat pipe is developed to properly understand a phenomenon which involves complex two phase thermo hydrodynamic interactions of the working fluid having decisive implications on net heat transfer. It consist of the heating and cooling baths. The tested CLPHPs were made of copper capillary tube. Both ends of the tube were connected together to form a closed loop structure. The CLPHP was formed from 10 copper tubes. The capillary tube has inner diameter of 3mm and outer diameter of 4 mm. The total length of the closed loop pulsating heat pipe is 6000 mm. The evaporator and condenser lengths are 150 mm and 150mm respectively in figure .5. A adiabatic sections is connected between evaporator and condenser for a length of 150 mm. The adiabatic section was well insulated with foam insulation. A water heater of 1000 W capacity insert in the hot water bathe to providing heat the evaporator copper coils during the experiments for heating the working fluid as well. 12J type thermocouples are used for the temperature measurement. The operating temperature range of these J type thermocouples is -50 to 500 °C with a maximum error of ±0.5°C. The temperature indicator fixed which is having 12 thermocouples. Three thermocouples are fixed in the evaporator section and two in the condenser section. The temperatures measured by three thermocouples in the evaporator section are named as T9, T10,and T11 respectively. The temperatures measured by two thermocouples in the condenser section are named as T3 and T4 respectively.T1 and T2 are the inlet and outlet temperature of condenser and T12 is measuring inlet water temperature of the condenser. The thermocouples are fixed on the walls of the copper tube. A temperature indicator indicate the temperature with the help of thermocouples. A pressure indicator shows the pressure inside the tubes. A flow meter of 6 LPH capacity measure the flow of water circulating in the condenser section from the cold water bathe. Experiments are repeated in order to ensure the consistency of the thermocouples. Two water pump used for the pumping the water circulation the both Cold and Hot bathe.

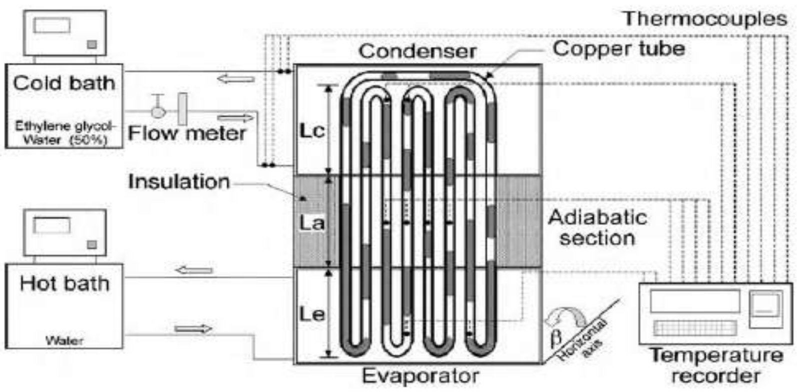

Figure.5. Experimental Set up

3.1-Working Of Set Up

The performance testing of CLPHPs may be conducted in two ways: (i) controlling the input heat flux and the condenser temperature, in which case the evaporator temperature is a dependent variable and, (ii) controlling the evaporator and condenser temperature to give dependent heat throughput. In the present experimental, the latter strategy was adopted. Essentially three parameters were fixed at the outset: (a) the average evaporator temperature was always maintained at 80˚C with the help of a large water cooling bath in figure.6..

Figure.6. Experimental set up of CLPHP

IV. RESULTS AND DISCUSSION

4.1. CFD based simulation

The closed loop heat pipe which is meshed with 1 mm mesh size is analyzed with ANSYS Fluent software with different boundary conditions and refrigerants. The refrigerants properties are set and then used in different phase i.e. in both gas as well as liquid form. Initially R134a is taken as a fluid flowing through evaporator in both the phases. Different filling ratios were used namely 50%, 70% and 83% respectively. Inclination angles are also varied to mainly as vertical and horizontal to find out the effects of inclination of closed loop heat pipe. Temperature variation from 318K (45°C) to 319K (46°C) shown in figure .7. , temperature 319K (46°C) are shown in figure 8. And temperature 319K (46°C) are shown in figure 9.

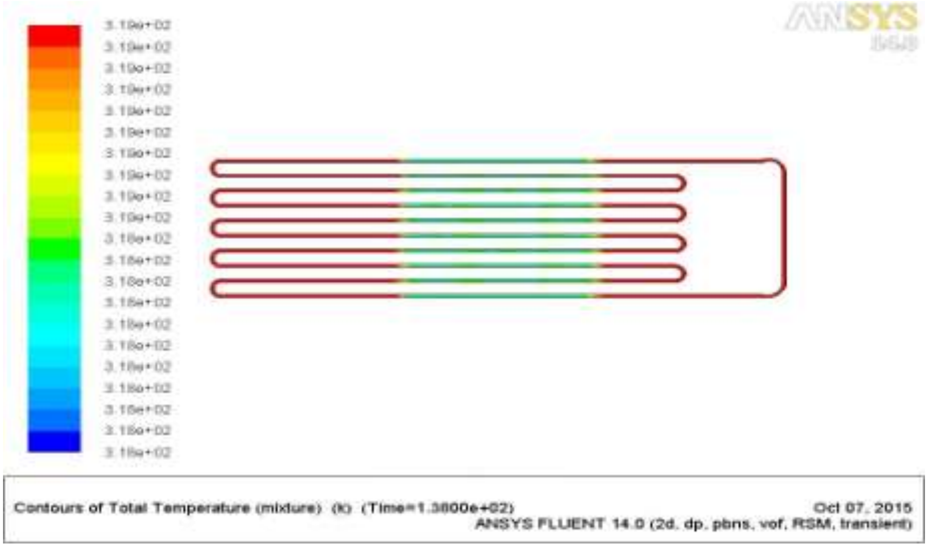

Figure.7. Temperature variation on horizontal closed loop pipe 83% FR

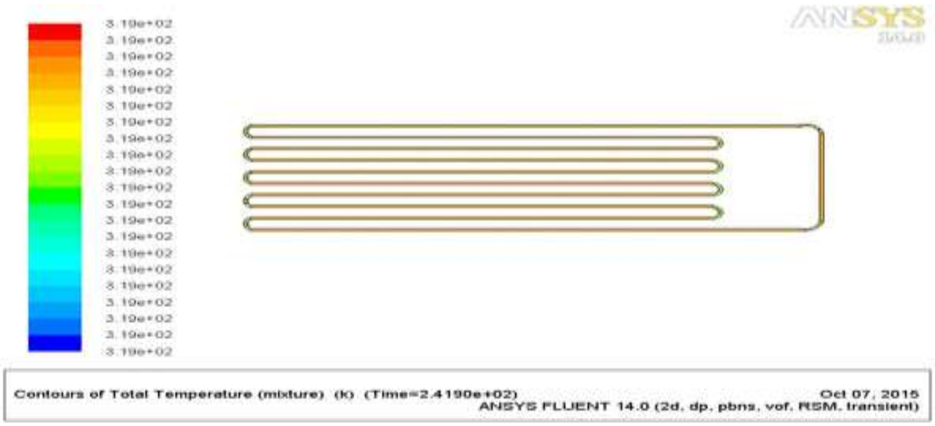

Figure.8. Temperature variation on horizontal closed loop pipe 70% FR

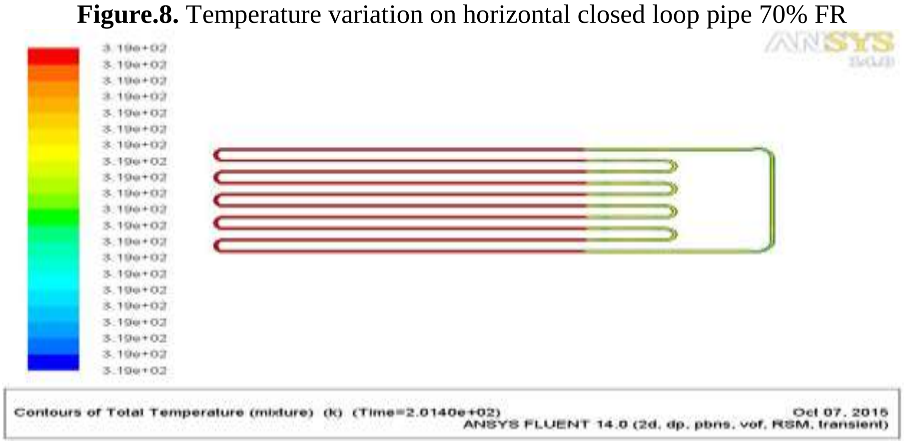

Figure.9. Temperature variation on horizontal closed loop pipe 50% FR in 5 Sec

Table-4.1.1. Various Temperatures during CFD based simulation

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
34	40	40	44	49	48	56	65	70	70	70	72

$T_e - T_c = T_9 - T_2$

$=70°C - 40°C$

$=30°C$

- PRESSURE INSIDE TUBE BUNDLE : 5 Kg/cm2
- 83% FILLING RATIO
- FLOW RATE :6 LPH
- T3, T4 = CONDENSER TEMPERATURE
- T9,T10,T11 = EVAPORATOR TEMPERATURE
- T1= INLET OF CONDENSER TEMPERATURE
- T2 = OUT LET OF CONDENSER TEMPERATURE
- T12 = INLET OF EVAPORATOR TEMPERATURE
- T5,T6,T7,T8 =ADIABATIC SECTION TEMPERATURE

All data in °C

For inclination angle 90 degree of condenser and evaporator with respective to ground

Table-4.1.2. Various Temperatures during CFD based simulation

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
33	38	38	43	48	47	51	63	69	69	69	72

$T_e - T_c = T_9 - T_2$

$=69°C - 38°C$

$=31°C$

- PRESSURE INSIDE TUBE BUNDLE : 4.2 Kg/cm^2
- 70% FILLING RATIO
- FLOW RATE :6 LPH
- T_3, T_4 = CONDENSER TEMPERATURE
- T_9,T_{10},T_{11} = EVAPORATOR TEMPERATURE
- T_1= INLET OF CONDENSER TEMPERATURE
- T_2 = OUT LET OF CONDENSER TEMPERATURE
- T_{12} = INLET OF EVAPORATOR TEMPERATURE
- T_5,T_6,T_7,T_8 =ADIABATIC SECTION TEMPERATURE

All data in °C

For inclination angle 90 degree of condenser and evaporator with respective to ground

Table-4.1.3. Various Temperatures during CFD based simulation

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
31	32	32	42	47	44	50	63	66	66	66	72

$T_e - T_c = T_9 - T_2$

$=66°C - 32°C$

$=34°C$

- PRESSURE INSIDE TUBE BUNDLE : 3 Kg/cm^2
- 50% FILLING RATIO
- FLOW RATE :6 LPH
- T_3, T_4 = CONDENSER TEMPERATURE
- T_9,T_{10},T_{11} = EVAPORATOR TEMPERATURE
- T_1= INLET OF CONDENSER TEMPERATURE
- T_2 = OUT LET OF CONDENSER TEMPERATURE
- T_{12} = INLET OF EVAPORATOR TEMPERATURE
- T_5,T_6,T_7,T_8 =ADIABATIC SECTION TEMPERATURE

All data in °C

For inclination angle 90 degree of condenser and evaporator with respective to ground

Table-4.1.4. Difference between Evaporator Temperature and Condenser Temperature during CFD based simulation

Sr. No.	Filling Ratio in %	$T_e - T_c$ (in °C)
1	83	30
2	70	31
3	50	34

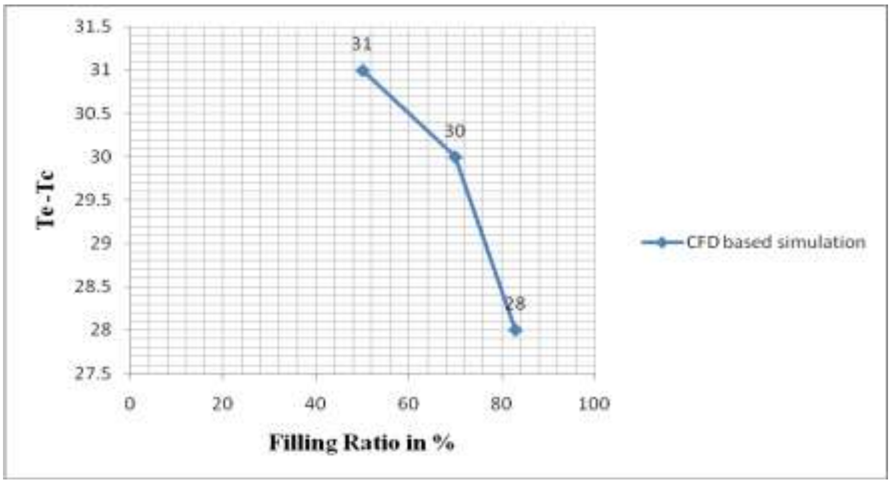

Figure.10. Difference between Evaporator Temperature and Condenser Temperature during CFD based simulation

4.2. Experimental process

Table-4.2.1. Various Temperatures during Experimental process

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
34	39	39	42	48	47	52	64	67	67	67	72

$T_e - T_c = T_9 - T_2$

$= 67°C - 39°C$

$= 28°C$

- PRESSURE INSIDE TUBE BUNDLE : 5 Kg/cm2
- 83% FILLING RATIO
- FLOW RATE :6 LPH
- T3, T4 = CONDENSER TEMPERATURE
- T9,T10,T11 = EVAPORATOR TEMPERATURE
- T1= INLET OF CONDENSER TEMPERATURE
- T2 = OUT LET OF CONDENSER TEMPERATURE
- T12 = INLET OF EVAPORATOR TEMPERATURE
- T5,T6,T7,T8 =ADIABATIC SECTION TEMPERATURE

All data in °C

For inclination angle 90 degree of condenser and evaporator with respective to ground

Table-4.2.2. Various Temperatures during Experimental process

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
33	35	35	41	47	45	50	62	65	65	65	72

$T_e - T_c = T_9 - T_2$

$= 65°C - 35°C$

$= 30°C$

- PRESSURE INSIDE TUBE BUNDLE : 4.2 Kg/cm^2
- 70% FILLING RATIO
- FLOW RATE :6 LPH
- T_3, T_4 = CONDENSER TEMPERATURE
- T_9,T_{10},T_{11} = EVAPORATOR TEMPERATURE
- T_1= INLET OF CONDENSER TEMPERATURE
- T_2 = OUT LET OF CONDENSER TEMPERATURE

- T_{12} = INLET OF EVAPORATOR TEMPERATURE
- T_5,T_6,T_7,T_8 =ADIABATIC SECTION TEMPERATURE

  All data in °C

For inclination angle 90 degree of condenser and evaporator with respective to ground

Table-4.2.3. Various Temperatures During Experimental process

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
31	33	33	40	46	43	48	61	64	64	64	72

$$T_e - T_c = T_9 - T_2 = 64°C - 33°C = 31°C$$

- PRESSURE INSIDE TUBE BUNDLE : 3 Kg/cm^2
- 50% FILLING RATIO
- FLOW RATE :6 LPH
- T_3, T_4 = CONDENSER TEMPERATURE
- T_9,T_{10},T_{11} = EVAPORATOR TEMPERATURE
- T_1= INLET OF CONDENSER TEMPERATURE
- T_2 = OUT LET OF CONDENSER TEMPERATURE
- T_{12} = INLET OF EVAPORATOR TEMPERATURE
- T_5,T_6,T_7,T_8 =ADIABATIC SECTION TEMPERATURE

All data in °C

For inclination angle 90 degree of condenser and evaporator with respective to ground

Table-4.2.4. Difference between Evaporator Temperature and Condenser Temperature During Experimental process

Sr. No.	Filling Ratio in %	$T_e - T_c$ (in °C)
1	83	28
2	70	30
3	50	31

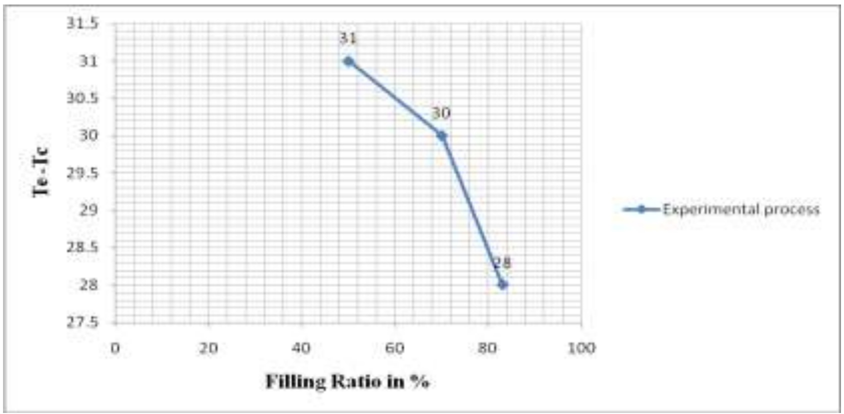

Figure.11. Difference between Evaporator Temperature and Condenser Temperature

4.3. Difference between CFD based simulation and Experimental process

Table-4.3.1. Difference between CFD based simulation and Experimental process

Sr. No.	Filling Ratio in %	$T_e - T_c$ (in °C), CFD based simulation	$T_e - T_c$ (in °C) , Experimental process
1	83	30	28
2	70	31	30
3	50	34	31

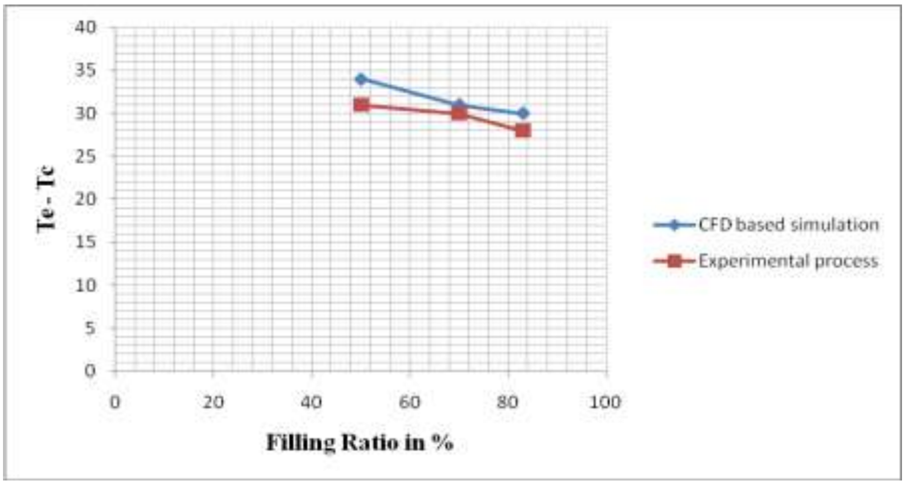

Figure-12. Difference between CFD based simulation and Experimental process

CONCLUSION

The closed loop pulsating heat pipe are studied using of various parameters . We are finding out the various temperatures using of refrigerant (R-134a). An experimental study and numerical study was performed on closed loop pulsating heat pipes (CLPHPs) to investigate the effects of inner diameter, filling ratio, operational orientation and heat load on thermal performance and occurrence of performance limitation in the form of evaporator dry out. Major findings are:

1) we are find out the maximum temperature Difference between Evaporator Temperature and Condenser Temperature during CFD based simulation are 34°C when Filling Ratio are 50 %. Also we are find out the maximum temperature Difference between Evaporator Temperature and Condenser Temperature During Experimental process are 31°C when Filling Ratio are 50 %. After this we find out the some error during fabrication of experimental setup.

2) Gravity certainly affects the heat output and performance of closed loop heat pipe.

3) In horizontal mode of operation and 50% filling ratio is found the minimum thermal resistance than any other orientation.

4) At 50% filling ratio of PHP is exhibit better heat transfer characteristics in all orientations .

5) In general, the CLPHPs obtain the best thermal performance and maximum performance limitation when they operate with 50% filling ratio.

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