Thermal Characteristics Analysis on Multi-Heat Pipe Induced Heat Exchanger

P. Ram Kumar, M.Sivasubramanian, P.RajeshKanna, P.Raveendiran

Abstract: ***In this investigation of multi heat pipe induced in heat exchanger shows the developments in heat transfer is to improve the efficiency of heat exchangers. Water is used as a heat transfer fluid and acetone is used as a working fluid. Rotameter is set to measure the flow rate of cold water and hot water. To maintain the parameter as experimental setup. Then set the mass flow rate of hot water as 40 LPH, 60LPH, 80 LPH, 100LPH, 120 LPH and mass flow rate of cold water as 20 LPH, 30 LPH, 40 LPH, 50 LPH, and 60 LPH. Then 40 ℃, 45 ºC, 50 ºC, 55 ℃, 60 ºC are the temperatures of hot water at inlet are maintained. To find some various physical parameters of Q_c, h_c, R_e, ε, P_r, R_{th}. The maximum effectiveness of the investigation obtained from condition of Thi 60 ℃, Tci 32 ℃ and 100 LPH mhi, 60 LPH mci the maximum effectiveness attained as 57.25%. Then the m_{hi} as 100 LPH, m_{ci} as 60 LPH and T_{hi} at 40 ℃ as 37.6%. It shows the effectiveness get increased about 34.3% to the maximum conditions.***

Keywords* : *Multi Heat pipe, Heat exchanger, Mass flow rates, Temperature of hot water, Heat transfer rate, Effectiveness.

I. INTRODUCTION

Now a days heat channels are in a few applications, where one has constrained space and the need of high warmth motion. Han Xiaoxing et al.[1] A novel concentric tube heat pipe exchanger to be utlized in waste heat recovery equipment with higher heat transfer efficiency at low temperature heat source with acetone as working fluid. Wermer et al. [2] Investigate scientific model manufacturing and a counter heat pipe with one of a kind heater and supply route frame work. The outcome demonstrate that heat pipe structure in equipped for taking action in a counter gravity start up is conceivable. Saud Ghani et al. [3] Investigate the execution of two fold pipe heat exchanger for air condition application with R-22 as refrigerant and came about the control utilization by blower is less with higher framework cooperative of execution. Shuangfeng Wang et al. [4] a test examination is directed to investigate the warmth transport ability of throbbing funnels (PHP) working with practical hot liquid by contracting them and un-adulterated water. The outcome demonstrate the heat transport ability of PHP can be improved by utilizing FS-39E liquid under explicit conditions. Geun Jae et al. [5] the present study investigated that warmth temperature. Xiahou Guowei et al. [6] a vertical radiator with multi heart beat build up closes and a plane vanishing end for vertical CPU cooling is created. Anandh Takawale et al. [7] This paper reports the result of an experimental study to investigate the performance comparison between two pulsating heat pipes namely, a flat plate pulsating heat pipe (FPPHP) and a capillary tube pulsating heat pipe (CTPHP). Tong Miin et al. [8] in this thermal performance of a radically rotating pulsating heat pipe (RPHP) formulate by the interconnected 1*6 mm channel in the slim cushion were investigated.

V.Kiseev et al. [10] This study focuses on two phase stage warm control frame work namely loop thermosyphons (LTS) filled with nanofluids and their use as LED cooling device . Abhinav malhotra et al. [11] Semi-conductor nano tubes present an exciting avenue to create very thin one dimensional nano structure using available technique. Due to the large surface to volume ratio, nanotubes allows for an effective control over thermal energy transfer. Ye Bai et al. [12] determine the heat transfer performance and mechanism of separate heat pipe under various condition. S.A. Lurie et al. [13] in the present investigation of topology improvement approach is proposed to decide optical geometry of wick wintered inside a level warmth pipe. M.A.Chernysheva et al. [15] the paper present a model of heat and mass transfer in a cylindrical evaporator of a loop heat pipe(LPH) with allowance for the peculiarities of heat exchange in the evaporation zone formed by vapor removal grooves. E.N.Pis mennyi et al. [16] the paper manages the consequence of test investigations of warmth exchange perception of transport process in dissipated zone of Al heat pipe.

In that certain parameters are considered for the investigations such as heat carrying fluid, working fluid, geometrical parameter of heat exchanger and heat pipes. In this experimental work the experimental setup is fabricated by inserting the multi heat pipe induced heat exchanger, acetone is used as working fluid for this experiment, heat carrying fluid is water. The hot water mass flow rate is 40 LPH, 60LPH, 80 LPH, 100LPH, 120 LPH and mass flow rate of cold water is 20 LPH, 30 LPH, 40 LPH, 50 LPH, 60 LPH . Then maintain 40 °C, 45 ºC, 50 ºC, 55 °C, 60 ºC for the temperatures of hot water at inlet. The experiment is carried out and heat transfer is examined with the heat transfer coefficient, heat transfer rate and effectiveness of the system. In this experimentation multi heat pipes are used to get maximum efficiency.

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II. EXPERIMENTAL SET UP AND PROCEDURE

A. Experimental set up

Multi heat pipe induced in heat exchanger is fabricated using the material which is given in Table 1. The experimental setup is fabricated by the following parameters which given in Table 2. Water is used as a heat transfer fluids and acetone (C_3H_6O) is used as a working fluid for the experiment. Cold water is set as a condenser section and hot water set as an evaporator section. The heat pipe is filled with the acetone for the experiment.

Table 1. Material used in the experimental setup

Properties	Materials
Heat pipe material	Cu
Shell material	GI
Condenser material	GI
Working fluid	Acetone
Wick material	SS

Table 2. Geometrical parameters of experimental setup

Properties	Dimensions
Total multi heat pipe length	1000 mm
Length of multi heat pipe evaporator	700 mm
Length of multi heat pipe condenser	200 mm
Length of adiabatic heat pipe	100 mm
Heat pipe inner Diameter	18 mm
Heat pipe outer Diameter	20 mm
Shell Diameter	35 mm
Number of heat pipes	03

Table 3. Thermo-physical properties of Acetone

Properties	Acetone
Boiling point	56.08°C
Melting point	-94.9 °C
Latent heat of evaporation (λ)	534 kJ/kg
Density of liquid (ρ_l)	784.5kg/m³

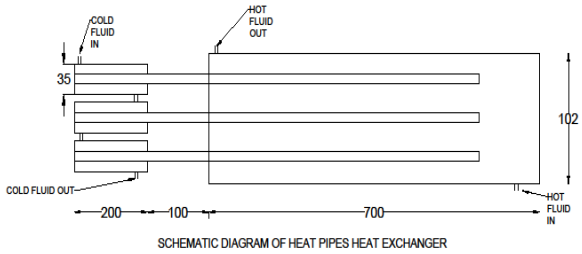

Fig 1. Schematic diagram of a Multi Heat-pipe Heat exchanger

B. Procedure

As shown in Table 1 the given parameters are set for experimental work. Water is a heat transfer fluid and acetone is used as a working fluid. Then some material are used for experimental setup like GI pipe, and Cu. The cold water is set as a condenser section and hot water set as an evaporator section. To maintain some parameter for experimental setup. Then set the mass flow rate flow of hot water as 40 LPH, 60LPH, 80 LPH, 100LPH, 120 LPH and mass flow rate of cold water as 20 LPH, 30 LPH, 40 LPH, 50 LPH, 60 LPH. The 40 °C, 45 ºC, 50 ºC, 55 °C, 60 ºC are the temperatures of hot water at inlet are maintained.

III. RESULTS AND DISCUSSION

In these parameters are considered for the investigation such as mass flow rates of cold and hot water, cold water temperature and hot water temperature are considered for study.

Heat transfer rate of cold water (Q_c)

$$Q_c = \dot{m}_c C_{ph}(T_{co} - T_{ci})$$

Heat transfer rate to hot water (Q_h)

$$Q_h = \dot{m}_h C_{ph}(T_{hi} - T_{ho})$$

Area of condenser section (A)

$$A = \Pi DL$$

Effectiveness for cold Fluid ($\in$)

$$\in = \frac{T_{c\,out} - T_{c\,in}}{T_{h\,in} - T_{c\,in}}$$

Heat transfer coefficient (h)

$$h = \frac{Q}{A * (\Delta T)_{lm}}$$

Log mean temperature difference ($(\Delta T)_{lm}$)

$$(\Delta T)_{lm} = \frac{(T_{hi} - T_{ci}) - (T_{ho} - T_{co})}{\ln \frac{(T_{hi} - T_{ci})}{(T_{ho} - T_{co})}}$$

Reynolds number (Re)

$$\mathrm{Re} = \frac{4\dot{m}_c}{\pi D_c \mu}$$

Nusselt number (Nu)

$$Nu = 1.67\left\{\frac{Re*Pr}{x/D}\right\}^{0.333}$$

Friction factor (f)

$$f = \frac{64}{Re} \quad (Re<2300)$$

Thermal Resistance (R_{th})

$$R_{th} = \frac{T_w - T_b}{Q_c}$$

$$T_b = \frac{T_{co} + T_{ci}}{2}, \quad T_w = \frac{\Sigma T_s}{3}$$

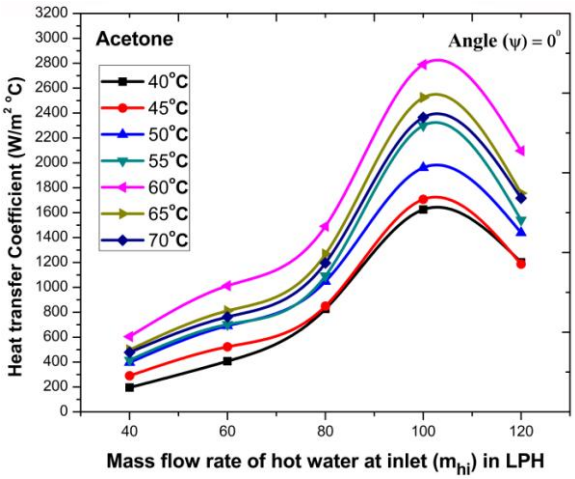

Fig 2. Mass flow rate of hot water at inlet vs Heat transfer coefficient

The graph is made with h_c vs m_{hi} is shown in figure 2. The h_c is attained at maximum T_{hi} and m_{hi}. T_{hi} at 60 °C, T_{ci} of 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} the h_c attained as 2790.02 W/m^2 °C, at same above condition for 120 LPH it reduced to 2097.23 W/m^2 °C. At 40 °C T_{hi}, 32 °C T_{ci} and 100 LPH of m_{hi}, 60 LPH m_{ci} the minimum h attained as 1625.01 W/m^2 °C, at same above condition for 120 LPH it reduced to 1202.42 W/m^2 °C From the above calculations it is observed that the h_c attained is maximum when T_{hi} and m_{hi} are maximum.

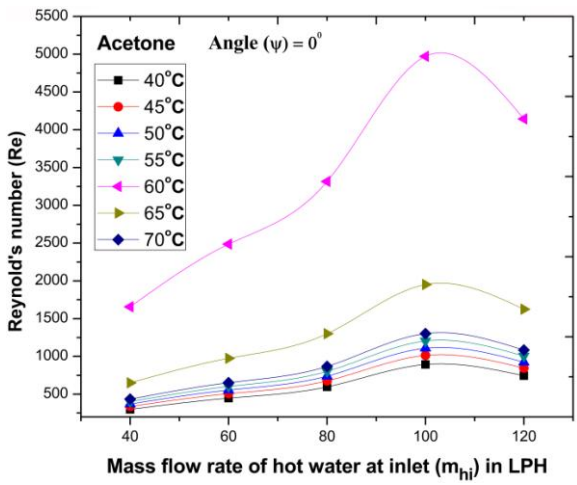

Fig 3. Mass flow rate of hot water at inlet vs Reynolds number

The graph in Figure 3. Shows the R_e vs m_{hi}. The variation in Reynolds number is observed in graph. T_{hi} at 60 °C, T_{ci} of 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} the R_e attained as 4972. At 40 °C T_{hi}, 32 °C T_{ci} and 100 LPH of m_{hi}, 60 LPH m_{ci} the minimum R_e attained as 893.39. In the both conditions at 120 LPH Re gets reduced. From the above basis the R_e get increased when T_{hi} and m_{hi} increased.

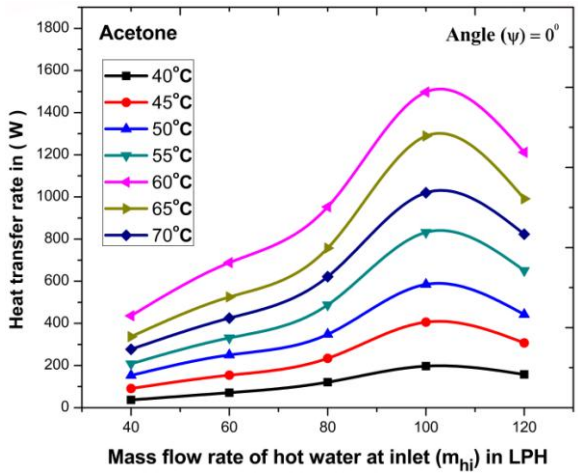

Fig 4. Mass flow rate of hot water at inlet vs Heat transfer rate

The plots graph is made with Q_c vs m_{hi} is shown in figure 4. The enhancement in Q_c is attained at maximum of T_{hi} and m_{hi}. The T_{hi} at 60 °C, T_{ci} of 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} the maximum Q_c attained as 1498.32 W. At T_{hi} 40 °C, T_{ci} 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} the minimum Q_c attained as 197.24 W. In 120 LPH it gets reduced. The maximum Q_c attained is due to maximum T_{hi} and maximum m_{hi}. From this it observed that as T_{hi} and m_{hi} increases, Q_c is increased for the given condition.

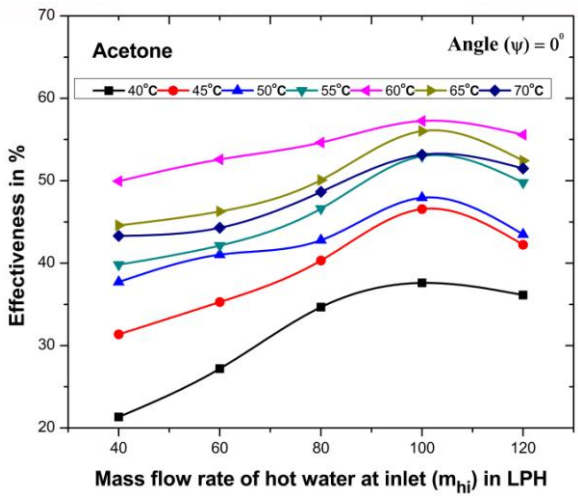

Fig 5. Mass flow rate of hot water at inlet vs Effectiveness

The graph in figure 5 shows the ∈ vs m_{hi}. The improvement in ∈ is attained at maximum T_{hi}. At T_{hi} 60 °C, T_{ci} 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} the maximum ∈ attained as 57.25% at 120 LPH it was 55.57%. The value of ∈ attained at 40 °C T_{hi}, 32 °C T_{ci} and 100 LPH m_{hi}, 60 LPH m_{ci} as 37.6 % at 120LPH it was 36.13%. In the both the conditions 120LPH it reduced. The Effectiveness get increased when the T_{hi} and m_{hi} get increased.

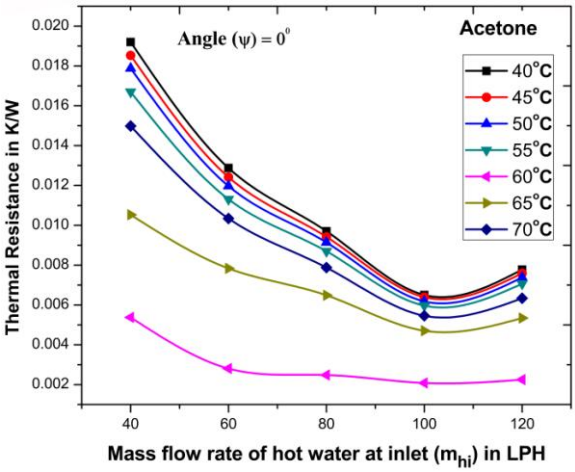

Fig 6. Mass flow rate of hot water at inlet vs Thermal resistance

The graph in Figure 6. Shows that R_{th} vs m_{hi} The Variation in Thermal resistance is attained at T_{hi} as 60 °C, T_{ci} 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} the minimum R_{th} attained as 0.00208. The value of R_{th} attained at 40°C T_{hi}, 32 °C T_{ci} and 100 LPH m_{hi}, 60 LPH m_{ci} as 0.00652. At 120 LPH the R_{th} gets increased. This shows that there is decreases in R_{th} is observed while increasing the mass flow rate and temperature at inlet condition.

IV. CONCLUSION

In this work heat pipe heat exchanger is fabricated and analysed with various mass flow rate (m_{hi}) and temperature inlet for both cold and hot water. The observation reveals that when mass flow rate for hot water increases the performance of the system also increases. When the (m_{hi}) increases to m_{hi} as 100 LPH, m_{ci} as 60 LPH, T_{hi} at 60 °C and T_{ci} as 32 °C the maximum heat transfer performace is achieved this is the optimum observed condition.

- Maximum heat transfer rate is attained from the condition the T_{hi} at 60 °C, T_{ci} of 32 °C and 100 LPH $m_{hi,}$ 60 LPH m_{ci} the maximum Q_c attained as 1498 W, which is 86.83% higher than the heat transfer rate obtained for m_{hi} as 100 LPH, m_{ci} as 60 LPH and T_{hi} at 40 °C as 197.24 W. This shows that at optimum condition as 120 LPH and 60 °C the maximum heat transfer rate is achieved.
- Highest effectiveness of the investigation obtained at condition T_{hi} 60 °C, T_{ci} 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} the maximum $\in$ attained as 57.25%. Which is 34.32% greater than the effectiveness obtained for m_{hi} as 100 LPH, m_{ci} as 60 LPH and T_{hi} at 40 °C as 37.6%. Effectiveness of the investigation is obtained maximum at optimum stated condition.
- Maximum heat transfer coefficient is obtained from the condition T_{hi} 60 °C, T_{ci} 32 °C and 100 LPH m_{hi}, 60 LPH m_{ci} is observed as 2790.02 W/m^2 °C that is 41.75% higher than the heat transfer coefficient achieved for m_{hi} as 100 LPH, m_{ci} as 60 LPH and T_{hi} at 40 °C as 1625.01 W/m^2 °C.
- Thermal resistance of the system tends to decreases, this increases the performance of the heat pipe heat exchanger, for the same stated condition it was 68.09% decrease trends are observed.
- Reynolds number tends to increase while increasing the mass flow rate of hot fluid and temperature at inlet condition, flow behaves laminar throughout the investigation there was 82.03% increase in values are observed for same above revealed condition.

APPENDIX

Nomenclature

C - Heat capacity ratio
Cu - Copper
GI - Galvanized iron
SS - Stainless steel
T - Temperature, (◦C)
C_p - Specific heat capacity of water, J/ (kg ◦C)
Nu - Nusselt number
Pr - Prandtl number
Q - Heat transfer rate, (W)
R_e - Reynolds number, (-)
R_{th} - Thermal resistance, (-)
h - Heat transfer coefficient, W/ (m^2 ◦C)
f - Friction factor, (-)
m - Mass flow rate, (LPH)
m_{ci} - Mass flow rate of cold fluid at inlet, (LPH)
m_{hi} - Mass flow rate of hot fluid at inlet, (LPH)
T_{ci} - Temperature of cold fluid, (◦C)
T_{hi} - Temperature of hot fluid, (◦C)
T_w - Average wall temperature, (◦C)
T_b - bulk mean cold fluid temperature, (◦C)
T_s - Surface temperature of condenser section, (◦C)

Suffix

i - inlet
o - outlet
c - cold
h - hot

Greek letter

$(\Delta T)_{lm}$ - Log mean temperature difference, (◦C)
$\in$ - Effectiveness, (%)

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