

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

Experimental Investigation of Heat Pipe Induced in Heat Exchanger

P. Ram Kumar^{1*}, P. Karuppasamy², M. Krishnan³, G. Gowthaman⁴, M.Sivasubramanian⁵, P.Raveendiran⁶

Assistant Professor, Department of Mechanical Engineering, Kalasalingam Academy of Research and Education,
Krishnankoil, Virudhunagar, Tamil Nadu, India^{1*}

U.G. Students, Department of Mechanical Engineering, Kalasalingam Academy of Research and Education,
Krishnankoil, Virudhunagar, Tamil Nadu, India^{2,3,4}

Associate Professor, Department of Automobile Engineering, Kalasalingam Academy of Research and Education,
Krishnankoil, Virudhunagar, Tamil Nadu, India⁵

Assistant Professor, Department of Mechanical Engineering, Annamalai University, Annamalai Nagar,
Tamil Nadu, India⁶

ABSTRACT: Investigation on thermal performances of the heat exchanger under the influence of heat pipe has been experimentally investigated. To augment the thermal performance of heat pipe, experimental investigations are carried out by considering the heat pipe in horizontal axis. Acetone is used as working fluid in the heat pipe and Water is used as heat carrying fluid. The temperature of hot water and cold water at inlet and mass flow rates for the both the conditions are considered in the investigation. Hot water mass flow rate ranges from 60 lph to 100 lph at the increase of 20 lph, cold water mass flow rate ranges from 30 lph to 50 lph at the increase 10 lph and temperature of hot water at inlet varying from 50°C, 55 °C to 60°C are considered for the investigation. In this work heat transfer coefficient, heat transfer rate and effectiveness of the above said conditions are investigated and reported. The investigation result states that maximum effectiveness is obtained with the hot water mass flow rate of 100 lph and temperature of hot water inlet at 60°C. In which the effectiveness obtained is 25% higher when compare to the same investigation at 100 lph and 50°C.

KEYWORDS: Heat pipe, Heat exchanger, Mass flow rate, Temperature of hot water, Heat transfer coefficient, Heat transfer rate, Effectiveness.

I. INTRODUCTION

In many industries applications of heat pipe plays a vital role from past decades. This heat pipe takes a new development in various fields to enhance the heat transfer with minimum heat input and temperature range. Heat pipes are being used with many working fluids. Heat pipes work effectively and dissipate a large amount of heat while it is filled with 100% of evaporator with acetone as a working fluid was concluded by EzhilVannan S et al. [1]. Leonard L. Vasiliev [2] discussed about the major role of types of heat pipe uses for different applications in modern heat exchangers. Heat pipes with ammonia as working fluid has higher efficiency than methanol for space and satellite applications was resulted by Vivek K. Patel [3]. H.G. Işık et al [4] developed a heat pipe with ammonia for space applications at flight specifications. Yuandong Guo et al. [5] developed a cryogenic loop heat pipe that works with methane inside would give best performance at different heat load supplied to secondary evaporator, attain a several heat transfer capacity at different temperature of heat sink. Pramod R. et al. [6] concluded that pure acetone has a good thermal performance when compared with methanol, ethanol and water. From 20 to 60 W of heat input the thermal resistance decreases quickly and slowly above 60 W. Mojtaba Mamourian et al. [7] showed that as the Reynold's number increases and Darcy number decreases with increase in heat exchanger effectiveness. He also stated that the

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

sensitivity of the mean Nusselt number to the Re and Da numbers and the porous substrate thickness is positive, also of the heat exchanger effectiveness sensitivity to the Re number is positive but to the Da number is negative. Saud Ghani et al. [8] have investigated the performance of double-pipe heat exchanger for air conditioning applications with R-22 as refrigerant and resulted that the power consumption by compressor is less with higher system coefficient of performance. This is also possible by reducing the evaporator flow rate which gives 53% lesser compressor work than the normal systems. N.T. Ravi Kumar et al. [9] analysed the heat transfer, friction factor and effectiveness of a double pipe heat exchanger with Fe_3O_4 /water nanofluid and concluded the results by the method of number of transfer units (NTU). Joao Ramos et al. [10] developed a CFD model for a heat pipe heat exchanger to recover waste heat and results were shown as that the modelling predictions were upto 10% of the experimental results. Hussam Jouhara et al. [11] designed and investigated a flat heat pipe to recover the waste heat from steel industries and results shows a better efficiency. Andrei Buelacu et al. [12] presented a heat transfer analysis which was used to recover waste heat from buildings and use the transferred heat for domestic applications like hot water and heating the room ventilation system with high efficiency and at less cost of manufacturing. Himel Barua et al. [13] investigated the filling ration for water and ethanol and stated that above 50% of filling ratio both the working fluids gives better performance but upto 80 % of filing ratio the performance will be much higher and above that temperature changes does not occur. Hussam Jouhara and Richard Meskimmon [14] proved that wraparound loop heat pipe heat exchanger working with water is efficient than heating, ventilation and air conditioning systems has a raise of about 18% effectiveness which was useful for energy applications. Ojha Pramod Kailash et al. [15] designed a pipe in pipe heat exchanger with higher efficiency for various parameters and varied with the simple inner tube and fin tube heat exchanger. Ravi Kumar Banjare et al. [16] discussed briefly about the materials that are used for heat exchanger also explained the performance of ceramics as material in heat exchanger material. Hossein Kavusi and Davood Toghraie [17] studied the performance of various nanofluids in heat pipe and resuted that the flow from evaporator to condenser section is done by wick material easily with a raise of thermal capacity also when fluid pressure drop is attain a certain level difference of temperature between the evaporator and the condenser increases. Vishal H Acharya [18] reviewed the performance of heat pipe with various parameters with effective flow rate and velocity. Durga Bastakoti et al. [19] Investigated performance of alcohols in heat pipes and resulted that surface tension and viscosity are main factor of performance of the heat pipe in addition with a statement of filling ratio is the first most important factor for the performance. R. Senthil et al. [20] investigated thermal efficiency of heat pipe with Al_2O_3 working fluid and showed that there was a better result which could be used practically.

The literatures, it is noticeable that certain parameters are considered for the investigations such as working fluid, heat carrying fluid, geometrical parameters of heat pipe and heat exchanger. In this experimental work the experimental setup is fabricated by inserting the heat pipe in heat exchanger, acetone is used as working fluid for this work, and water as heat carrying fluid. The mass flow rate of hot water as 60 lph, 80 lph and 100 lph and mass flow rate of cold water as 30 lph, 40 lph and 50 lph. 50 °C, 55 °C and 60 °C are the temperatures of hot water at inlet. With the above said constrains the experiment is carried out and heat transfer behaviour is examined with the heat transfer rate, heat transfer coefficient and effectiveness of the system.

II. EXPERIMENTAL SETUP & PROCEDURE

Experimental setup

Heat pipe heat exchanger is fabricated with materials used in the experimental setup are given in Table 1. The parameters of the fabricated experimental setup with heat pipe induced in heat exchanger are given in Table 2. Hot water section is selected as evaporator section, cold water section is selected as condenser section and in adiabatic section no heat transfer takes place with environment. Acetone is used as working fluid for this investigation and water as heat carrying fluid. Properties of acetone [21] are given in Table 3. To measure the mass flow rates of hot and cold water rotameters are used in this study. In this study to measure the temperatures thermocouples are used. Prior to begin the test, ensuring that the unwanted particles in heat pipe are removed and acetone is filled in the heat pipe. To minimize the heat loss in the system experimental setup is well insulated.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

Table 1: Materials used in the experimental setup

Heat pipe material	Copper
Shell material	U-PVC
Condenser material	U-PVC
Working fluid	Acetone
Wick material	Stainless steel

Table 2: Geometrical parameter of experimental setup

Total heat pipe length	1000 mm
Heat pipe evaporator length	700 mm
Heat pipe condenser length	200 mm
Heat pipe adiabatic length	100 mm
Heat pipe inner diameter	18 mm
Heat pipe outer diameter	20 mm
Shell diameter	35 mm

Table 3: Working fluid properties

Working fluid	Acetone
Boiling point	56.05 °C (132.89 °F; 329.20 K)
Melting point	-94.7 °C (-138.5 °F; 178.5 K)
Density	784 kg/m ³
Thermal conductivity	125.45 J/(mol-K)
Working range	0 to 120 °C

Procedure

As shown in Figure 1 the experimental setup is fabricated with heat pipe induced in heat exchanger. Mass flow rate of 60 lph and inlet temperature of 50 °C are the primary conditions of the hot water and for cold water mass flow rate is 30 lph and inlet temperature is ambient temperature ie. 32.5 °C throughout the investigation. The study is accomplished with hot water mass flow rates of 80 and 100 lph, cold water mass flow rates of 40 and 50 lph and temperatures of hot water is 55 °C and 60 °C.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

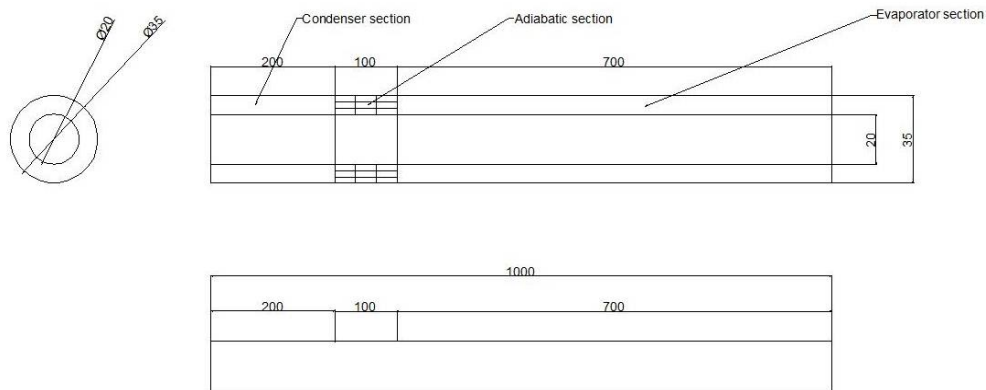


Figure.1 Schematic diagram of the Experimental setup of Heat pipe heat exchanger.

III.RESULTS AND DISCUSSION

Parameters that are considered for the investigation such as mass flow rates of hot and cold water, temperatures of hot and cold water are considered for the study.

Heat transfer coefficient is calculated are shown as,

$$h = \frac{Q}{A * (\Delta T)_{lm}} \quad (1)$$

Heat transfer rate is measured for different conditions of hot and cold water is shown as,

Heat Rejected by hot water

$$Q_h = \dot{m}_h C_{ph}(T_{hi} - T_{ho}) \quad (2)$$

Heat Gained by cold water

$$Q_c = \dot{m}_c C_{ph}(T_{co} - T_{ci}) \quad (3)$$

Area of condenser section

$$A = \pi DL \quad (4)$$

Log mean temperature difference

$$(\Delta T)_{lm} = \frac{(T_{hi} - T_{ci}) - (T_{ho} - T_{co})}{\ln \frac{(T_{hi} - T_{ci})}{(T_{ho} - T_{co})}} \quad (5)$$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

Effectiveness for cold Fluid is calculated as,

$$\epsilon = \frac{T_{c\ out} - T_{c\ in}}{T_{h\ in} - T_{c\ in}} \quad (6)$$

The plots of graph is made with Q_c vs T_{hi} is shown in figure 2. The enhancement in Q_c is attained at maximum of T_{hi} and m_{hi} . The T_{hi} at 60 °C, T_{ci} of 32.5 °C and 100 lph m_{hi} , 50 lph m_{ci} the maximum Q_c attained as 558.1 W. At T_{hi} 50 °C, T_{ci} 32.5 °C and 100 lph m_{hi} , 50 lph m_{ci} the minimum Q_c attained as 284.9 W. The maximum Q_c attained is due to the maximum T_{hi} and maximum m_{hi} . From this it is observed that as T_{hi} and m_{hi} increases, Q_c is increased for the given condition.

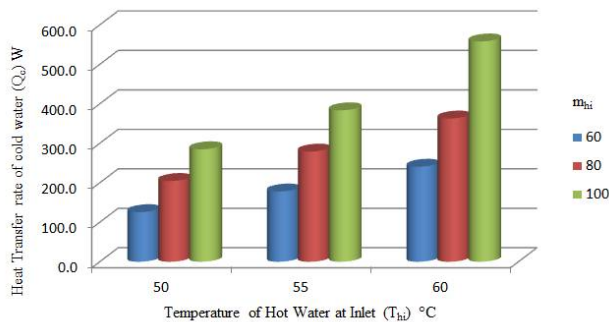


Figure 2 Temperature of hot water at inlet vs Heat transfer rate of cold water (Q_c).

The interpretation of graph is made with h vs T_{hi} is shown in figure 3. The enhancement in h is attained at maximum T_{hi} and m_{hi} . T_{hi} at 60 °C, T_{ci} of 32.5 °C and 100 lph m_{hi} , 50 lph m_{ci} the h attained as 991 W/(m²K). At 50 °C T_{hi} , 32.5 °C T_{ci} and 100 lph m_{hi} , 50 lph m_{ci} the minimum h attained as 815.6 W/(m²K). From the above calculations it is observed that the h attained is maximum when T_{hi} and m_{hi} are maximum and also with increase in $(\Delta T)_{lm}$ the h reduces along with increase in Q_c the value of h raises.

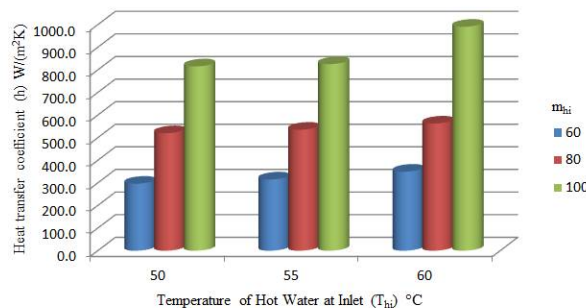


Figure 3 Temperature of hot water at inlet (T_{hi}) vs Heat transfer coefficient (h).

The graph in in figure 4 shows the ϵ vs T_{hi} . The improvement in ϵ is attained at maximum T_{hi} . At T_{hi} 60 °C, T_{ci} 32.5 °C and 100 lph m_{hi} , 50 lph m_{ci} the maximum ϵ attained as 34.9%. The value of ϵ attained at 50 °C T_{hi} , 32.5 °C T_{ci} and 100 lph m_{hi} , 50 lph m_{ci} as 28 % it is lesser than the above effectiveness.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

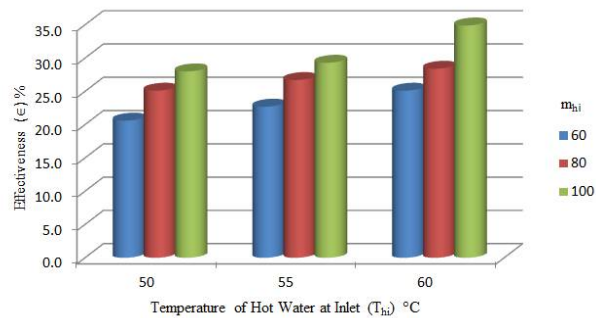


Figure 4 Temperature of hot water at inlet (T_{hi}) vs Effectiveness (ε).

The interpretation of graph is made with ε vs m_{hi} is shown in figure 5. The enhancement in ε is attained at maximum m_{hi}. With 100 lph of m_{hi}, 50 lph of m_{ci}, T_{hi} as 60 °C, T_{ci} of 32.5 °C the maximum ε attained is 34.9%. This shows that effectiveness of the heat pipe is improved with increase in mass flow rate of hot water at inlet condition.

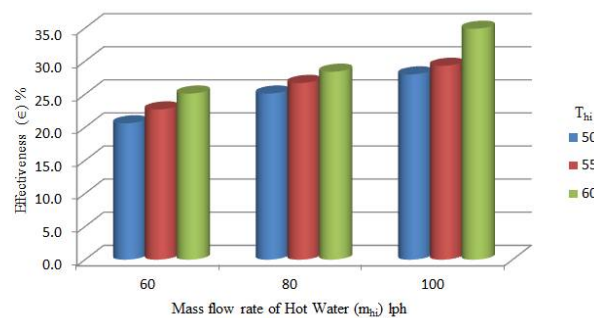


Figure 5 Mass flow rate of hot water at inlet (m_{hi}) vs Effectiveness (ε).

IV. CONCLUSION

In this work heat pipe heat exchanger is fabricated and analysed with various mass flow rate and inlet temperature of both hot and cold water. The observation reveals that optimum mass flow rate for hot and cold water is determined as 100 lph and 50 lph. The temperature of the system is observed as 60 °C at hot water inlet condition.

- Maximum heat transfer coefficient is obtained from the optimum condition is observed as 991 W/(m²K) that is 21.5% higher than the heat transfer coefficient attained for m_{hi} as 100 lph, m_{ci} as 50 lph and T_{hi} at 50 °C as 815.6 W/(m²K).
- Maximum heat transfer rate is attained from the optimum condition as 558.1 W which is 95.89% higher than the heat transfer rate obtained for m_{hi} as 100 lph, m_{ci} as 50 lph and T_{hi} at 50 °C as 284.9 W.
- Highest effectiveness of the investigation obtained at optimum condition as 34.9% which is 25% greater than the effectiveness obtained for m_{hi} as 100 lph, m_{ci} as 50 lph and T_{hi} at 50 °C as 28%.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 11, November 2018

REFERENCES

- [1]S. Ezhilvannan, P. M. Shravan, and S. K. A, "Experimental Investigation of Conventional Heat Pipe using Different Working Fluids," International Journal of Engineering Trends and Technology, vol.38, issue.7, pp.352-354, 2016.
- [2]L. L. Vasiliev, "Heat Pipe in Modern Heat Exchangers Heat pipes in modern heat exchangers," Applied Thermal Engineering, vol.25, pp.1-19, 2005.
- [3]V. K. Patel, "An efficient optimization and comparative analysis of ammonia and methanol heat pipe for satellite application," Energy Conversion and Management, 2018, vol.165, pp.382-395, 2018.
- [4]H. G. I, C. Ömür, A. B. Uygur, and İ. Horuz, "A novel burst test approach for the qualification of heat pipes developed for space applications," International Journal of Pressure Vessels and Piping, vol.165, pp.241-248, 2018.
- [5]Y. Guo, G. Lin, H. Zhang, and J. Miao, "Investigation on thermal behaviours of a methane charged cryogenic loop heat pipe," Energy, vol.157, pp.516-525, 2018.
- [6]P. R. Pachghare and A. M. Mahalle, "Effect of pure and binary fluids on closed loop pulsating heat pipe thermal performance," Procedia Engineering, vol.51, pp.624 – 629, 2013.
- [7]K. M. Shirvan, S. Mirzakhani, S. A. Kalogirou, H. F. Oztop, and M. Mamourian, "Heat transfer and sensitivity analysis in a double pipe heat exchanger filled with porous medium," International Journal of Thermal Sciences, vol.121, pp.124-137, 2017.
- [8]S. Ghani, S. Mahmoud, A. Gamaledin, M. Mohammed, and M. Ali, "Experimental investigation of double-pipe heat exchangers in air conditioning applications," Energy and Buildings, vol.158, pp.801-811, 2018.
- [9]N. T. R. Kumar, P. Bhramara, B. Mulat, L. S. Sundar, M. K. Singh, and A. C. M. Sousa, "Heat transfer , friction factor and effectiveness analysis of Fe₃O₄ / water nano fluid flow in a double pipe heat exchanger with return bend," International Communications in Heat and Mass Transfer, vol.81, pp.155-163, 2017.
- [10]J. Ramos, A. Chong, and H. Jouhara, "Experimental and numerical investigation of a cross flow air-to-water heat pipe-based heat exchanger used in waste heat recovery," International Journal of Heat and Mass Transfer, vol.102, pp.1267-1281, 2016.
- [11]HussamJouhara, SulaimanAlmahmoud, AmishaChauhan, Bertrand Delpech, Giuseppe Bianchi, Savvas A. Tassou, RocioLlera, Francisco Lago and Juan Jose Arribas, "Experimental and theoretical investigation of a flat heat pipe heat exchanger for waste heat recovery in the steel industry," Energy, vol.141, pp.1928-1939, 2017.
- [12]A. Burlacu, G. Sosoi, R. Ștefan, M. Bărbuță, and A. Burlacu, "Energy efficient heat pipe heat exchanger for waste heat recovery in buildings," Procedia Manufacturing, vol.22, pp.714-721, 2018.
- [13]H. Barua, M. Ali, M. Q. Islam, and C. M. Feroz, "Effect of filling ratio on heat transfer characteristics and performance of a closed loop pulsating heat pipe," Procedia Engineering, vol.56, pp.88-95, 2013.
- [14]H. Jouhara and R. Meskimmon, "An investigation into the use of water as a working fluid in wraparound loop heat pipe heat exchanger for applications in energy efficient HVAC systems," Energy, vol.156, pp.597-605, 2018.
- [15]OjhaPranodKailash, ChoudharyBishwajeet NK, GajeraUmang B, PrajapatSumit B, KarangiyaGopal A, "Design and experimental analysis of pipe in pipe heat exchanger," International Journal Of Modern Engineering Research, vol.5, pp.42-48, 2015.
- [16]R. K. Banjare, P. K. Sen, and G. Sahu, "A Paper on the Analysis of Effect of Material Used In Heat Exchanger and Its Performance," International Journal of Research in Advent Technology, vol.3, pp.45-47, 2015.
- [17]H. Kavusi and D. Toghraie, "A comprehensive study of the performance of a heat pipe by using of various nanofluids," Advanced Powder Technology, vol.3, pp.1-11, 2017.
- [18]V. H. Acharya, "A Review on Investigation of Shell and Tube Heat Exchanger For Different Parameter," International Research Journal of Engineering and Technology, vol.4, pp.875-878, 2017.
- [19]DurgaBastakoti, Hongna Zhang, WeihuaCai and Fengchen Li, "An experimental investigation of thermal performance of pulsating heat pipe with alcohols and surfactant solutions," International Journal of Heat and Mass Transfer, vol.117, pp.1032-1040, 2018.
- [20]R. Senthil, D. Ratchagaraja, R. Silambarasan, and R. Manikandan, "Contemplation of thermal characteristics by filling ratio of Al₂O₃nanofluid in wire mesh heat pipe," Alexandria Engineering Journal, vol.55, pp.1063-1068, 2016.
- [21]<https://en.wikipedia.org/wiki/Acetone>.