Journal of Manufacturing Engineering, June 2019, Vol. 14, Issue. 2, pp 071-075

THERMAL PERFORMANCE OF INTERNALLY GROOVED HEAT PIPE WITH DIFFERENT FLOW RATE AND ORIENTATION

https://doi.org/10.37255/jme.v4i2pp071-075

Aruna V[1] Alagappan N[2] and Ashokumar I[3]

[1]Assistant professor, Smr East Coast College of Engineering and Technology, Tamilnadu, India
[2]Assistant Professor, Annamalai University, Tamilnadu, India
[3]Assistant Professor, Annamalai University, Tamilnadu, India

ABSTRACT

In this present work reports an orientation and flow rate involves the thermal performance of heat pipe. Grooved heat pipe were filled with CuO nanofluid and DI water. Thermal performance and their resistance are discussed. The heat pipe is an experimentally Analyzed with different orientation and flow rate of cooling component with same heat input.

Keywords: *orientation, internally grooved heat pipe, flow rate, CuO nanofluid, thermal performance and efficiency.*

1. Introduction

Generally heat pipe is a device which transfer the heat from one region to another and simultaneously change the phase from solid to gaseous or liquid to gaseous. The heat pipe having three parts are, an evaporator, an adiabatic and condenser sections. The working fluid is injected by evaporator with certain filling ratio which evaporate to vapour absorbing thermal energy. The vapour travels through an adiabatic section without energy loss traveled vapour reached condenser section. The cooling component flows over the condenser, it absorbs the heat from vapour. Inside the pipe vapour condenses back to liquid flows back to an evaporator section due to gravity or capillary action. The process was repeated. It is a close loop cyclic process. The wick structure is nothing but an exerts a capillary pressure on the liquid phase of the working fluid.

Of various means transfer of heat, heat pipes are used for cooling purpose in many applications like industries, space, solar panels etc. Thermal performance of heat pipe various depend upon specification, orientation and flow rate of the heat pipe. Apart from these working fluid and their filling ratio also plays an important role of heat pipe.

Heat transfer performance of a horizontal micro grooved heat pipe using CuO nanofluid as the working fluid can improve the thermal performance of the heat pipe and there is an optimal mass concentration which is estimated to be 1.0 wt% to achieve the maximum heat transfer enhancement. Under an operating pressure of 7.45 kPa, the heat transfer coefficients of the evaporator can be enhance by 46% and the CHF can be maximally enhance by 30% when substituting CuO nanofluids for water [1]. For same working fluid the inclination angle has a strong effect on the heat transfer performance of heat pipes using both water and the nanofluid. The inclination angle of 45^0 corresponded to the best thermal

Performance for heat pipes using both water and nanofluid. The investigation indicated that the thermal performance of an inclined miniature gooved heat pipe can be strengthened by using CuO nanofluid [4]. The total heat resistance and maximum heat removal capacity of the heat pipe using aqueous CuO nanofluid can maximally reduce by 50% and increase by 40% compare with that of the heat pipe using water at steady state condition. For unsteady startup process, substituting the nanofluid for water as the working fluid, not only improve the thermal performance, but also reduce significantly the startup time. Both the operations are characteristics by cylindrical miniature grooved heat pipe [2]. Heat pipe performance with wick structures act as low capillary limit work best under gravity assisted conditions, where the evaporator s located below the condenser. It is not desirable to use groove or mesh heat pipes when the orientation of the evaporator is on top of the condenser. For 6mm outer diameter, the groove heat pipe has better thermal performance than mesh and sintered power metal [3].

By analyzing thermal performance of heat pipe DI water was widely used as a base fluid. When DI water was compared to CuO nanofluid with different tilt

**Corresponding Author - E- mail: arunaveer@gmail.com*

angels 45^0 orientation CuO nanofluds gives better performance [5]. By increase the tilt angle improves the thermal performance [5,7] For same orientations TiO_2 and DI water have low thermal performance as compared to CuO nanofluid [6]. 60^0 tilt angle gives good thermal performance with titanium nanoparticles[10]. Thermosyphon type heat pipe with iron oxide nanofluid also gives better thermal resistance at increase in an inclination. But its performance reduced when concentration of nanoparticles increased in DI water[8,13,15]. When helically – micro grooved heat pipe filled with Al_2O_3 nanofluid revealed that inclination of heat pipe and filling ratio of working fluid affect the performance of heat pipe and thermal resistance decreases by increasing the filling ratio and heat transfer coefficient increases[10]. By comparing the most common nanoparticles, namely Al_2O_3, CuO and TiO_2 as the working fluid, the heat pipe thermal resistance, temperature distribution and maximum capillary heat transfer was observed. The nanoparticles within the liquid enhance the thermal performance of heat pipe by reducing the thermal resistance while enhancing the maximum heat load it can carry [11]. Silver nano fluid gives better thermal resistance at 60% filling ratio and decreases regarding increasing the power input [14].

Not only experimentally, numerically also it was proven that concentration of nano particles and their sizes affect the thermal resistance and efficiency[9,13]. By comparing aluminium, copper oxide and silver nanoparticles in numerically with different concentration and particle sizes. temperature difference between an evaporator and condenser section, increases with increase in thermal capacity and fluid flow inside the pipe is also increases [12]. Thermal resistance, thermal distribution and maximum capillary heat transfer has been affected by the concentration of the nanofliuds [13].

In this work, an experimental investigation employing CuO nanofluids is performed in order to study thermal performance and thermal resistance of grooved heat pipe. The CuO nanofluid was prepared by two step method. The results were finally compared with DI water.

2. Experimental setup

Copper material heat pipe was fabricated with the length of 600mm. It was divided into 3 sections which were an evaporator(180mm), an adiabatic(220mm) and condenser(200mm). grooved type wick structure was used in heat pipe. Inside diameter of the heat pipe is 8mm and 10mm outside dia repectively. Sheet type heater was used to heat an evaporator section.

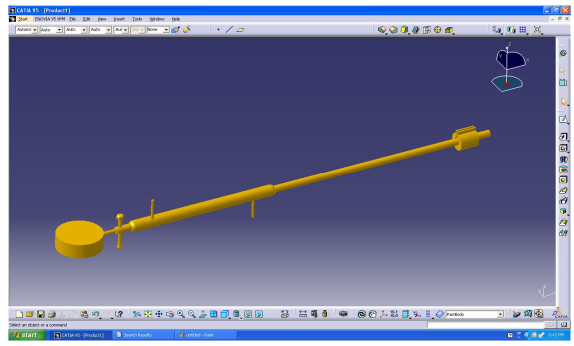

Fig. 1 View of heat pipe (CATIA V5)

CuO nanofuid (working fluid) is injected inside the evaporator section. The working fluid suck the heat from source and change the phase from liquid to vapour, travels through an adiabatic section and reaches the condenser. Cooling water flows around outside of the condenser, cools the vapour. Cooled vapour back to the liquid form and reaches an evaporator section due to capillary action and gravity. After the condensation starts the thermal resistance and temperature difference were tested. An experimental reading were taken for 22.5^0 orientation, 50W power input, 90ml/min & 110 ml/min flow rates. And then the heat pipe placed at 67.5^0 orientation, readings were taken for same power input(50w). 90ml/min and 110ml/min flow rate of cooling water were used for both an orientations and working fluids. K type thermocouples are coupled in heat pipe by getting the temperature difference at each process. 9 **-** no. of thermocouples are used.

Table 1 Dimensions and specifications of heat pipe and their set up.

Sl. no	Heat pipe	Dimensions
1.	Total length	600 mm
2.	Evaporator length	180 mm
3.	Adiabatic section length	220 mm
4.	Condenser length	200 mm
5.	Inner diameter	8 mm
6.	Outer diameter	10 mm
7.	No.of thermocouples	8 nos
8.	Heater capacity	100 W
9.	wattmeter	0 – 1000 W
10.	Auto-transformer	230 V, 5 A
11.	Rotameter (max)	330 ml/min

Thermocouples were connected with data loggers to pretend the temperature. Predicted values are plotted by the use of laptop which is connected with data logger.

3. Test procedure

The experiment, after optimising using DOE, is carried out with varying the samples/fluids. This is the beginning of the experimental process. The heat pipe is first filled with the Nano fluids and the thermocouples are connected in the Data-logger and configuration is done in it. The Wattmeter and the Auto-transformer connections are checked. First set of reading is taken based on the combination obtained on applying DOE. The same procedure is repeated for the processes involving the varying of Heat Input from 40W to 80W, varied in steps of 10W, the varying of Orientation of Heat Pipe from 0° to 90° varied in steps of 22.5° increment, the varying of Flow Rate of cooling water from 80ml/min to 120ml/min, varied in steps of 20ml/min. The corresponding temperatures i.e., T1 to T9 are noted and simultaneously the vacuum pressure reading is noted from the Pressure Gauge. The readings are taken till obtaining the steady-state. Next step is the changing of working fluid to DI water. After changing the working fluid the same procedure is followed, as followed for the Nano fluids. The readings are tabulated in the tabular column and calculations are done for finding out the Thermal resistance and Efficiency for each and every step. These values are plotted in the graphs and comparison is done between Nanofluids and DI water outputs.

4. Result and discussion

After getting the results by using data logger and pc, an outputs were plotted as graphs. Heat transfer vs thermal resistance and efficiency were analysed.

In fig 2, heat pipe with CuO nanofluids shows the variation of thermal resistance increases in heat transfer at 50w heat input. From the graph clearly shows at 67.5^0, 110 ml/min have 0.543^0c/w thermal resistance, but it gives 0.667^0c/w at 90ml/min with same orientation. It gives better idea that decreases in flow rate increases thermal resistance. At 22.5^0 orientation at 90 ml/min gives 0.646^0 c/w and 0.6044^0c/w at 110 ml/min. From an orientations increase in flow rate of cooling component decrease the thermal resistance.

In fig 3, heat pipe with CuO nanofluids shows the variation of efficiency with increase in heat transfer at 50w heat input. It can be observed that at 22.5^0 tilt angle , an efficiency is maximum and minimum efficiency is obtained at 67.5^0 orientation of the heat pipe. Compared to both the flow rate of cooling medium 22.5^0 orientation lowest flow rate of cooling medium have high thermal efficiency.

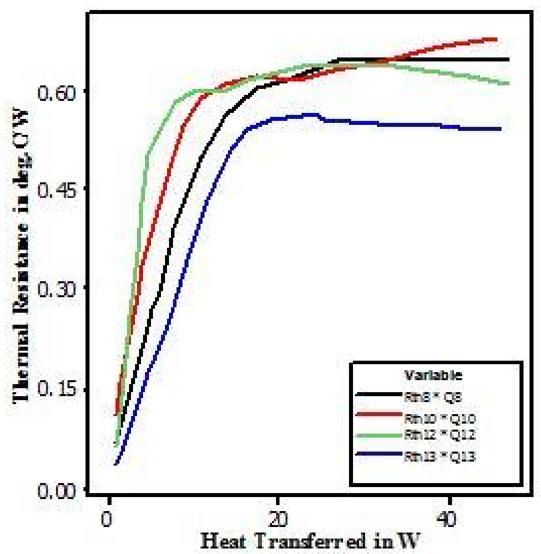

Fig. 2 Thermal resistance for CuO

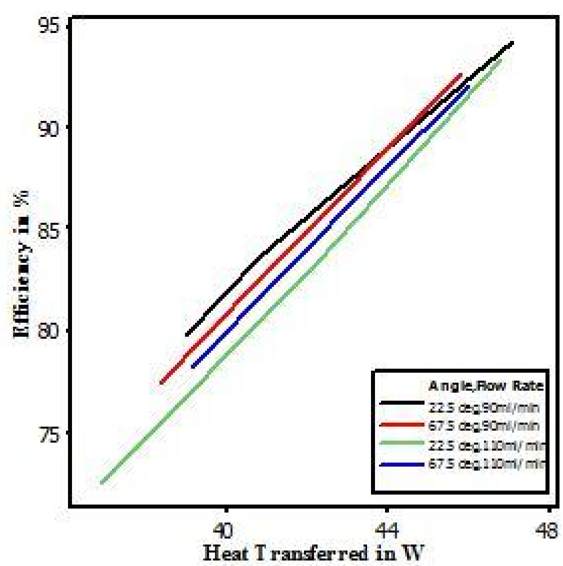

Fig. 3 Efficiency curve for CuO

In fig 4, heat pipe with DI water shows the variation of thermal resistance with increase in heat transfer at 50w heat input. It shows that at 67.5^0 orientation, 90 ml/min have 0.531 ^{0}c/w thermal resistance and 0.567^0c/w at 110 ml/min respectively. At 22.5^0 orientation gives a thermal resistance of 0.506 ^{0}c/w at 90 ml/min, 0.480^0c/w at 110 ml/min respectively. Above values are clearly indicates that enhance the orientation and flow rate increases the thermal resistance.

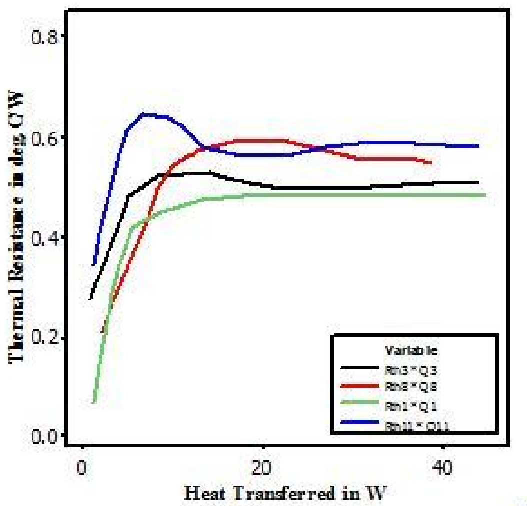

Fig. 4 Thermal performance for DI water

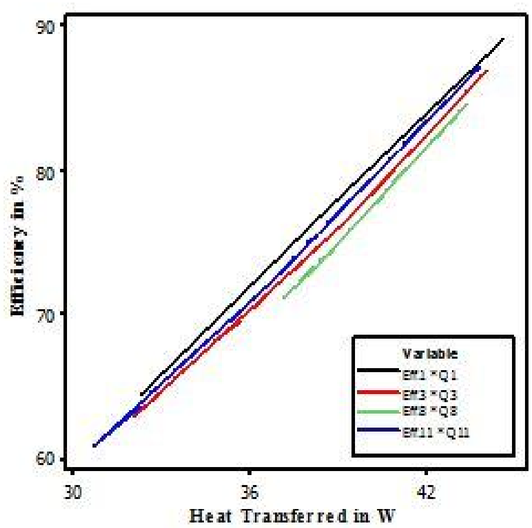

Fig. 5 Efficiency curve for DI water

In fig 5, heat pipe with DI water shows the variation of efficiency with increase in heat transfer at 50w heat input. It can also be observed that, at 22.5^0 orientation, the efficiency is maximum and minimum efficiency is obtained at 67.5^0 orientation of heat pipe. And while increase the flow rate increases the efficiency at same heat input.

While comparing the thermal resistance of both the working fluids 67.5^0 orientation have higher than 22.5^0 orientation. Which means increase in orientation, thermal resistance increases efficiency of heat pipe decreases. The decrease is depend upon the flow rate of cooling water from condenser section. When angle of inclination was increased, inside the heat pipe the working fluid moves fast due to capillary action and gravity.. so the process was sudden and increase the flow rate, simultaneously thermal energy absorption is also reduced from coolant water.

Efficiency curves for CuO nanofluids and DI water were plotted at fig 4&6 . CuO nanofluid have 94.1%, 93.6% efficiencies at 22.5^0 orientation and 90 ml/min and 110 ml/min respectively. For the same flow rates but 67.5^0 have 91.6% and 92% efficiencies. DI water have 87.9%, 89% efficiencies at 22.5^0 orientation and 90 ml/min and 110 ml/min respectively. For the same flow rates but 67.5^0 have 86.6% and 87.4% efficiencies.

Table 2 Comparative tabulation of CuO & DI water at 50W heat input

Orientation of the pipe	Flow rate (ml/ min)	R_{th}		Efficiency		% of variation	
		CuO	DI	CuO	DI	Rth	Eff
22.5^0	90	0.646	0.506	94.1	87.9	0.216	.065
	110	0.604	0.480	93.6	89.0	0.205	0.049
67.5^0	90	0.667	0.531	91.6	86.6	0.203	0.054
	110	0.543	0.567	92.0	87.4	-0.044	0.050

It is concluded that the thermal performance of CuO is 52.49% and 0.386 ^{0}c/w at 45^0 tilt angle [16]. In this paper, thermal performance of the grooved heat pipe is 94.1 and 0.667 ^{0}c/w at 22.5^0 orientation, which has been proven that decrease in angle and flow rate of heat pipe increases the thermal efficiency.

5. Conclusion

In this paper deals with thermal performance and thermal resistance of internally grooved heat pipe with CuO nanofluid and DI water, two tilt angles, two flow rates with 50w input power of heat pipe were experimentally tested. The conclusion of the result is,

- Thermal resistance of internally grooved heat pipe increases the orientation and flow rate for both working fluids.
- From the working fluids CuO nanofluid enhance the thermal resistance than DI water.
- CuO nanofluid exorbitant efficiency than DI water at 22.5^0 orientation and 90 ml/min flow rate.
- Results demonstrate the internally grooved heat pipe provide good thermal efficiency at lower the tilt angle and flow rate of cooling component.

References

1. *Xue Fei Yang, Zhen-Hua Liu and Jie Zhao (2008), "Heat transfer performance of a horizontal micro-grooved heat pipe using CuO nanofluid", Journal of Micromechanics and Microengineering, Vol. 18 (3), 035 – 03.*

2. *Guo-Shan Wang, Bin Song and Zhen-Hua Liu (2010), "Operation characteristics of cylindrical miniature grooved heat pipe using aqueous CuO nanofluids", Experimental Thermal and Fluid Science (2010) Vol: 34 (8), 1415-1421.*

3. *Dong-ryun Shin, Seok-ho Rhi, Taek-kyu Lim and Ju-chan Jang (2011), "Comparative study on heat transfer characteristics of nanofluidic thermosyphon and grooved heat pipe", Journal of Mechanical Science and Technology Vol: 25(6), 1391-1398.*

4. *Zhen-Hua Liu, Yuan-Yang Li and Ran Bao (2010), "Thermal performance of inclined grooved heat pipes using nanofluids", International Journal of Thermal Sciences, Vol. 49(9), 1680-1687.*

5. *Kumaresan G, Venkatachalapathy S and Lazarus Godson Asirvatham (2014), " Experimental investigation on enhancement in thermal characteristics of sintered wick heat pipe using CuO nanofluids" International journal of heat and mass transfer. Vol.72, 507-516.*

6. *Manimaran R, Palaniradja K, Alagumurthi N and Humain J (2014), " Experimental comparative study of heat pipe performance using CuO & TiO2 nanofluids" , International journal of energy research, Vol. 38, 573-580.*

7. *Kumaresan G and Venkatachalapathy S (2014), "Heat transfer studies on circular heat pipe using CuO nanofluids", International journal of mechanical and production engineering. Vol. 2, 81-84.*

8. *Gabriel Huminic, Angel Huminic, Ion Morjan and Florian Dumitrache (2011), "Experimental study of the thermal performance of thermosyphon heat pipe using iron oxide nanoparticles", International journal of heat and mass transfer, Vol. 54, 656-661.*

9. *Taoufik Brahim and Abdelmajid Jemni (2016), "Numerical case study of packed sphere wicked heat pipe using Al2O3 and CuO based water nanofluid", Case studies in thermal engineering, Vol. 8, 311- 321.*

10. *Waely I A Aly, Moustafa A Elbalshouny, H M Abd El-Hameed and M Fatouh (2017), "Thermal performance evaluation of a helical micro grooved heat pipe working with water and aqueous Al2O3 nanofluid at different inclination angle and filling ratio", Applied thermal engineering, Vol. 110, 1294-1304.*

11. *Maryam Shafahi, Vincenzo Bianco, Kambiz Vafai and Oronzio Manca (2010), "An investigation of the thermal performance of cylindrical heat pipes using nanofluids", International Journal of Heat and Mass Transfer, Vol. 53 (1-3), 376-383.*

12. *Hossien Kavusi and Davood Toghrai (2017), " A comprehensive study of the performance of a heat pipe by using of various nanofuids", Advanced powder technology, Vol. 28, 3074-3084.*

13. *Marayam Shafahi, Vincenzo Bianco, Kambiz Vafai and Orenzio Manca (2010), "An investigation of thermal performance of cylindrical heat pipe using nanofluids", International journal of heat and mass transfer, Vol. 53, 376-383.*

14. *Yu – Hsing Lin, Shung- Wen Kang and Hui – Lun Chan (2008), " Effect of silver nanofluid on pulsating heat pipe thermal performance", Applied thermal engineering, Vol 28 (11-12), 1312-1317.*

15. *Paisarn Naphon, Pichi Assadamongkol and Teerapong Boriak (2008), "Experimental investigation of titanium nanofluids on the heat pipe thermal efficiency", International communication on heat and mass transfer, Vol. 35, 1316-1319.*

16. *Aruna V and Alagappan N (2017), " Performance Analysis of Grooved Heat Pipe using Nanofluiods", Recent advance in science and engineering. Vol. 11 (8) 372-376.*

