International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-03, June 2019

Analysis Of Heat Pipe Of Different Materials With Different Fluids

[1]Arun Kumar, [2]Pankaj Kumar

[1]P.G Scholar, [2]Assistant professor department of ME, BIT Sindri, Dhanbad, India.

[1]arun11mence@gmail.com, [2]deoghar100@gmail.com

Abstract - Heat pipes are one of the most effective procedures to transport thermal energy from one point to another, mostly used for cooling. In the present work heat transfer and effectiveness of different heat pipe of material like copper, aluminum, high-grade steel and nickel with different fluids like acetone, ammonia, Freon, methanol, water will be investigated. It depends on a mix of conduction and convective heat transfer, which makes it to an intricate heat transfer problem. The point of this examination is to explore the thermal performance and effectiveness of heat pipe by estimating the temperature difference of fresh warm and return cold liquid through the evaporator and condenser side. The optimum effectiveness of heat pipe is determined and contrasted and the exploratory outcomes.

Keywords: condenser, Electronics cooling, evaporator, Heat Pipe, Inclination angle, nanofluid, wick

I. INTRODUCTION

Heat pipes have emerged as the most reliable, structurally simple heat dissipating device with excellent heat transfer capability. It can offer thermal conductivity several times better than good heat conducting material (copper, silver etc.). Hence, it is named as "thermal super conductor". It has no moving parts and does not require any power input [1-3]

A heat pipe is a heat transfer gadget that joins the standards of both thermal conductivity and phase transition to effectively transfer heat between two solid interfaces. Heat pipe are perceived as a standout amongst the most productive detached heat transfer advances accessible. A heat pipe is a structure with a high thermal conductivity that empowers the transportation of heat while keeping up practically uniform temperature along its warmed and cooled areas. All in all, heat pipes are uninvolved heat exchange gadgets ready to ship a lot of heat over generally long separations, with no moving parts, utilizing phase change procedures and vapor dispersion. The fundamental structure of a heat pipe comprises of an emptied cylinder mostly loaded up with a working liquid that exists in both fluid and vapor stages [4, 5].

Gravity sintered metal powder is efficient for heat transformation. Wick is used to return the working fluid after condensation to evaporator section by capillary action of working fluid due to surface tension. The Heat pipe is a gadget dependent on the rule of thermo hydrodynamics of working liquid. It is involved three segment evaporator, adiabatic and condenser area. Working liquid conveys the Heat from the Heat source by dissipation and rejected it at condenser by condensation. Vapor weight contrast b/w evaporator and condenser drive the vapor from evaporator to condenser. Latent heat librates at condenser to because of stage change phenomenon. It gives the benefit of heat exchange between little temperatures contrasts over an extensive separation. Heat pipe made up of three imperative things pipe material, working liquid and wick structure. The material utilized for Heat pipe should have high thermal conductivity and similarity with the working liquid utilized. The material utilized for Heat pipe might be copper, nickel and stainless steel and working fluid are acetone, ammonia, Freon, methanol, potassium and water. For the most part, copper is utilized due to high thermal conductivity. Utilization of working liquid relies on the thermo-physical properties of working liquid like immersion temperature, latent heat, specific heat, viscosity, density. Wick structure use for capillary action for returning the working fluid from condenser to evaporator [6]. With the improvement of electronic industry and decrease in size heat scattering is getting to be vital. The expulsion of the heat produced during the task of the electronic gear is extremely vital for improving the life of the hardware. So the thermal administrations are incredible tests. Considering the other cooling strategies heat pipe is a powerful arrangement as a result of amazing heat transfer capacity and basic straightforwardness. Heat pipe moves heat from one end to the next without the utilization of a pump. It has high heat remove capacities and can remove heat with exceptionally less temperature contrast between the hot and cold end [7].

II. LITERATURE REVIEW

Performance of heat pipe for different materials

COPPER

 DOI : 10.35291/2454-9150.2019.0244

Heat pipe technology continues developing in the direction of high operation temperature and high power capacity. In addition, technologies tend to use micro machining techniques in the areas of microelectronics applications. In recent years, the design theories have been maturing, and new approaches have been proposed, e.g., new wick structures and new materials**.**

Feng cai [8] investigates the manufacturing and experimental investigation of copper heat pipes. The performance testing mainly consisted of steady-state operating tests. Six heat pipe configurations were employed. The 100 copper mesh over charged water, the100 copper mesh normally charged water, the 50 copper mesh normally charged water, the 50 and 100 composite copper mesh over charged water, the 100 copper mesh acetone, and the nickel foam normally charged water. Three non-heat pipe copper tube configurations were also tested for comparison: the copper tube with 100 copper meshes, and the copper tube with 100 copper mesh and water. All these pipe configurations were tested with insulation and three orientations: horizontal, gravity assisted vertical, and against gravity vertical. These heat pipes were also cooled in three different approaches: natural forced and enhanced forced convections. The experimental results indicated that compared with the non-heat pipe copper tube configurations, for the same evaporator temperature constraint, the heat pipe improved the heat transfer capacity up to 400 percent and 730 percent. Also compared with the heat pipe copper tube configurations, the heat pipe significantly improved the axial thermal conductivities in the range from 260 percent to 1300 percent, depending on the testing conditions.

Senthil Kumar et al.[9]study the Effect of Inclination Angle in Heat Pipe Performance Using Copper Nanofluid. The examination talks about the impact of heat pipe inclination, type of working liquid and heat contribution on the thermal efficiency and thermal resistance. From this examination, it is discovered that the heat effectiveness of the heat pipe improves about 10% when copper nanofluid is utilized as a working liquid than the DI water.

Kang et al. [10] talked about the heat improvement of heat pipe execution utilizing silver nano-liquid as the working liquid. The higher thermal presentation of nano-liquids shows nanofluid potential as a substitute for ordinary unadulterated water in grooved heat pipes. This discovering review makes nano-liquid considerably more appealing as a cooling liquid for gadgets with high energy density. The test results demonstrated that the heat obstruction of heat pipe with nanofluids was lower than that of pipes containing unadulterated water.

Zhenping Wan et al.[11] contemplate Thermal performance of a miniature loop heat pipe utilizing water-copper nano-liquid. This examination tentatively researches the impact of a nanofluid on the warm qualities of a uniquely planned mLHP and investigates the component of heat move upgrade of the nanofluid in the mLHP. The ideal mass focus is 1.5 wt%. The thermal performance and improvement of the mLHP utilizing the nanofluid results from the decrease of the contact point, the upgrade of boiling heat transfer, and a stored nano-particle coat on the boiling surface.

H T Lim et al.[12] examine the fabrication and evaluation of a copper flat micro heat pipe working under adverse-gravity orientation. The manufacture of microgrooves was finished utilizing a laser micromachining strategy and water was utilized as the working liquid. Fan-molded microgrooves were found to initiate a more prominent narrow weight than triangular microgrooves of a comparative size. Ensuing test outcomes affirmed that regardless of its little size, 56 mm (L) × 8 mm (W) × 1.5 mm (H), the FMHP had a high heat transport limit; the most extreme rate of heat transfer was 8 W under stable task conditions and 13 W at the dry out point. Moreover, the FMHP worked under unfriendly gravity conditions with little change in cooling limit, a key preferred position for application in present day portable hardware.

Roger R. et al. [13] examine the Water-copper nanofluid application in an open loop pulsating heat pipe (PHP). This paper introduced a fundamental examination on the capability of utilizing nanofluid in an open loop PHP for passive warm control. The presence of solid nano-particles in the working liquid adds to expanding the nucleation destinations vital for air pocket development. Since more air pockets were produced, increasingly serious pulsations were seen during the PHP activity, which brought about more nearness of vapor in the channels. Subsequently, higher thermal conductance was seen when contrasted with the PHP activity with unadulterated water, regardless of the improvement in the general warm presentation watched.

STAINLESS STEEL

Paul J. Wirsch et al. [14] examine the Performance Characteristics of a Stainless Steel/Ammonia Loop Heat Pipe. The reason for the investigations was to decide the working qualities and the most extreme heat transport rate of the treated steel/ammonia loop heat pipe.

Gian Piero Celata et al. [15] Experimental tests on a stainless steel loop heat pipe with a flat evaporator. the exploratory outcomes appearing thermal qualities of a loop heat pipe (LHP) with the evaporator in the state of a flat plate having a functioning distance across of 50 mm and a thickness of 13 mm. The loop and the wick are made of stainless steel and water is utilized as working liquid.

Putra Nandy et al.[16] examine the exhibition of the lithium-ion battery thermal management system utilizing level plate loop heat pipe for electric vehicle application. This analysis prompts the down to earth capability of flat plate loop heat pipe use in the thermal administration arrangement of the lithium-ion battery. The flat plate loop heat pipe could start-up at heat motion load as low as 0.48 W/cm^2. Temperature overshoot marvels were seen during the start-up period. The best execution of the level plate circle heat pipe was gotten with acetone utilized as working liquid with a heat transition flux of 1.61 W/cm^2. The thermal resistance accomplished was 0.22 W/°C. The greatest evaporator temperature with alcohol and acetone was about 50°C, which is inside the working temperature scope of regular lithium-particle batteries. At heat stacks above 1.61 W/cm^2, the presentation of the level flat plate

 DOI : 10.35291/2454-9150.2019.0244

ISSN : 2454-9150 Vol-05, Issue-03, June 2019

loop heat pipe with alcohol is anticipated to inexact those with acetone.

Peyghambarzadeh et al.[17] examined experimentally the thermal performance of dual diameter circular heat pipe under different working fluids such as water, methanol and ethanol . Their outcomes demonstrated that higher thermal transfer Coefficients are gotten for water and ethanol in correlation with methanol. Besides, expanding heat transition flux the evaporator thermal transfer Coefficient. On account of methanol, some decrease in thermal transfer Coefficient was at high heat transitions which can be because of surface dry out impact. Expanding the inclination point decline the heat pipe heat obstruction.

Lloyd A. Nelson et al.[18] study about the heat pipe thermal mounting plate for cooling electronic circuit cards. Heat pipe technology may be utilized to cool circuit card-mounted electronic components. A heat pipe thermal mounting pipe has a very high thermal conductivity and provides a relatively uniform temperature surface for attaching of circuit card-mounted electronic components.

NICKEL

M. Bonnefoy et al.[19] investigate the Effective Thermal Conductivity of Saturated Sintered Nickel Loop Heat Pipe Wicks. This investigation measured the effective conductivity of sintered nickel wicks with variations in the saturating fluid. The results in vacuum and in air showed that the conductivity of the nickel dominated the effective conductivity in these conditions. Moreover, it was found that the temperature had almost no influence on the value of the effective conductivity within the range of studied temperatures. The results obtained with methanol and water gave higher values of effective conductivity.

Valery M. Kiseev et al.[20] studied the experimental optimization of capillary structures for loop heat pipes and heat switches. The examination was coordinated to acquire an ideal structure of evaporator. The tests were performed consecutively to cover the accompanying parts of the plan of the fine structure: plans of vaporization (old style and transformed meniscus plot), thickness and material of the slim structure, format, and measurement of the vapor grooves.

XIN GongMing et al.[21]experiment on the development of sintered Ni-Cu wicks for loop heat pipes. Results show that capillary wicks were successfully fabricated by using two different methods; the optimal capillary wick was found to be sintered at 650℃ for 30 min, using direct loose sintering technique, with 90% nickel and 10% copper. The wicks could reach the porosity of 70.07% and the permeability of 10^{-13} m^2 order, with mean pore radius of 0.54 μm.

ZhiChun Liu et al. [22] studied the operational characteristics of flat type loop heat pipe with bi-porous wick. Conceptual Loop heat pipes (LHPs) are two-stage heat transfer gadgets that use the dissipation and buildup of working fluid to transport heat. From the test outcomes, it is discovered that, in the horizontal position, the loop can start-up with a heat load extend between 20 W and 160 W(heat flux of 16.8 W/cm^2) with evaporator temperature less than 85℃. At heat load between 30 W and 80 W, temperature ranges are watched all through the loop, be that as it may, the impact of this wavering on the exhibition of the loop isn't noteworthy. During an irregular loading test, the loop can stand a load bounce as high as 100 W without a task failure. The thermal resistance of the LHP lies between 0.46 °C/W to 2.28 °C/W.

III. SYSTEM DESCRIPTION

Heat pipe is consisting of three sections are:

a) Evaporator section
b) Adiabatic section
c) Condenser section

In the evaporator section i.e. at heat source working fluid vaporizes and converts into vapour. Then this vapour is passed through an adiabatic section (where no heat loss occurs) to condenser Section (heat sink) where latent heat of fluid releases to surroundings. Temperature of working fluid always exists between triple point and critical point. Working fluid always remains in saturated state inside the heat pipe.

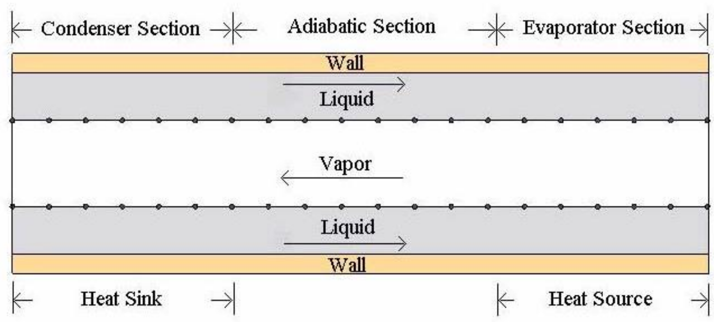

Fig 1. A cut-away view of a heat pipe.[23]

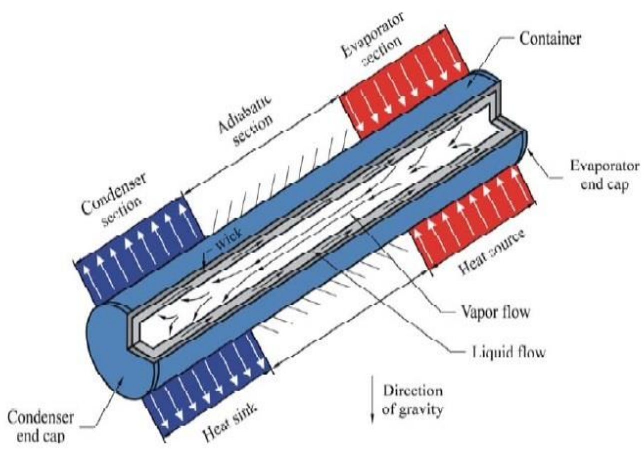

Fig-2. HEAT PIPE CONSTRUCTION AND OPERATIONAL DETAILS

 DOI : 10.35291/2454-9150.2019.0244

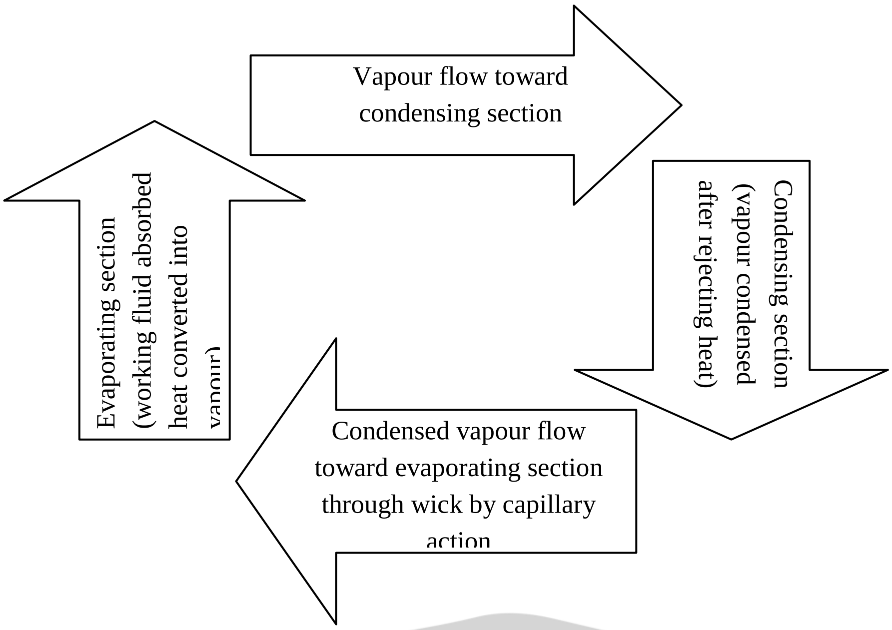

Fig 3. SCHEMATIC FLOW DIAGRAM OF WORKING PRINCIPLE OF HEAT PIPE

In radial direction working fluid composed of three sections are:-

I. Container/ shell
II. Working fluid
III. Wick structure (liquid flow section)

(i) CONTAINER: container is a shell or tube to contain the working fluid and wick within itself.

It is made up of different types of material are copper, aluminum, steel, tungsten, titanium. Material used for container must have higher thermal conductivity and must be compatible with working fluid used. Generally copper is used for higher thermal conductivity approximately 400 w/m° C and low cost as compared to other material.

Table1. Heat pipe vessel materials

Vessel material	Working fluid	Temperature range (°C)
Aluminum	Liquid nitrogen Freon Ammonia Acetone	-213 to -173 -43 to 27 -73 to 27 52 to 127
Stainless steel	Ammonia Acetone	-73 to 27 -52 to -27
Nickel	Ammonia	-73 to 27
Copper	Acetone water	52 to 127 52 to 277
Tungsten	Sodium	627 to 1227

(ii) **WORKING FLUID**: working fluid selection in heat pipe depends on the type of material used. Different types of working fluids are water, ammonia, ethanol, methanol, acetone, lithium, sodium, nitrogen, helium. Nitrogen or helium used for low temperature application and Lithium, sodium and potassium used for high temperature applications. It is subjectively profitable to have high fluid and vapor densities, low fluid and vapor viscosities, high latent heat of vaporization and high surface tension for the working liquid. Determination of the working liquid is administered by the accompanying criteria:

(i) Suitable liquid and warm properties;
(ii) Compatibility with the wick material;
(iii) Chemical strength at raised temperatures; and
(iv) The wetting angle between the working liquid and the wick and between the working liquid and divider materials (this angle is required to be is primarily determined by the liquid entrainment <90 °)

Table 2. Heat pipe working fluids

Medium	Melting point(°C)	Boiling point at atmospheric pressure	Useful range (°C)
Ammonia	-78	-38	-60 to 100
Freon-11	-111	24	-10 to 120
Acetone	-95	57	0 to 120
Methanol	-98	64	10 to 130
Potassium	62	774	500 to 1000
Water	0	100	30 to 100

(iii) **WICK STRUCTURE**: Wicks are developed with one kind of material or machining system. The screen wick is apparently the easiest and most basic type of wick structure. It comprises of a metal or material texture which is folded over a mandrel and embedded into the heat pipe. It may be axial grooved, wire mesh, sintered powder, and woven fiber glass. Wire mesh made up of particular type of material like steel and alloy. For gravity assisted heat pipe grooved wick, heat pipe gives higher heat transfer rate and for capillary against. The purpose of a wick in the heat pipe is

 DOI : 10.35291/2454-9150.2019.0244

(i) to provide the necessary flow passages for the return of the condensed liquid,
(ii) to maintain surface forces at the liquid-vapour interface for development of the required capillary pumping pressure the required and
(iii) to provide a heat flow path between the inner walls of the container and the liquid-vapour interface

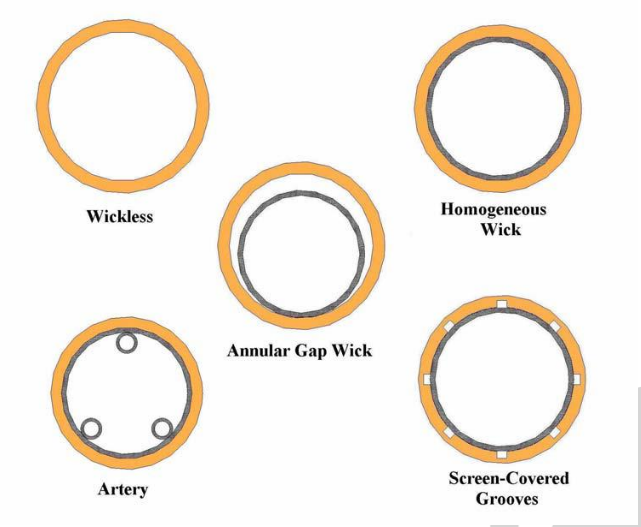

Figure 3. Some wick structures typically used in heat pipes. [23]

IV. CALCULATION

Assumptions for heat pipe calculation

The accompanying suppositions have been made before composing the administering conditions

1. The vapour flows are considered to be laminar.
2. The vapor is considered to be saturated at t = 0 (time).
3. All thermo physical properties are assumed constant except for the vapor density, which is computed from the operating pressure and specific heat which is linear with respect to temperature.

Wick is assumed as a solid with effective thermal conductivity of sodium liquid and steel, because conductivity is high for molten metal (sodium) and by maintaining the capillary limitation during calculation

Thermal resistance of heat pipes

To investigate the thermal performance of heat pipe, the heat transferred by the heat pipe, the thermal resistances at the evaporator (R_e) as well as condenser sections (R_C) and also the total resistance of heat pipes (R_T) are calculated. Heat transferred by the heat pipe is calculated using the heat balance equation as

$$Q_{out} = \dot{m}_l c_{pl}(T_{out} - T_{in})$$

Thermal resistances at the evaporator and condenser sections are evaluated using equations

$$R_e = \frac{\Delta T_e}{Q_{in}}$$

$$R_c = \frac{\Delta T_c}{Q_{out}}$$

Where $\Delta T_e = Te - Tv$ and $\Delta T_c = Tv - Tc$

Also the total thermal resistance of the heat pipe is determined by

$$R_T = \frac{\Delta T}{Q_{out}}$$

Where $\Delta T = Te - Tc$

Heat transfer coefficient of the heat pipes

The heat transfer coefficients of evaporator and condenser are determined from

Equations

$$h_e = \frac{q_e}{T_{e,i} - T_{sat}}$$

Where $q_e = \frac{Qin}{\pi d l_e}$

$$h_C = \frac{q_c}{T_{sat} - T_{c,i}}$$

Where $q_C = \frac{Qout}{\pi d l_c}$

V. CONCLUSIONS

The experiment of investigating thermal performance of heat pump is done by varying the angle of inclination, pipe materials, and working fluids. From the results the following conclusion can be made

- The coolant stream rate insignificantly affects the execution of the heat pump.
- Performance of heat pump relies on the inclination angle. Better execution is found for a inclination angle of 90^o.
- Heat input significantly affects the execution of the heat pump. It is discovered that the general heat transfer coefficient is higher for higher heat input.
- It is seen that for a similar heat input and inclination angle of a copper heat pipe with acetone as working fluid performs superior to anything the other heat pipe materials.

VI. NOMENCLATURE

Q_{out}	Total heat out at condenser section (kw/cm^2)
m_l	Mass flow rate of liquid (kg/sec)
C_{pl}	Specific heat capacity of liquid (kj/kg-℃)
R_e	Thermal resistances of evaporator (kw/℃)
R_c	Thermal resistances of condenser (kw /℃)
R_T	Total Thermal resistances of evaporator (kw /℃)
q_e	Heat flux in Evaporator (kw/cm^2)
q_c	Heat flux in condenser (kw/cm^2)

DOI : 10.35291/2454-9150.2019.0244

h_e	Heat transfer coefficients of evaporator (w/m^2-°C)
h_c	Heat transfer coefficients of condenser (w/m^2-°C)
T_{sat}	Saturation temperature of fluid (°C)
l_e	Length of evaporator section (mm)
l_c	Length of condenser section (mm)
d	Diameter of heat pipe (mm)

REFERENCES

[1] Chernysheva MA, Maydanik YF: Simulation of thermal processes in a flat evaporator of a copper–water loop heat pipe under uniform and concentrated heating, IJHMT (2012)

[2] . Faghri A: Heat pipe science and technology, by Taylor & Francis (1995)

[3] . Faghri A: Review and advances in heat pipe science and technology, Journal of heat transfer by ASME(2012)

[4] Vasiliev, L.L., 2008, "Micro and miniature heat pipes – Electronic component coolers", Applied Thermal Engineering 28, pp. 266-273. Journal article.

[5] http://architecture.mit.edu/house_n/web/resources/tutorials/House_N%20Tutorial%20Heat%20Pipes.htm

[6] Faghri, A., Chen, M. M., Mahefkey, E. T., Simultaneous Axial Conduction in the Fluid and the Pipe Wall for Forced Convective Laminar Flow with Blowing and Suction at the Wall, International Journal of Heat Mass Transfer, 32 (1989), 2, pp. 281-288.

[7] Ku J, Ottenstein L, Douglas D, Hoang T. Technology Overview of a Multi-Evaporator Miniature Loop Heat Pipe for Spacecraft Applications. J Spacecr Rockets. 2012;49(6):999–1007.

[8] Feng Cai ,B. Eng. manufacturing and experimental investigation of copper heat pipes Published Heritage Branch 395llington Street Ottawa ON K1A 0N4

[9] Senthilkumar , Vaidyanathan, Sivaraman study the Effect of Inclination Angle in Heat Pipe Performance Using Copper Nanofluid, www.sciencedirect.com.

[10] Kang S W, Wei W C, Tsai S H, Yang S Y, Experimental investigation of silver nano-fluid on heat pipe thermal performance, App Ther Engg 2006; 26: 2377 2382.

[11]] Z. Wan, J. Deng, B. Li, Y. Xu, X. Wang, Y. Tang, Thermal performance of a miniature loop heat pipe using water-copper nanofluid, Applied Thermal Engineering (2014), doi: 10.1016/j.applthermaleng.2014.11.010

[12] H T Lim, S H Kim, H D Im, K H Oh and S H Jeong Fabrication and evaluation of a copper Flat micro heat pipe working under adverse-gravity orientation journal of micromechanics and micro engineering J. Micromech. Microeng. 18 (2008) 105013 (8pp) doi:10.1088/0960-1317/18/10/105013

[13]] Roger R. Riehl*, Nadjara dos Santos "Water-copper nanofluid application in an open loop pulsating heat pipe" applied thermal engineering 42 (2012) 6e10

[14] Paul J. Wirsch and Scott K. Thomas "Performance Characteristics of a Stainless Steel/Ammonia Loop Heat Pipe" JOURNAL OF THERMOPHYSICS AND HEAT TRANSFER Vol. 10, No. 2, April-June 1996

[15] Gian Piero Celata *, Maurizio Cumo, Massimo Furrer "Experimental tests on a stainless steel loop heat pipe with flat evaporator" Experimental Thermal and Fluid Science 34 (2010) 866–878 journal homepage: www.elsevier.com/locate/etfs.

[16] Putra Nandy, Bambang Ariantara, Rangga Aji Pamungkas, Experimental investigation on performance of lithium-ion battery thermal management system using flat plate loop heat pipe for electric vehicle application, Applied Thermal Engineering (2016), http://dx.doi.org/doi: 10.1016/j.applthermaleng.2016.01.123.

[17] Wang PY ,Chan XJ, Liu ZH , Liu YP. Application of nano fluid in an inclined mesh wicked heat pipes Thermochim Acta 2012;539;100-8.

[18] Lloyd A. Nelson, Villa Parks; Kalwant S. Sekhon, Fullerton, "the heat pipe thermal mounting plate for cooling electronic circuit cards" Continuation of Ser. No. 559,353, Mar. 17, 1975,abandoned.

[19] M. Bonnefoy and J. M. Ochterbeck "Effective Thermal Conductivity of Saturated Sintered Nickel Loop Heat Pipe Wicks" 37th AIAA Thermophysics Conference 28 June - 1 July 2004, Portland, Oregon

[20] Kiseev VM, Vlassov V V., Muraoka I. Experimental optimization of capillary structures for loop heat pipes and heat switches. Appl Therm Eng [Internet]. 2010;30(11–12):1312–9. Available from: http://dx.doi.org/10.1016/j.applthermaleng.2010.02.010

[21] Xin G, Cui K, Zou Y, Cheng L. Development of sintered Ni-Cu wicks for loop heat pipes. Sci China, Ser E Technol Sci. 2009;52(6):1607–12.

[22] Liu Z, Li H, Chen B, Yang J, Liu W. Operational characteristics of flat type loop heat pipe with biporous wick. Int J Therm Sci [Internet]. 2012;58:180–5. Available from: http://dx.doi.org/10.1016/j.ijthermalsci.2012.02.027

[23] Jankowski TA. Numerical and Experimental Investigations of a Rotating Heat Pipe. 2007;131. Available from: http://www.osti.gov/scitech/servlets/purl/901587

 DOI : 10.35291/2454-9150.2019.0244