Performance Analysis of Heat Pipe at different Orientations

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ABSTRACT

Heat pipe is a heat transfer device that combines the principles of thermal conductivity and phase transition to efficiently manage transfer of heat between two solid interfaces. The main feature of heat pipe is that it can be designed to transport heat between the heart source and the heat sink with very small temperature difference. The factors affecting the performances of heat pipe are various limits such as Viscous limit, Sonic limit, Capillary limit, Boiling limit, Entrainment limit. Enhancement in Performance of heat pipe can be done on the basis of selection of various working fluids. Based on Orientation of pipe, performance can be analysed and results obtained are compared with horizontal orientation. Another main component is its wick structure. The wick structure and the working fluid in the heat pipe play a very important role in thermal performance of heat pipe. Wick structure is responsible for capillary pumping force and is directly limited to capillary limit. Position of condenser and evaporator i.e. the inclination of heat pipe affects is thermal performance. Heat pipe performance with composite wick structure at different angles of inclination and acetone as working fluid is studied.Heat pipe performance with "Meshing" as wick structure at different angles of inclination and"Acetone" as working fluid is studied. In this work, we are going to do experiment on meshing wick structure heat pipe placed at different orientations. From this experimentation we here by conclude that Meshing structure heat pipe thermal performance is very less affected by gravity and angle of orientation because of high capillary action of the wick.

Keywords-*Heat pipe, wick structure, working fluid, thermal performance*.

1. INTRODUCTION

A heat pipe is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces. At the hot interface of a heat pipe a liquid in contact with a thermally conductive solid surface turns into a vapour by absorbing heat from that surface. The vapour then travels along the heat pipe to the cold interface and condenses back into a liquid – releasing the latent heat. The liquid then returns to the hot interface through capillary action, centrifugal force, or gravity, and the cycle repeats. Due to the very high heat transfer coefficients for boiling and condensation, heat pipes are highly effective thermal conductors

Fig 1. Cross-section of Mesh Wick Structure of Heat Pipe

A typical heat pipe consists of a sealed pipe or tube made of a material that is compatible with the working fluid such as copper for water heat pipes, or aluminium for ammonia heat pipes. Typically, a vacuum pump is used to remove the air from the empty heat pipe. The heat pipe is partially filled with a working fluid and then sealed. The working fluid mass is chosen so that the heat pipe contains both vapour and liquid over the operating temperature range. Below the operating temperature, the liquid is too cold and cannot vaporize into a gas. So basically a heat pipe is a heat transfer device that combines the principles of both thermal conductivity and phase transition to effectively transfer heat between two solid interfaces.

2. LITERATURE REVIEW

Gerardo Carbajal, Haydn N.G. Wadley, Douglas T. Queheillalt[1] A multifunctional sandwich panel combining efficient structural load support and thermal management characteristics has been designed and experimentally assessed. The concept is based upon a truncated, square honeycomb sandwich structure. In closed cell honeycomb structures, the transport of heat from one face to the other occurs by a combination of conduction through the webs and convection/radiation within the cell. A thermodynamic model was used to guide the design of the heat pipe sandwich panel. We describe the results of a series of experiments that validate the operational principle of the multifunctional heat pipe sandwich panel and characterize its transient response to an intense localized heat source. The systems measure thermal response to a localized heat source agrees well with that predicted by a finite difference method model used to predict the thermal response.

R.A. Hossain, M.A.K Chowdhuri, C. M. Feroz[2] An experimental investigation is carried out also to investigate the performance of the MHP with different experimental parameters. These experimental parameters include inclination angle, coolant flow rate, working fluid and heat input. Inclination angle are varied from 300 to 900, whereas coolant flow rate and heat input are varied from 0.3 lit/min to 1.0 lit/min and 0.612 W to 8.71W respectively. Three different types of working fluids are used; acetone, ethanol and methanol. For each working fluid, heat transfer characteristics are determined experimentally for different inclination angle and different coolant flow rate at different heat input. Acetone is proved to be better as working fluid. A correlation is also made for acetone to relate other experimental parameters for determination of heat transfer coefficient

Per Wallin[3] This paper focuses on the selection on working fluid for performance enhancement of heat pipe. Heat pipes are common in many application fields for example cooling of electronics. The design of a heat pipe is rather complex with many things to consider. In this project the focus is the get knowledge about who to select the working fluid to be used. Three different types of working fluids are used; acetone, ethanol and methanol.

R.Manimaran ,K.Palaniradja , N.Alagumurthi , J.Hussain[4] Heat pipes are heat transfer devices that enhances large amount of heat which works on the principle of evaporation and condensation of a working fluid. In spite of wide application of heat pipe in microelectronics cooling system the trend of the chips performance and power utilization has been increased each year and a complete understanding of mechanism has not yet been completed even though it has the ability to operate against gravity and a greater maximum heat transport capability.

Frederic Lefevre , Jean-Baptiste Conrardy, Martin Raynaud , Jocelyn Bonjour[5]
Experimental investigations of two different flat plate heat pipes (FPHP) are presented. The capillary structure is made of one or two screen mesh layers for the first FPHP and screen mesh covered grooves for the second FPHP. The heat pipes, filled with methanol, were tested in different configurations i.e. with various locations of heat sinks and heat sources, numbers and natures of the heat sinks and orientation. Water heat exchangers were first used as heat sinks to estimate the performance of the capillary structures. The results show the interest of this solution for the proposed application. The method chosen to assemble this FPHP prototype with meshes is very simple and cheap. On the contrary, the performance of the heat pipe obtained with the association of grooves and meshes is not as high as one could expect. Indeed, if this capillary structure allows working in tilted unfavourable position, which is not possible with grooved heat pipe, a clear nucleate boiling limitation is observed for rather small heat fluxes.

B.Ch. Nookaraju, P S V Kurmarao, H.Prashanth, C.Pradeep[6] In this work the researchers had done the experiment on sintered copper wicked heat pipe placed at different orientations and note the heat transfer rates of the heat pipes at each position. The temperature at evaporation section and condensation section of the heat pipe is measured using K type thermocouple. From this experimentation we here by conclude that sintered copper wicked heat pipe thermal performance is very less affected by gravity and angle of orientation because of high capillary action of the wick.

3. WORKING PRINCIPLE

The heat pipe is a passive heat transfer device with an extremely high effective thermal conductivity. Its heat transfer capability ranges from one hundred to several thousand times that of an equivalent piece of copper because of its two-phase heat transfer mechanism. When constructing the heat pipe, it is evacuated and then filled with the working fluid before being sealed. Hence its internal pressure is equal to the vapour pressure of the working fluid. When heat is applied to the evaporator section of the heat pipe, the working fluid vaporizes. In thermodynamics, pressure change is directly proportional to temperature change. Hence, at a slightly higher temperature and pressure at the evaporator section, it creates a pressure gradient that forces the vapour to flow to the cooler regions of the heat pipe. As the vapour condenses on the heat pipe walls, the latent heat of vaporization is transferred to the condenser. The capillary wick then transports the condensate back to the evaporator section. This closed loop process continues as long as heat is applied. The wickstructure is a concerned factor because good structure generates stable capillary pumping pressure, maintainsthe circulation of the fluid against the liquid and vapour flow losses, and against adverse body forces, such as gravity.

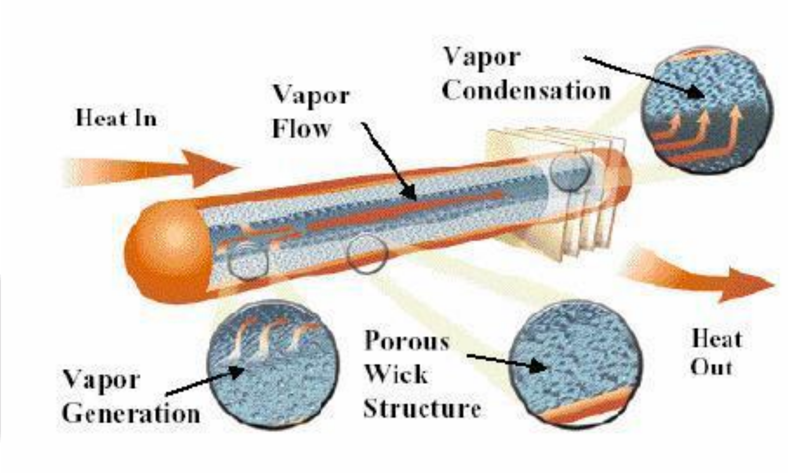


Fig 2.Operation of heat pipe

3.1 EFFECT OF TILT ANGLE

The orientation is important for the operation of a heat pipe. Depending on conditions, a heat pipe can operate in horizontal position or in vertical position. For the horizontal position of a heat pipe, gravity has no effect. But in vertical position gravity can assist or oppose to the operation of the heat pipe. The tilt of a heat pipe is classified into two types; favourable tilt and adverse tilt. Favourable tilt is the tilt position where gravity assists heat pipe operation. In favourable tilt, condenser is positioned above evaporator. By this way, liquid return from condenser to evaporator is assisted by gravity. Therefore, capillary pumping pressure can overcome more pressure losses and this increases the heat transfer capacity of the heat pipe, in terms of capillary limit. Other type is adverse tilt. In this tilt condition, evaporator is positioned above condenser. Therefore, the liquid in the condenser shall overcome gravity force to return to evaporator. This creates extra drag for capillary pumping pressure to overcome. As a result, heat transfer capacity of the heat pipe decreases. Therefore, it is preferable for a heat pipe to operate in favourable tilt position, if possible.

4. PROBLEM DEFINITON

Heat pipe is a heat transfer device used for cooling purposes in many applications like space applications, electronic equipment cooling, energy systems, human body temperature cooling etc. It has very high effective thermal conductivity. From the study it is found that enhancing the performance of heat pipe has become necessary because of wide applications of heat pipe.

This project also focuses on enhancing the performance of heat pipe by proposing the modified heat pipe. The proposed model of heat pipe will be having the greater surface area since we know that by increasing the surface area increases the heat transfer rate. Enhancement in Performance of Heat pipe can be done on the basis of selection of Working Fluid and its wick structure. To study the Thermal Performance and Effect of angle of inclination on its Performance proper setup need to be constructed. The man Problem of the research is to

concentrate on the Variation of the readings of Heat pipe based on factors like Thermal Resistance, capillary limit, efficiency, etc., when we taking 'Acetone' as working fluid and meshing as Wick structure.
So, the researcher had decided to work with meshing wick structure and to conduct experimental study of heat pipes at various orientations.

4.1OBJECTIVES

- To analyse Thermal Performance of heat pipe.
- To study the effect of angle of inclination on performance of heat pipe.
- To study the effect of mesh wick structure on heat pipe performance.

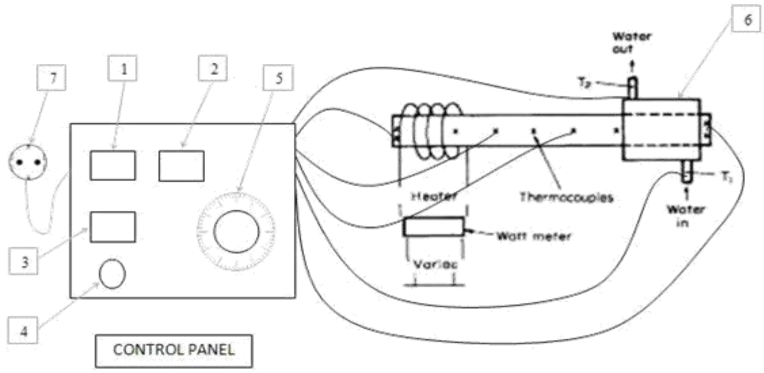
5. MEHTHODOLOGY

The heat pipe is placed in the position as shown in the experimental setup. The degree of inclination is then set by moving the water jacket in an inclined way. The angle is measured by using angle measuring instrument attached on wood table. The two thermocouples are fixedto the two ends of heat pipe i.e. one at evaporator section and other at condenser section with the help of locking screw. The heater is placed at the evaporator section and the heat input is given by switching on the heater. The amount of heat input can be varied through dimmer stat provided on setup. Water is being pumped continuously at condenser section through a water jacket to take away the heat from the condenser.

The temperatures at evaporator and condenser sections are measured using thermocouple which is displayed on the setup. The temperatures are noted once the system reaches steady state. The mass of water flow is calculated by taking time required to fill the certain amount of 1000ml in the measuring jar. The same procedure is conducted by varying the inclination and readings are noted.

- The experiment is conducted on composite meshes wick structure heat pipe by varying the input and the angle of inclination.
- The set-up consists of a wooden table which is used to support heat pipe and incline it at desired angles to study the effect of gravity.
- A control panel is used to measure heat supplied to heat pipe. It displays the supply current and voltage readings through digital ammeter and voltmeter. Supply voltage and current are varied by dimmer stat.
- A K-type thermocouple is used to measure the temperature at various positions.
- Condenser is assembled with the heat pipe to absorb the heat released from the condenser end.
- Analysing various factors such as Thermal Resistance, Capillary limit etc. and recording the readings.

Fig 3. Actual Test setup



1. Digital Ammeter
2. Digital Voltmeter
3. Temperature Indicator
4. Temperature Shift Switch
5. Dimmer stat
6. Condenser
7. Main Plug

Fig 4. Schematic Diagram of Test Setup

5.1. SPECIFICATIONS OF COMPONENTS

One of the design parameter of heat pipe is selecting the operating temperature range. In this project setting the Operating temperature range as 20-70oC, since there are many conventional application falling in this range. The boiling point of the acetone falls in the selected operating temperature. Selecting the working fluid as acetone, since useful range of acetone is 0-100oC. The compatible material for acetone is steel with high thermal conductivity. Hence, the steel is selected as pipe wall material. The larger the diameter more cross-sectional area available to allow the vapour to move from the evaporator to condenser. This allows the greater power carrying capacity. Hence, selecting the outer diameter 12mm and length 250mm, with L/D=20.83 as it will give a greater power carrying capacity and better understanding of fluid flow will be performed on it.

Specifications:

1. Wall Material: Copper.
2. Working Fluid: Acetone
3. Wick Structure: Meshing
4. Thermocouple: Resistance Temperature Detectors (RTDs).

Dimensions:

(A) For Heat Pipe

1. Length of pipe: 250mm
2. Outer diameter of heat pipe: 12.5mm
3. Inner diameter of heat pipe: 10mm
4. Mesh size: 180 holes/inch
5. Diameter of wire: 0.04mm

(B)For Control Panel

1. Ammeter: 0-5 mA
2. Voltmeter: 0-300 V.
3. 4-channel Digital Temp. Indicator (0*°C-500°C*) with RTD Thermocouple.

6. RESULT TABLE

A. At an Inclination angle - 0°

Qin (W)	T1 (°C)	T2 (°C)	Qout (W)	η%	Avg. (η)%
37.5	36	38	177.144	47.23	58.59
50	34	39	295.24	59.04	
62.5	39	40	59.048	97.47	
75	40	44	236.192	31.49	

Table 1. observation for 0° Inclination.

B. At an Inclination angle - 30°

Qin (W)	T1 (°C)	T2 (°C)	Qout (W)	η%	Avg.((η)%
37.5	34	36	118.096	31.49	24.79
50	42	44	118.096	23.61	
62.5	45	48	177.144	28.34	
75	48	50	118..096	15.74	

Table 2. observation for 30° Inclination.

C. At an Inclination angle - 50°

Qin (W)	T1 (°C)	T2 (°C)	Qout (W)	η%	Avg. (η)%
37.5	40	42	118.096	31.49	27.77
50	42	46	59.048	35.54	
62.5	45	48	177.144	28.34	
75	48	50	118.096	15.74	

Table 3. observation for 50° Inclination.

D. At an Inclination angle - 90°

Qin (W)	T1 (°C)	T2 (°C)	Qout (W)	η%	Avg. (η)%
37.5	38	40	118.096	31.49	33.79
50	37	40	117.144	35.42	
62.5	40	43	117.144	39.36	
75	42	47	295.24	28.89	

Table 4. observation for 90° Inclination.

7. CONCLUSIONAND DISCUSSION

7.1 Conclusions

Average Efficiency of heat transfer through heat pipe at an inclination angle 0° is 58.59%

Average Efficiency of heat transfer through heat pipe at an inclination angle 30° is 24.79%

Average Efficiency of heat transfer through heat pipe at an inclination angle 60° is 27.77%

Average Efficiency of heat transfer through heat pipe at an inclination angle 90° is 33.79%

7.2 Discussion

Efficiency of Heat pipe is more when Heat pipe is at Horizontal position i.e. at 0° therefore it is a favourable position of heat pipe. while efficiency goes on decreasing as we inclined the heat pipe through various angle to Vertical position which will result in unfavourable condition of heat pipe.

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