

EFFECT OF FILLING RATIO AND INPUT HEAT FLUX ON THE PERFORMANCE OF HEAT PIPE: A REVIEW

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Abstract

Thermal management in various fields is a contemporary issue's. Pulsating heat pipes are relatively new entrants to the family of heat pipes used for higher heat removal. Heat transfer mechanism is a natural convection in condenser section. Experiments are conducted with filling ratio as 40%, 50% and 60%. Heat input is varied as 10W, 20W, 30W, 40W and 50W. The results indicated better system performance with lower level of filling ratio and at higher heat input. In addition to some approaches such as changing the working fluid or number of turns in a pulsating heat pipe (PHP), geometrical changes are also appealing for enhancing the thermal performance of this type of heat pipes. In order to characterize this pulsating heat pipe, can use various working fluids, such as acetone, methanol, water and n-pentane, with applied thermal power ranging from 25 W to 550 W, air temperatures ranging from 10 C to 60 C, and inclination angle between 0° to 90°.

1. Introduction

Heat pipes are used in various applications due to their very high thermal conductance and reliability. A two-phase phenomenon has proved to be better technique to increase the heat transfer rate from heat source. The most common form of them is composed of a long capillary tube bent into turns PHPs can also exist in flat plate style, in which a number of channels are created on a flat plate. Micro PHPs are another kind of PHPs, which are mainly used in cooling of electronic chips and they are more efficient compared to other methods of micro-cooling.

PHPs are classified into two main groups: Open Loop Pulsating Heat Pipes (OLPHPs) and Closed Loop Pulsating Heat Pipes (CLPHPs).

In CLPHP the two ends of the tube are connected to one another and working fluid is able to circulate, which enhances its capability of transporting heat from evaporating section to condensing section. A PHP consists of a single plain meandering tube of capillary dimensions with many U-turns. The tube is initially evacuated and then partially filled with a working fluid. PHPs have extended its applications in Fuel cells, radiators, hybrid vehicles, chip cooling, air-conditioning, air to air heat exchanger, solar and waste heat recovery systems and many more.

2. Literature Survey

1. Harshal Gamit has performed an experiment to investigate effect of Filling ratio and input heat flux on performance of pulsating heat pipe. Water as a working fluid.

He has been observed that 50% filling ration gives better performance at 2.15 inner diameter of PHP, pressure 9×10^{-5} mbar and the mode of cooling is Forced air cooling.

2. M. Aboutalebi has performed an experiment to investigate on performance of a rotating closed loop pulsating heat pipe, it was also pointed out that the best filling ratio is 50% and 50 rpm to 800rpm and at 50% filling ratio condenser gives better performance. He has admit water and R-142b as a working fluid and mode of cooling is forced air cooling.

3. G. Burban has performed an experiment to investigate of a pulsating heat pipe for hybrid vehicle applications, working fluid as an Acetone, Methanol, water, n-pentane and 50% filling ratio, 2.5mm inner diameter and forced air cooling as a mode of cooling. Air velocity is 0.25 m/s to 2 m/s. he has been grouped acetone - n-pentane and water - methanol.
4. Kuo-Hsiang chien performed A novel design of pulsating heat pipe with fewer turned applicable to all orientations, he has been observed that at 0-90 inclination, 2mm inner diameter and the filling ratio above 50% and water as a working fluid and forced air cooling as a mode of cooling.

He has been observed that water as a working fluid and the filling ratio above 50% gives better performance.

5. Mauro Mameli has performed an empirical experiment of Closed loop pulsating heat pipes, Part B: visualizing and semi- modeling, water, ethanol, R-123 and FC-72 as a working fluid at different filling ratio's as 0.15-0.3 for water, 0.25-0.55 for ethanol, 0.35-0.6 for R-123, 1.1 ID and 2 OD, angle of inclination is 0-90 and modes of cooling is Forced air cooling.

Sr. No.	Di (mm)	Author	Mode of Cooling	FR (%)	Pressure	Air /water Velocity	Inclination Angle	Working Fluid
1	2.15	Harshal Gamit[1]	Force air cooling	20-80	9*10e-5 mbar	NA	NA	Water
2		M. Aboutalebi [2]	Force air cooling	25-75	NA	NA	NA	Water and R-142b
3	2.5	G. Burban[3]	Force air cooling	50	NA	0.25 m/s to 2 m/s	NA	Acetone, Methanol, Water, n-pentane
4	2	Kuo-Hsiang Chien[4]	Force air cooling	40-70	NA	NA	0-90	Water
5	ID-1.1 OD-2	Mauro Mameli [6]	Force air cooling	0.15–0.3 (for water) 0.25– 0.55 (for ethanol) 0.35–0.6 (for R-123)	NA	NA	0-90	Water, ethanol, R-123 and Fc-72 (Fluorinert Electronic Liquid)
6	5.6m m in 20C° 5.0m m in 100C	E. Sedighi[7]	Water Cooling	40-70	NA	420 cm ³ /min (water)	0-90	Fc-72 (Fluorinert Electronic Liquid)
7	2	Sameer Khandekar [5]	Water Cooling [20degree]	50	NA	NA	0-90	R-123

6. E. Sedighi has performed of Thermal instability of a Closed loop pulsating heat pipe: combined effect of orientation and filling ratio, FC-72 as a working fluid, angle of inclination 0-90, water velocity 420 cm³/min, 5.6mm ID at 20° C and 5.0mm at 100° C, at 40-70 % filling ratio gives better performance. Modes of cooling is Water cooling.
7. Sameer khandekar has performed an experiment to investigate The thermal characteristics of single-turn pulsating heat pipe with an extra branches, ID 2mm, angle of inclination 0-90, r-123 as working fluid and 50% filling ratio.

He has been observed that 50% filling ratio gives better performance and modes of cooling is Water cooling.

In view of the numerous applications of CLPHP, the present paper is aimed to investigate the following objectives:

- (1) The effect of Filling Ratio (FR) on the performance of CLPHP.
- (2) The effect of input heat flux on the performance of CLPHP.

3. Experimental Setup

The experimental setup is developed with 2.15 mm internal diameter copper tube with 9 turns and shown in Fig. 1(b). Evaporator section is fabricated with the help of cartridge heaters ($\text{Ø}10.0 \times 40\text{mm}$) of 100 W. Copper tubes were inserted in the heater block. The adiabatic section is developed by wrapping glass wool on copper tubes.

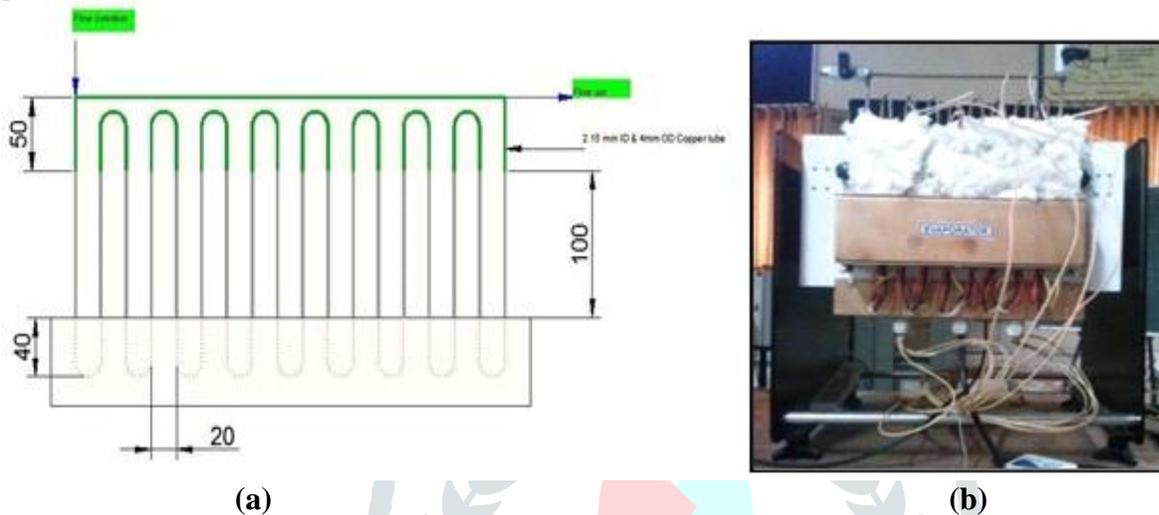


Fig. 1 (a) schematic diagram (b) experimental setup

The glass wool is wrapped firmly to reduce the heat loss from this section. In condenser section, Copper tubes with bends are kept open in atmosphere to dump the heat into the atmosphere. Schematic diagram with geometrical dimensions are shown in Fig. 1(a). Data acquisition system is used to scan and record the data on computer in each 2 seconds. A carbon dimmer is used to adjust input voltage and subsequently heat fluxes. K-type thermocouples are used at different locations in evaporator (total 09 numbers) and condenser section (total 04 numbers) for temperature measurement. Vacuum pump is used to evacuate the system up to 9×10^{-5} mbar.

The system is first flushed with the help of pressurized air followed by evacuating the system with the help of vacuum pump. Desired quantity of fluid is admitted to the system with the help of a syringe & filling valve. Now close the valve & set system for heating. Heat input is controlled with the help of dimmer. Data logging is started immediately with heating & thermal performance of CLPHP is monitored as well as calculated.

4. Results & Discussion

The effect of filling ratio in PHP is presented in this section. The system performance is measured in terms of thermal resistance (R_{th}). Thermal resistance of a system is the measurement of a body's ability to prevent heat from flowing through it and calculated from Eq.

$$R_{th} = \frac{(T_e - T_c)}{Q}$$

T_e and T_c are average steady-state evaporator and condenser temperatures respectively and Q is the heat input in the evaporator. The influence of Filling Ratio (FR) and input heat flux is discussed in the following sections.

4.1 Effect of Filling Ratio

Filling ratio represents the amount of liquid present in the system by its volume percentage. Experiments are conducted with varying FR as 40%, 50% and 60%. Filling ratio represents the amount of liquid present in the system by its volume percentage. If FR=0%, the system acts as conduction mode of heat transfer which shows very high value of thermal resistance. If FR=100%, the system acts as thermo syphon. For FR=60%, larger volume of the system is occupied by the working fluid. Hence fewer bubbles would be formed in the system. So, bubble pumping action is reduced and system performance lowers. Contrary for FR=40%, bubble would find it easier to move in the system as compared to FR=60%. More bubbles would generate in the system which leads to better pumping action. Hence, improve the performance of the system.

4.2 Effect of input Heat flux-

Input heat-flux is the driving force for pulses in the CLPHP. PHP may be used to various heat load conditions. To investigate the influence of various heat fluxes on the performance of CLPHP, experiments are carried out for input heat fluxes ranging from 10W to 50W at different FR. the thermal resistance of the system decreases with increase in heat flux. Thermal resistance is observed higher for FR=40% compared to FR of 50% and 60% at lower value of heat input. It starts to decrease with increase in input heat flux at all FR. From 60W till the maximum heat input level (100 W) the CLPHP undergoes a sudden increase of the thermal resistance, which appears directly related to the combined effect of gravity and the heat input level.

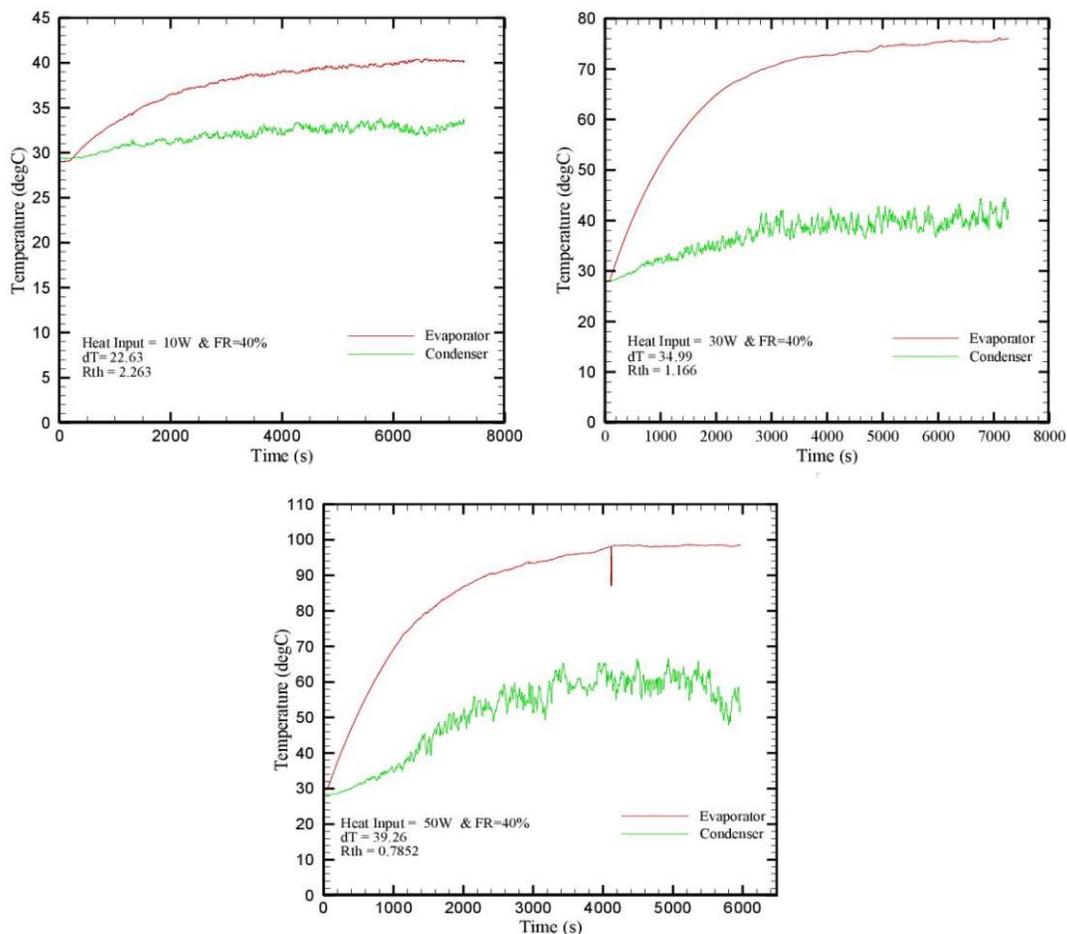


fig1. Effect of FR at 10W, 30W, 50W heat input [1]

As shown in Fig. 1, different temperature variation is observed for evaporator and condenser sections when heat flux is kept constant at 30W and FR is varied as 40%, 50% and 60%. It is observed that increase in FR increases the system thermal resistance for the same heat input.

The similar effect is observed for heat flux of 40 W and FR of 40% and 60% as shown in Fig. 2. For all heating conditions and FR=40%, the system performs better as compared to that of 50% and 60%. This is because of

the bubble dynamics as well as latent heat advantage coupled with sensible heat transport through liquid plug is sufficient to get pulsating mode advantage [1].

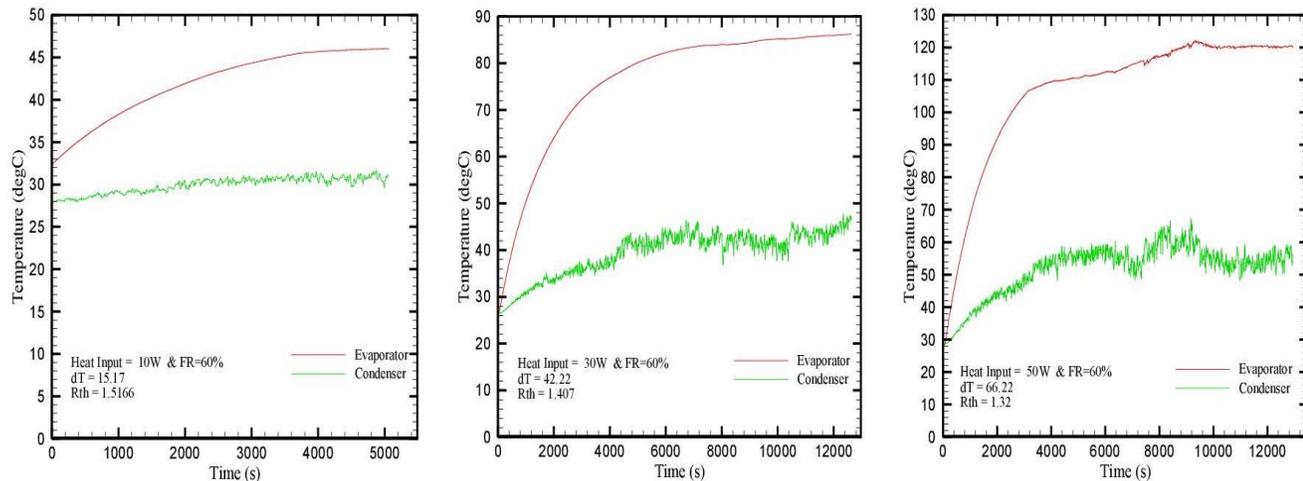


Fig.2 Effect of FR at 10W, 30W, 50W heat input [1]

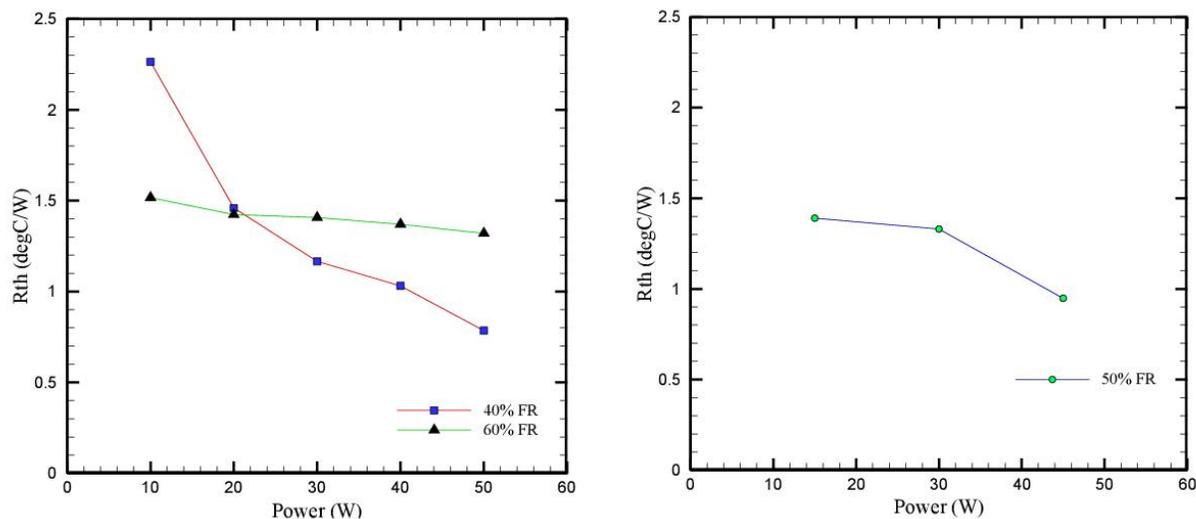


Fig.3 Effect of input heat flux on thermal resistance for different FR [1]

Thermal resistance is observed higher for FR=40% compared to FR of 50% and 60% at lower value of heat input. It starts to decrease with increase in input heat flux. The influence of input heat flux on thermal resistance of the system at different FR is shown in Fig.3.

5. Conclusion

The present paper is an attempt to investigate the performance of the CLPHP. The conclusion drawn from the present paper is as follows:

1. The system performs better with lower FR for the same input heat flux.
2. The evaporator temperature T_e and condenser temperature T_c increase with increase in both FR and input heat flux [1].
3. The results showed that the thermal resistance decreases with the rise of heating power due to the rise of circulating speed. For the increase of inclinations among the test CLPHPs, the thermal Resistance decrease with the rise of inclinations due to gravity effect [4].

6. REFERANCES

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