ISSN- 2350-0530(O) ISSN- 2394-3629(P)
IF: 4.321 (CosmosImpactFactor), 2.532 (I2OR)

INTERNATIONAL JOURNAL OF RESEARCH – GRANTHAALAYAH
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Science

# A REVIEW OF EXPERIMENTAL STUDY AND CFD BASED SIMULATION OF CLOSED LOOP PULSATING HEAT PIPE

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**DOI:** https://doi.org/10.29121/granthaalayah.v4.i7.2016.2619

## ABSTRACT

***Closed loop pulsating heat pipe is very effective tool for removal of heat from very small electronic devices. In this study various literature related to CLPHP are studied and various parameters that effect the performance of CLPHP. It was found from literature that length of pipe, Number of turns, cooling fluid effect the performance of pipe.***

**Keywords:**
*Oscillating behavior, Cooling fluid, Heat pipe.*

**Cite This Article:** Monika Tiwari, and Dr. Nilesh Diwakar, "A REVIEW OF EXPERIMENTAL STUDY AND CFD BASED SIMULATION OF CLOSED LOOP PULSATING HEAT PIPE" International Journal of Research – Granthaalayah, Vol. 4, No. 7 (2016): 265-270.

## 1. INTRODUCTION

A heat pipe is a heat-transfer device that is used for effectively managing the heat transfer between two interfaces. A heat pipe has a liquid in contact with a thermally conductive solid surface which is turned into vapor by absorbing heat from that surface. The vapor then moves along the heat pipe to the cold interface and condensed to a liquid again and in the process releases the latent heat. The liquid further returns back to the hot interface and the cycle is repeated. Heat pipes are considered as highly effective thermal conductors because of very high heat transfer coefficients for boiling and condensation.

There are two types of pulsating heat pipe:
1) Closed loop heat pipe
2) Open loop heat pipe

Closed loop pulsating heat pipe are most efficient than open loop devices because of the fluid circulation that is superposed upon the oscillations within the loop. Closed loop pulsating heat pipes (CLPHPs) are complex heat transfer devices having a strong thermo-hydrodynamic coupling governing the thermal performance. Close Loop Pulsating heat pipes (CLPHPs) are best suited for microelectronics. The pipe is first evacuated and then filled slowly using working fluid. The tube at one end receives heat further transferring it to the other end by a pulsating action of the liquid–vapor/slug-bubble system. The liquid and vapor slug/bubble transport is caused by the thermally induced pressure pulsations inside the device and no external mechanical power is required. The type of fluid and the operating pressure inside the pulsating heat pipe depend on the operating temperature of the heat pipe. The region between evaporator and condenser is adiabatic. T

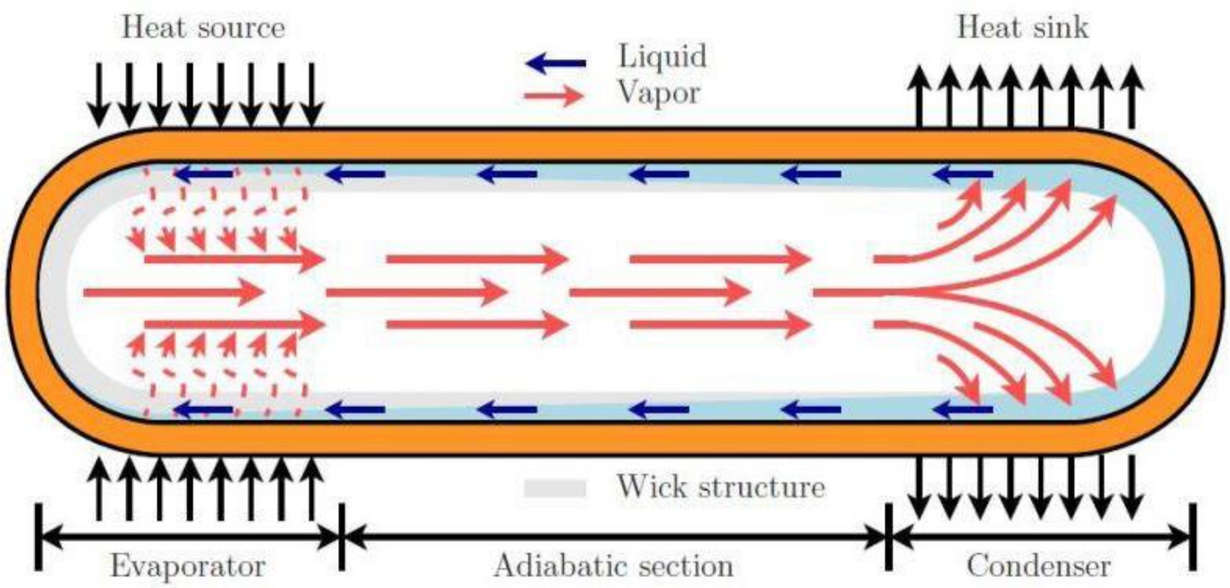


***Figure 1:*** Schematic diagram of Heat Pipe

## 2. REFRIGERANTS

"Freon" is a trade name for a family of haloalkane refrigerants manufactured by DuPont and other companies. These refrigerants were commonly used due to their superior stability and safety properties: they were not flammable at room temperature and atmospheric pressure, nor obviously toxic as were the fluids they replaced, such as sulfur dioxide. Haloalkanes are also an order(s) of magnitude more expensive than petroleum derived flammable alkanes of similar or better cooling performance. Unfortunately, chlorine- and fluorine-bearing refrigerants reach the upper atmosphere when they escape. In the stratosphere, CFCs break up due to UV radiation, releasing their chlorine free radicals.

These chlorine free radicals act as catalysts in the breakdown of ozone through chain reactions. One CFC molecule can cause thousands of ozone molecules to break down. This causes severe damage to the ozone layer that shields the Earth's surface from the Sun's strong UV radiation, and has been shown to lead to increased rates of skin cancer. The chlorine will remain active as a catalyst until and unless it binds with another particle, forming a stable molecule. CFC refrigerants in common but receding usage include R-11 and R-12. Newer refrigerants with reduced ozone depletion effect such as HCFCs (R-22, used in most homes today) and HFCs (R-134a, used in most cars) have replaced most CFC use. HCFCs in turn are being phased out under the Montreal Protocol and replaced by hydrofluorocarbons (HFCs), such as R-410A, which lack chlorine. However, CFCs, HCFCs, and HFCs all have large global warming potential. Newer refrigerants are currently the subject of research, such as supercritical carbon dioxide, known as R-744. These have similar efficiencies compared to existing CFC and HFC based compounds, and have many orders of magnitude lower global warming potential.

## 3. IMPORTANCE OF REFRIGERANT

The thermodynamic efficiency of a refrigeration system depends mainly on its operating temperatures. However, important practical issues such as the system design, size, initial and operating costs, safety, reliability, and serviceability etc. depend very much on the type of refrigerant selected for a given application. Due to several environmental issues such as ozone layer depletion and global warming and their relation to the various refrigerants used, the selection of suitable refrigerant has become one of the most important issues in recent times.

## 4. REFRIGERANT SELECTION CRITERIA

Selection of refrigerant for a particular application is based on the following requirements:

- Thermodynamic and thermo-physical properties.
- Environmental and safety properties.
- Economics.

Experimentally investigated the performance of closed loop pulsating heat pipe using a single turn pipe to demonstrate the complex hydrodynamics. Optimum filling ratio and optimum inclined angle were found on the basis of best performance of CLPHP. There is great effect of gravity and number of turns on the performance of closed loop pulsating heat pipe by experimentation of closed loop heat pipe of different number of turns. CLPHP was made up of copper tubes of 1.0 and 2.0 m internal diameter,[2]. The fluids employed are ethanol, water and R-123. the behavior of wall temperature oscillations in a closed-loop pulsating heat pipe using non-linear analyses on temperature data. The tests were performed with heat pipe consisting of 5turns and made of copper capillary tube which had an internal diameter of 2 mm, [3] .Ethanol is used as the working fluid with filling ratios (FR) of 30%, 50% and 70%. Wall temperature fluctuations were recorded under three different heating power inputs of 37, 60, and 87 W. Various methods like pseudo-phase-plane trajectories, correlation dimensions (DE), Lyapunov exponents, and recurrence plots were used to analyze the non-linear dynamics characteristics of temperature oscillation data [6]. Further, a numerical code to investigate the thermal performance of closed loop pulsating heat pipe (CLPHP). This model takes into consideration the effects of the local pressure losses due to the presence of turns which have always been neglected by previous models; it can simulate CLPHPs working with different fluids (ethanol, R123 and FC-72), different number of turns, various inclination angles as well as different input heat fluxes at the evaporator [8]. Two heat pipes made of copper capillary tubes with an overall size of 122 mm X57 mmX5.5 mm is used for the experimental study, one had 16 parallel square channels having a uniform cross-section of 2 mm X 2 mm (uniform CLPHP), while the other had 16 alternative size of parallel square channels (non-uniform CLPHP; a cross-section 2 mm X 2 mm

 ISSN- 2350-0530(O) ISSN- 2394-3629(P)
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and a cross-section of 1mm X 2 mm in alternating sequence). Test results shows that the performance of PHP rises with the inclination but the uniform channel CLPHP is not functional at horizontal configuration whereas the proposed non-uniform design is still functional even at horizontal arrangement [12]. Split type air conditioner for residence has two disadvantages. Firstly, the large pressure drop occurred in the condenser as refrigerant flows inside very small copper tube which further causes higher compressor power, resulting in decrease of Coefficient of Performance (COP). Secondly, a lot of wasted heat losses to surrounding since the refrigerant has to condense after passing through condenser. To recover pressure drop and heat from the condensing process, this study stated to use the CLOHP instead of the conventional condenser in split type air conditioner. It can be seen after the experiments that COP of the conventional condenser was higher than the CLOHP condenser while energy efficiency rating (EER) of the conventional condenser was lower than the CLOHP condenser. the heat transfer characteristics of closed loop pulsating heat pipe (CLPHP). Thermal efficiency of CLPHP for different filling ratios with two different working fluids, water and ethanol are compared with each other[15]. The aim of research work presented in this paper is to better understand the heat transfer characteristics of these mechanisms through experimental investigations. Experiments are conducted on a CLPHP made of capillary tube of 2.2 mm inner diameter. Filling ratios of 100 %, 82.5%, 63%, 41.3% and 28% are used for finding out heat transfer characteristics and the performance of the CLPHP. The results indicate that the performance of this device changes with change of working fluid, filling ratios and heat input [16]. The effect of inclination angle and working fluid on the heat transfer characteristics and performance of CLPHP. The experiments were performed using two different working fluids water and ethanol with inclination angle of 0° (vertical), 30°, 45°, 60°, 75° and 90° (horizontal). The CLPHP is made of 148 cm long copper capillary tube of 3.0 mm outer diameter and 2.0 mm inner diameter creating a total of 13 turns. The total length of evaporator section is 39.5 cm and condenser section is 31.5 cm; while the rest is assumed to be adiabatic[18]. The evaporator section is heated by electrical heat input, while the condenser section is cooled by atmospheric air flow. Since a PHP is recognized as a two phase heat transfer device, for comparative studies it is operated as a double-phase system by filling it 70% with the working fluid. The comparative study results in a better understanding of the underlying physics of the PHP operation. The experimental results indicate a strong influence of gravity and thermo physical properties of the working fluid on the performance of the CLPHP. The results demonstrate the effect of the input heat flux, inclination angle and physiochemical properties of the working fluid on the thermal performance of the device. the Startup heat load, maximum heat load and optimum fill ratio of Pulsating Heat Pipe (PHP) of 16 turn, 1 mm ID, 2 mm OD and 9.6 m total length experimentally for water and ethanol as working fluids. PHP is operated in vertical bottom heat mode. Evaporator and condenser temperatures are maintained at 100oC and 28oC respectively [19]. Temperature fluctuations of adiabatic section at startup and maximum heat loads are reported. Experimental results indicate that, startup heat load is independent of fill ratio, but maximum heat load depends on fill ratio. Optimum fill ratio for maximum heat load depends on working fluid for a given PHP and operating temperatures. the quasi-steady state corresponding to best thermal performance consists of continuous unidirectional flow circulations, while the state corresponding to poor thermal performance is characterized by the intermittent bidirectional flow reversals. A temporal scaling analysis is presented to estimate the order of magnitude of the equilibrium frequency of phase change and ensuing oscillations [20]. These order-of-magnitude estimates closely match with the experimentally observed frequencies. The spectral contents of each quasi-steady state are analyzed and it is found that dominant frequencies of flow oscillations are in the range of 0.1 to 3.0 Hz with each quasi-steady state exhibiting a characteristic power spectrum. This provides the necessary velocity scaling estimates, primary information needed for any progress in design of pulsating heat pipes.

From the literature review it can be concluded that various authors mainly studied various parameters that affects the performance of closed loop pulsating heat pipe. Also it is found that the main emphasis is given on analyzing the physics behind the working of closed loop heat pipe by using mathematical equations or with the aid of any numerical solvers or by experimental analysis in order to improve the efficiency and performance of closed loop heat pipes.

## 5. CONCLUSION

Various parameters involved in the closed loop pulsating heat pipe are studied. It was found that the gravity, number of loops, length and diameter of pipe and refrigerant used all play a significant role in the performance of CLPHP.

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