INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online) / 2278-7631 (Print)

Literature Review on Heat Transfer Characteristics of Closed Loop Pulsating Heat Pipe and Thermal Performance

Nilesh Gedam
PG Student, Mechanical Engineering Department,
G.H. Raisoni College of Engineering, Nagpur, India

Dr. P.V. Walke
Faculty, Mechanical Engineering Department,
G.H. Raisoni College of Engineering, Nagpur, India

Abstract:
Closed loop pulsating heat pipes (CLPHPs) are complex heat transfer devices having a strong thermo hydrodynamic coupling governing the thermal performance. A wide range of pulsating heat pipes is experimentally studied thereby providing vital information on the parameter dependency of their thermal performance. Bubble generation and growth in the evaporator and simultaneous collapse in the condenser. The internal diameter is a parameter which necessarily affects the very definition of a pulsating heat pipe. CLPHP design is to make the thermal performance. To take data accuracy of heat transfer by measuring the volume flow rate. And the inlet and out let temperature of coolant flowing through the condenser section. Try to make close loop in between condenser and evaporator. Thermal performance report within ±30% accurate. Controlling the input heat flux and the condenser temperature evaporator temperature is a dependent variable. There are some important data to evaluate the thermal performance of PHPs, such as heat load, heat flux, and average evaporator temperature. In this paper, a wide range of pulsating heat pipes is experimentally studied thereby providing vital information on the parameter dependency of their thermal performance. The influence characterization has been done for the variation of internal diameter, number of turns, working fluid and inclination angle (from vertical bottom heat mode to horizontal orientation mode) of the device. CLPHPs are made of copper tubes of internal diameters 2.0 and 1.0 mm, heated by constant temperature water bath and cooled by constant temperature water–ethylene glycol mixture (50% each by volume). The number of turns in the evaporator is varied from 5 to 23. The working fluids employed are water, ethanol and R-123. The results indicate a strong influence of gravity and number of turns on the performance.

Introduction

Oscillating, loop type or pulsating heat pipes (PHPs) are a relatively new type of heat transfer devices, which may be classified in a special category of heat pipes. They have been introduced in the mid-1990s. The first predecessor of the family of PHPs appeared in the 1990s , a few examples of which are shown in Fig. 1. The basic structure of a typical pulsating heat pipe consists of meandering capillary tubes having no internal wick structure. It can be designed in at least three ways: (i) open loop system, (ii) closed loop system and (iii) closed loop pulsating heat pipe (CLPHP) with additional flow control check valves, as shown in Fig.. The closed passive system thus formed is evacuated and subsequently filled up partially with a pure working fluid. The optimum quantity of working fluid needed depends on various parameters and is still an area of research. Temperature gradients give rise to temporal and spatial pressure disturbances in the wake of phase change phenomena (bubble generation and growth in the evaporator and simultaneous collapse in the condenser). The generating and collapsing bubbles act as pumping elements transporting the entrapped liquid slugs in a complex oscillating–translating–vibratory fashion; a direct consequence of thermo-hydrodynamic coupling of pressure/temperature fluctuations.

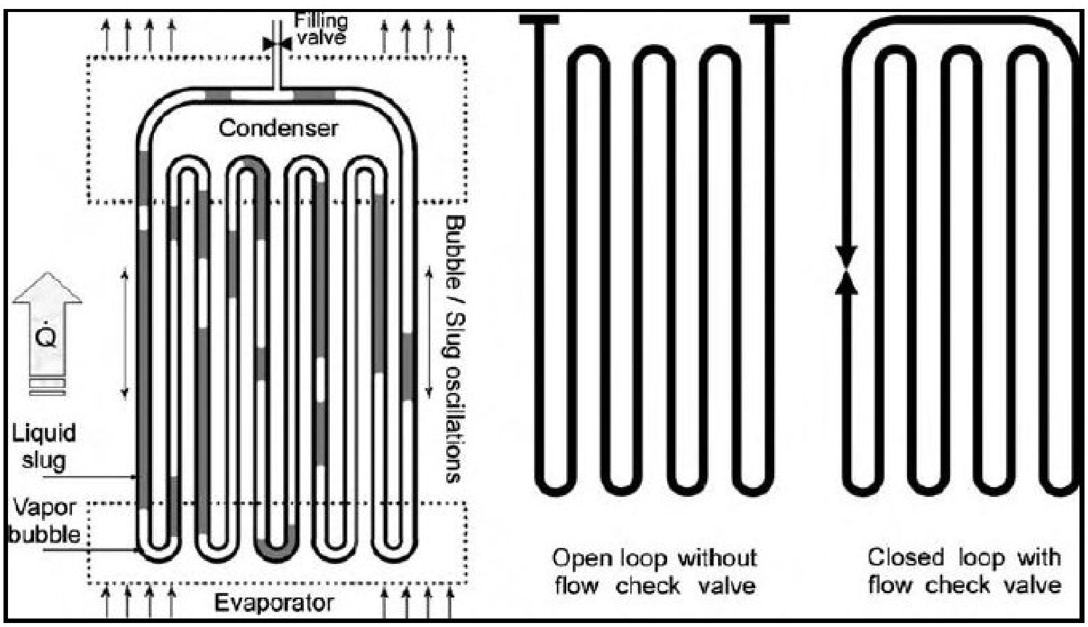

Figure 1: Closed loop pulsating heat pipe and its design

A closed loop pulsating heat pipe is thermally more advantageous than an open loop device because of the possibility of fluid circulation. Although a certain number of check valves have shown to improve the performance, miniaturization of the device makes it difficult and expensive to install such valve(s). Therefore, a closed loop device without any check valve(s) is most favorable from many practical aspects. This experimental matrix aimed at better understanding the quantitative parameter dependency of CLPHPs. It is well known that there are various limitations of the performance of heat pipes, e.g. capillary limit, boiling limit, entrainment limit, sonic limit, viscous limit. With regard to cooling electronic devices, the capillary and boiling limits are in general the most important ones. In both cases the limit will manifest itself by an unacceptable over overheating of the evaporator due to lack of cooling working fluid (dry-out, burn-out). While quite some research has been performed on the operational behavior and physical phenomena in PHPs, including various experimental studies.

Effect Of Filling Ratio On Performance

The thermal performance of the CLPHP with 2 mm ID tubes for the horizontal heat mode with the filling ratios 30%, 50% and 70%, respectively. A reasonable explanation is that the total liquid inventory in the CLPHP with 2 mm ID tubes is considerably higher (about 4 times) than that in the CLPHP with 1 mm ID tubes. The second difference is that performance differences due to the different filling ratios are much smaller in the CLPHP with 2 mm ID tubes than in the CLPHP with 1 mm ID tubes.

Effect Of Operating Orientation

One of the aims of good CLPHP design is to make the thermal performance, as far as possible, independent of the operating orientation. At a first glance, two physical phenomena affect the CLPHP performance with respect to orientation. The first is of course, the effect of gravity on slug flow and the second is the effect of total number of meandering turns on the level of internal temporal and spatial dynamic pressure perturbations. In addition to these two, the input heat flux is also a strong parameter, which affects dynamic instability ,especially in density wave oscillations, and is therefore believed to affect the thermal performance of CLPHPs with respect to orientation. This aspect remains to be further explored and will not be highlighted in this paper. It is to be noted that for performance in vertical orientation, the effect of input heat flux has already been experimentally demonstrated, when the number ofturns is higher than the critical value, although the performance improves with increasing the inclination angle from horizontal orientation, the performance remains nearly comparable from vertical position to about 60°.

Literature Review

- The first examples of the family of modern PHPs appeared in 1990 [Akachi, 1990] as shown in following figure 2. In this patent, twenty four different preferred embodiments of what is referred to as */RRS 7\SH +HDW 3LSH* were described. All the proposed structures were characterized by the presence of at least one non return flow check valve integrated in the tubes for imposing a preferred flow direction.

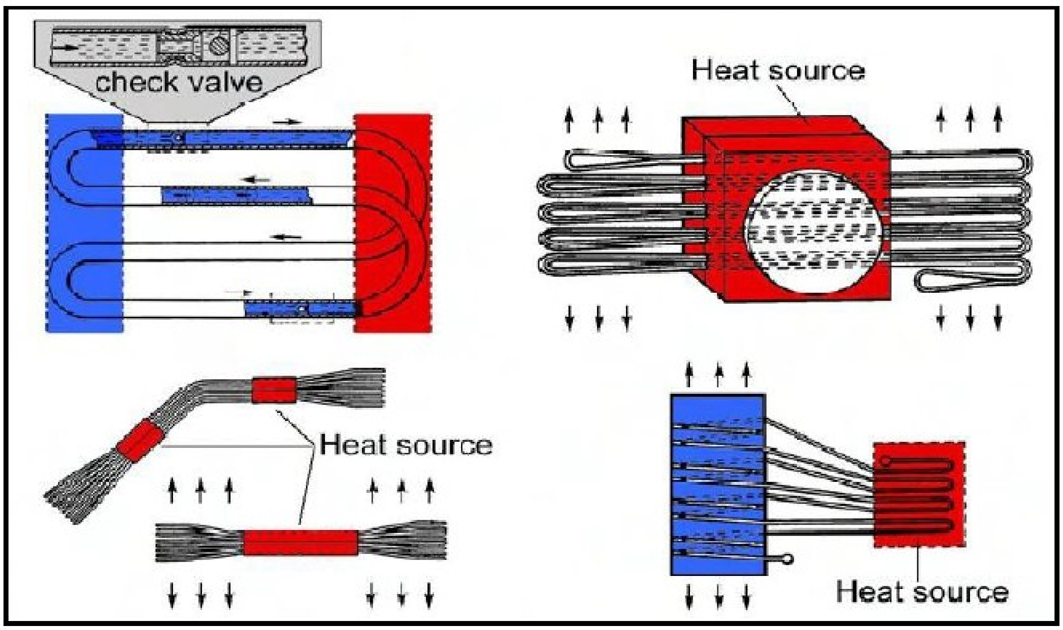

Figure 2: Some practical designs of pulsating heat pipes

- Maezawa et al. [1995] studied an open loop PHP consisting of 20 turns of copper tube (ID 1.0 mm) of total length 24 meters. R 142b was used as the working fluid. Heat was supplied with flat electrical heaters sandwiched around the evaporator section and a water jacket was used in the condenser section. Filling ratio and inclination were varied and the typical results with the set up are shown in Figure 2 5. Temperature fluctuations at the adiabatic wall section were also recorded.

- Kawara et al. [1996] have undertaken a visualization study of an open loop PHP employing proton radiography for motion visualization (refer Figure 2 6) . A 20.0 mm proton beam was passed through the test section and converted to visible light by a fluorescent screen. The PHP was formed of rectangular grooves of 0.6 x 0.7 mm! in a 190 x 50 x 1.3 mm" base plate.
- TS Heatronics Ltd., Japan [Akachi et al. 1996; Akachi and Miyazaki, 1997; Akachi and Poliăek, 1997] have developed a range of PHPs termed as μHEATLANE, and μKENZAN, fins (Figure 2 7 a, b) with material combinations such as stainless steel liquid N2, copper with water, methanol, R 113 and R 142b and aluminum R 142. Typical thermal resistance of about 0.3 K/W at an air cooling velocity of 3 m/s was obtained for KENZAN fins (outside dimensions 60.0 x 60.0 x 65.0 mm") fabricated from copper tubes (ID 0.7 mm, OD 1.0 mm) filled with R142b, having 152 turns and soldered to a copper base plate. Similar fin structures, as depicted in Figure 2 7 b, have been employed for MCM and IGBT cooling.
- Maezawa et al. [1997] have tested another set of open loop PHPs with R 142b and water as the working fluid with a filling ratio of 50%. The heat pipes, both having 40 turns with a total length of 52.5 meters were made of copper tube of ID 2.0 mm and 1.0 mm respectively. Effect of diameter and working fluid was observed as shown in Figure 2 8. It can be seen that the performance for the bottom heat mode was better than the horizontal operation mode. In addition, poor performance for top heat mode was observed.
- Hosoda et al. [1999] fabricated a CLPHP consisting of 10 turns with a glass tube having OD 4.0 mm and ID 2.4 mm. Water was used as the working fluid with a small amount of black ink added for visualization. The evaporator and condenser sections were enclosed in an acrylic box and supplied with hot water (varied from 55ƒC to 70ƒC) and cold water (30ƒC fixed). The adiabatic section was also enclosed and evacuated. Figure 2 9 shows the effect of heat throughput and filling ratio vs. temperature difference between the evaporator and condenser. The accuracy of measurements was not very high and so the data should be looked at as providing only quantitative trends.

Conclusion

A range of closed loop pulsating heat pipes has been experimentally investigated to study the effects of various influence parameters.

- Gravity certainly affects the heat throughput. Although the internal diameter of the tubes tested in the present study,
- For FR = 50% the CLPHP shows the maximum performance limit and the lowest thermal resistance.
- By changing the orientation from vertical toward horizontal, a change in the thermal resistance with respective to the reference vertical orientation observed.

Reference

1. P. Charoensawan, S. Khandekar, M. Groll, P. Terdtoon, Closed loop pulsating heat pipes – Part A: parametric experimental investigations, Appl. Therm. Eng. 23 (2003) 2009–2020.
2. S. Khandekar, P. Charoensawan, M. Groll, P. Terdtoon, Closed loop pulsating heat pipes – Part B: visualization and semi-empirical modeling, Appl. Therm. Eng. 23 (2003) 2021–2033.
3. S. Khandekar, N. Dollinger, M. Groll, Understanding operational regimes of pulsating heat pipes: an experimental study, Appl. Therm. Eng. 23 (2003) 707–719.
4. S. Rittidech, P. Terdtoon, M. Murakami, P. Kamonpet, W. Jompakdee, Correlation to predict heat transfer characteristics of a closed end oscillating heat pipe at normal operating condition, Appl. Therm. Eng. 23 (2003) 497–510.
5. X.M. Zhang, J.L. Xu, Z.Q. Zhou, Experimental study of a pulsating heat pipe using FC-72, ethanol and water as working fluids, Exp. Heat Transfer 17 (2004) 47–67 J.L. Xu, X.M. Zhang, Start-up and steady thermal oscillation of a pulsating heat pipe, Heat Mass Transfer 41 (2005) 685–694.
6. J.L. Xu, Y.X. Li, T.N. Wong, High speed flow visualization of a closed loop pulsating heat pipe, Int. J. Heat Mass Transfer 48 (2005) 3338–3351.
7. M.B. Shafii, A. Faghri, Y. Zhang, Thermal modeling of un looped and looped pulsating heat pipes, ASME J. Heat Transfer 123 (2001) 1159–1172.
8. M.B. Shafii, A. Faghri, Y. Zhang, Analysis of heat transfer in un looped and looped pulsating heat pipes, Int. J. Numer. Meth. Heat Fluid Flow 12 (2002) 585–609.
9. Y. Zhang, A. Faghri, Heat transfer in a pulsating heat pipe with open end, Int. J. Heat Mass Transfer 45 (2002) 755–764.
10. Y. Zhang, A. Faghri, Oscillatory flow in a pulsating heat pipe with arbitrary number of turns, J. Thermophys. Heat Transfer 17 (2003) 340–347.
11. R.T. Dobson, Theoretical and experimental modeling of an open oscillatory heat pipe including gravity, Int. J. Therm. Sci. 43 (2004) 113–119.
12. P. Sakulchangsatjatai, P. Terdtoon, T. Wongratanaphisan, P. Kamonpet, M. Murakami, Operation modeling of closed end and closed loop oscillating heat pipe at normal operating condition, Appl. Therm. Eng. 24 (2004) 995–1008.
13. Y. Miyazaki, H. Akachi, Oscillating heat pipe with check valves, in: Proc. 6th Int. Heat Pipe Symposium, Chiang Mai, Thailand, 1996.