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Design Parameters of Pulsating/Oscillating Heat Pipe: A Review

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Abstract— Closed loop pulsating heat pipe is a small heat transfer device especially suited for thermal management of electronic application .The unique feature of CLPHP compared with conventional heat pipe is that, there is no wick structure to return the condensate to the evaporator section, thus there is no counter flow between the liquid and the vapour .This paper reviews an influence of various design parameter and operational orientation on a PHP/OHP. This paper attempt theoretical and experimental investigation and scrutinized that internal diameter of tube and orientation numbers of turn's evaporator length, adiabatic length affect the performance of PHP/OHP. A filling ratio of 50% of its total volume is optimum.

Keywords- CLPHP, PHP/OHP.

I. INTRODUCTION

There are novel technologies which consist of small in size and shape electronic devices, because they are more efficient and compact in nature , due to this it has less area for cooling system , to manage these type of problem i.e. thermal management of microelectronic devices there is a requirement of miniaturization of heat exchangers[1]. A pulsating heat pipe or oscillating heat pipe has best potential to handle the above problem. A pulsating heat pipe / oscillating heat pipe are relatively young members in the family of heat pipe. In such type of device a heat transfers mechanism that can transport large quantities of heat with a very small difference in temperature [6]. PHPs/OHPs were first presented in 1971 by Smyrnov in a Russian Patent, and in 2004 in a US patent [2]. Next was by Akachi.H. suggested a new variant of the PHPs construction in 1990[3].

II. CONSTRUCTION

The basic structure of PHP/OHP is small, light weight, simple in structure and highly efficient. It consists of meandering capillary tubes having no internal wick structure arranged in serpentine manner. It can be designed in at least three ways:

a) open loop system
b) Closed loop system and
c) Closed loop pulsating heat pipe (CLPHP) with additional flow control check valves

The closed passive system thus formed is evacuated and subsequently filled up partially with a pure working fluid, which distributes itself naturally in the form of liquid – vapor plug and slugs inside the capillary tube.

It has been shown by previous studies that 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. Studies have already identified various design parameters affecting the performance of CLPHPs [4, 5].

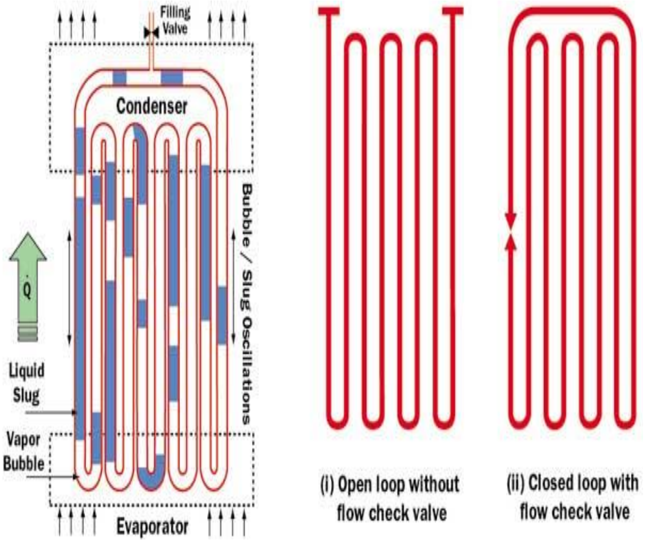

Fig 1. Schematic of pulsating heat pipe and its design variations from "An introduction to pulsating heat pipe by Manfred Groll et.al.2003."

III. OPERATION

The device is first evacuated and subsequently filled up partially with a pure working fluid. The entire essence of thermo-mechanical physics lies in the two-phase, bubble–liquid slug system formed inside the tube-bundle due to the dominance of surface tension forces. This tube-bundle receives heat at one end and is cooled at the other. 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 with the void fraction (mal-) distribution. This causes heat transfer, essentially as a combination of sensible and latent heat portions [4, 5] .

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IV. INFLUENCE OF VARIOUS DESIGN PARAMETERS

S.Khandekar et.al. [7] has another PHP setup was made consisting of 10 glass tubes (ID 2.0mm) connected by copper U-turns. As input parameters, fill rate, heat load, and tilt angle are varied. Axial temperature distribution is recorded with thermocouples. The results enable explanations for operational characteristics and performance limits, which are influenced by capillary resistance, gravity, and thermo fluid dynamic effects. The measured thermal resistances were strongly influenced by the tilt angle, fill rate, and cross-section geometry. The best performance of the PHPs with rectangular cross section was observed with fill rates less than 10% in vertical orientation.

P. Charoensawan et.al [8]; has a work on effect to CLPHP thermal performance depends on various parameter like internal diameter of tube, number of turns, working fluid and inclination angle of the device and experimentally studied. The conclusion of this experimentation were, gravity has a great influence on the performance on the CLPHP, internal diameter must be specified with critical Bond number within the limit, the performance can be increased by increasing the ID and/or no. of meandering turns, the buoyancy forces effect bubble shape . Different fluids are beneficial under different operating conditions and the relative share of latent heat and sensible heat, flow behavior.

Honghai Yang et.al. [9] were presents paper on experimental study on the operational limitation of closed loop pulsating heat pipes (CLPHPs). Three operational orientations were investigated, viz. vertical bottom heated, horizontal heated and vertical top heated orientations. The effects of inner diameter, operational orientation, filling ratio and heat input flux on thermal performance and performance limitation were investigated. The CLPHPs were operated till a performance limit characterized by serious evaporator overheating (dry-out) occurred. Rather high heat loads could be accommodated. An experimental study was performed on two closed loop pulsating heat pipes (CLPHPs) to investigate the effects of inner diameter, filling ratio, operational orientation and heat load on thermal performance and occurrence of performance limitation in the form of evaporator dry-out. In general, the CLPHPs obtain the best thermal performance and maximum performance limitation when they operate in the vertical bottom heat mode with 50% filling ratio. As the inner diameter decreases, performance differences due to the different heat modes (i.e. the effect of gravity) become relatively small and even insignificant.

The effect of inner diameter and inclination angles on operation limit of a closed loop oscillating heat pipes with check valves (CLOHP/CV) were studied in this paper. Copper tubes of ID 1.77 and 2.03 mm with 10 turn, with R123 was used as the working fluid. The inclination angles were 0, 20, 40, 60, 80 and 90° with 5 equal lengths for evaporator, adiabatic and condenser sections. P.Meena et al [10] were concluded that when the inner diameter changed from 1.77-2.03 mm the critical temperature increased. And when increase the inclination angles from 0 until to 90° the critical temperature increased.

S. Rittidech et.al.[11] a visualization study of the internal flow patterns of a closed–loop oscillating heat-pipe with check valves (CLOHP/CV) at normal operating condition for several evaporator lengths (Le), and ratio of check valves to number of turns (Rcv) has been conducted. This article describes the effects of varying Le, and Rcv on flow patterns. It was found that the internal flow patterns could be classified according to the Le and Rcv as follows: At the high heat source when the Le decreases the main flow changes from the bubble flow with slug flow to disperse bubble flow. The Rcv decreases the main flow changes from the disperse bubble flow with bubble flow to disperse bubble When the velocity of slug increases, the length of vapor bubbles rapidly decreases and the heat flux rapidly increases. The ratio of check valves to number of turns decreases the main flow changes from the dispersed bubble flow with bubble flow to disperse bubble flow for the high heat source.

P. Meena, et.al. [12] has aims to study the effect of evaporator section lengths and working fluids on operational limit of closed loop oscillating heat pipes with check valves (CLOHP/CV). It is experimentally concluded when the evaporator lengths increased the critical heat transfer flux decreased. There was working fluids change from R123 to Ethanol and water the critical heat flux decreased. The latent heat of vaporization affects the critical heat flux. The working fluid with the lower latent heat of vaporization exhibits a higher critical heat flux.

Stéphane Lips Ahlem Bensalem et.al. [13] various experiments were conducted on two full-size pulsating heat pipes (PHP) which differed from their diameter, number of turns, and working fluid. The analysis of the experimental results for low heat fluxes the PHP performance is sensitive to the orientation and for high heat fluxes, it is independent from the orientation. The experiments were conducted at the scale of a single branch of a PHP. The test section was either adiabatic or heated. The adiabatic experiments brought to therefore the importance of dynamic contact angles in the flow and the dissymmetry between the advancing and receding contact angle. The non-adiabatic experiments showed that at low flux, the flow is disturbed by bubble nucleation, while at high heat flux; the main heat transfer mechanism is thin film evaporation, with a completely different thermal and hydrodynamic behavior.

N. Panyoya et.al. [14] the purpose of this research was to determine the effects of aspect r ratios (ratio of evaporator length to the inner diameter of tube) and number of meandering turns on performance limit of an inclined closed-loop oscillating heat pipe. The geometrical sizes, which were the variable parameters were the internal diameter, the evaporator section length of, the adiabatic and condenser section length of each set was equaled to the evaporator length and the numbers of meandering turn and also variable inclination angles adjusted by10°.The result indicated that the aspect ratio, the ratio of evaporator length by internal diameter and number of meandering turns significantly affect the maximum heat flux and inclination angle. The effects of aspect ratios and number of meandering turns on maximum heat flux of an inclined CLOHP have been thoroughly investigated in this study. In the case of aspect ratio, it can be seen that, the highest maximum heat flux occurs at inclination angle about 70-90° and lower value of aspect ratio. In the case of number of meandering turns, it can be seen that, when number of meandering turns increases, number of meandering turns does not affect to the maximum heat flux. In the case of inclination angle, it can be seen that, when the inclination angle increases from 0-90°, the maximum heat flux increases with respect to increasing numbers of tubes.

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Moreover the highest maximum heat flux occurs at vertical position to about 70°.

P. Sakulchangsatjatai et.al. [15] this research studies the effect of length ratios on heat transfer characteristic of Closed Loop Oscillating Heat Pipe with Non-Uniform Diameter (CLOHP/NUD) i.e. inner diameter of capillary tube were alternated connection and bent into several numbers of turns and both ends were connected to form of loop. It was found that, the CLOHP/NUD transferred higher heat than the conventional Closed Loop Oscillating Heat Pipe (CLOHP) with the same heat transfer area because the working fluid flowed in only one direction. Working fluid moved to condenser section in larger inner diameter and returned to evaporator section in smaller inner diameter**.** The heat transfer performance of CLOHP/NUD can be improved if one directional circulation of working fluid can be induced. The effects of length ratios and working fluids on the heat performance of CLOHP/NUD have been experimentally investigated and conclude heat flux increased when the length ratio decreased.

V. CONCLUSION

From the above literature review it can be conclude that the various design parameters affect the working performance of the pulsating heat pipe. The internal diameter of the tube effect the heat transfer rate if the internal diameter is greater or lesser according to the tube length i.e. No proportion occurs there will be effect of gravity and surface tension on the working of the PHP.The working fluid is as per the require condition and orientation of the PHP. The inclination angle also a vital effect on performance of the PHP, vertical PHP can work efficiently than the horizontal PHP; from the above literature review it is found that inclination angle from 70° to 90° is efficient performance. Number of meandering turns effect performance of PHP directly proportional to heat transfer flux.

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