Scope of CFD analysis in closed loop pulsating heat pipe Review Paper

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Abstract- **A heat pipe is device used to transfer Heat from hot surface to cold surface. It combines the principles of both thermal conductivity and phase changes to efficiently manage the transfer of heat between two solid surfaces. Heat Pipes are of two types. 1) Open loop pulsating Heat pipe 2) Closed loop pulsating Heat pipe. Closed loop Pulsating Heat pipe gives better results. The performance of CLPHP greatly depends on filling ratio, working fluid, internal diameter, inclination, pipe material etc. Although a lot of research have been done improvement can be done in the performance.A lot of research papers & literatures are reviewed.The Research Papers of Sameer khandekar, Piynun Charoenswan , Ya ling He, Xiangdong, Hua Han are studied . Working fluid generally taken as water + Ethanol filling ratio taken as 30%-50 %. In most of the cases filling ratio is taken as low upto 50% & pipe arrangement is also almost horizontal. But there are a lot of possibilities of improvement in Heat Transfer by changing pipe material, increasing filling ratio up to 80 % & by taking working fluid as R134 or R22.CFD Analysis can be done for creating model of heat pipe & different conditions can be applied for comparative study.**

INTRODUCTION

A heat pipe is a device that combines the principles of both thermal conductivity and phase change to efficiently manage the transfer of heat between two solid surfaces. At the hot interface of a heat pipe a liquid in contact with solid surface turns into a vapor by absorbing heat from that surface. The vapor then travels along the heat pipe to the cold surface 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. this cycle repeats again & again. Due to the very high heat transfer coefficients for boiling and condensation, heat pipes are highly effective thermal conductors. The effective thermal

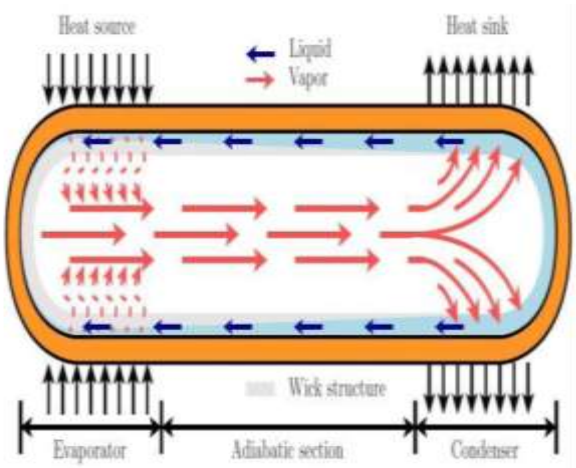

Fig 1. Schematic diagram of Heat Pipe

Pulsating heat pipe has many numbers of U-turns of tube.The diameter is very small also called capillary diameter. Tubes are partially filled with the working fluid. When the diameter of the tube is so small (<2mm) then the working fluid distributs itself in the form of vapor & liquid slug. It has no wick material inside the tube.

There are mainly two types of pulsating heat pipe:

1) Closed loop heat pipe
2) Open loop heat pipe

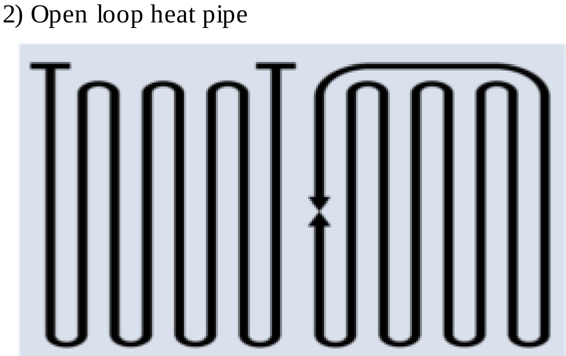

Fig 2 Open and Closed loop pulsating Heat pipe

Closed loop Pulsating heat pipe-In Closed Loop Pulsating Heat Pipe both end are closed & fitted with check valve. 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) typically suited for microelectronics cooling consists of a plain meandering tube of capillary dimensions with many U-turns and joined end to end. The pipe is first evacuated and then filled partially with a working fluid.

Working Principle-The heat is absorbed in the evaporator region and is carried out through the pipe by the evaporation of the fluid. The high temperature vapor moves toward the condenser by the action of buoyancy force. At the condenser it rejects the heat and coverts into liquid droplets. These droplets move to the evaporator due to gravity. One end of the CLPHPs tube bundle receives heat, transferring it to the other by a pulsating action of the working fluid. During operation, there exists a temperature gradient between the heated and cooled end. Small temperature differences also exist amongst the individual 'U' bends of the evaporator and

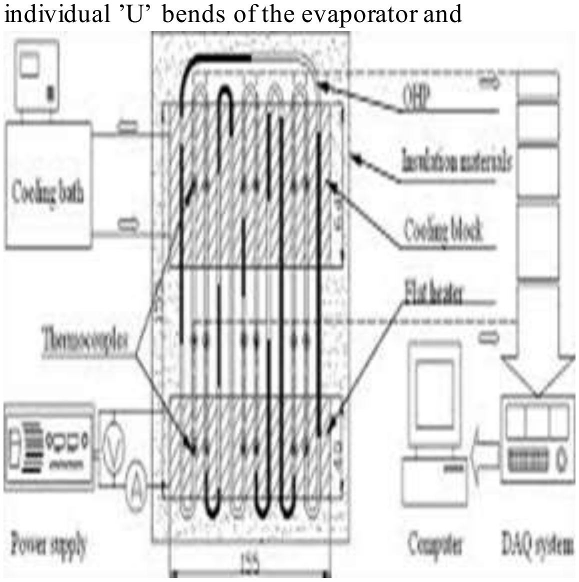

Fig 3 Closed loop pulsating heat pipe

condenser due to non-uniform heat transfer rates. Since each tube section between the evaporator and the condenser has a different volumetric distribution of the fluid, the pressure drop associated with each sub-section is different. This causes pressure imbalances leading to thermally driven two-phase flow responsible for the thermo fluidic transport.

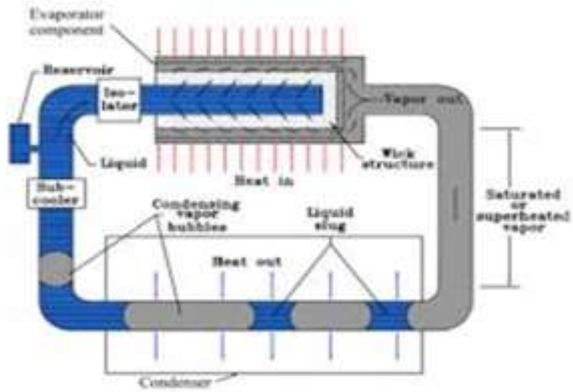

Fig.4 Mechanism of CLPHP

Parameters affecting the performance of CLPHP-The various parameters which affect the performance of a closed loop pulsating heat pipe are:

- Working Fluid
- Internal Diameter
- Total tube length
- Length of evaporator, adiabatic section and condenser.
- Number of turns or loops
- Filling ratio
- Inclination angle

II LITERATURE REVIEWS

1) Khandekar & charoenswan (ref. 10) taken copper tube pipe with internal dia 2.0 mm, working fluid-water+Ethanol+R123. The modification can be possible by taking different filling ratios like 70%-80% , no of turns & different working fluids like-R134, R-22 etc.

2) Piyanun Charoenswan(ref 11) in his conference paper presented the performance of Horizontal closed loop pulsating heat pipe. Taken parameters as 26 number of turns, 30% filling ratio, water + Ethanol as working fluid for optimum results. The results can be further improved by changing inclination, filling ratio, no. of turns etc. With the help of CFD Analysis we can create models of Closed Loop Pulsating Heat Pipes and analyze the performance of Heat pipe by changing different parameters like no of turns, inclination angle, filling ratios, working fluids.By increasing Filling ratio in the range of 70%-85% there is great chances of improvement in performance. Because in this case bubble formation & liquid slag are in balanced form wchich is beneficial for heat transfer. R134 & R22 are used in

refrigeration process for better performance. So these working fluids can also be used in heat pipe for betterment.

3) Kuo Hsiian Chien(ref 2) in his paper presented a pulsating heat pipe (PHP) concept in which PHP is with fewer turns and is operated horizontally. Two heat pipes were made of copper tubes with an overall size of 122 mm 57 mm 5.5 mm is investigated, one had 16 parallel square channels having a uniform cross-section of 2 mm 2 mm (uniform CLPHP), and the other had 16 alternative size of par-allel square channels (a cross-section 2 mm 2 mm and a cross-section of 1 mm 2 mm in alternating position).It is non Uniform CLPHP. Test results showed 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. The results can be further improved by changing inclination, filling ratio, no. of turns etc. With the help of CFD Analysis we can create models of Closed Loop Pulsating Heat Pipes and analyze the performance of Heat pipe by changing different parameters like no of turns, inclination angle, filling ratios, working fluids.By increasing Filling ratio in the range of 70%-85% there is great chances of improvement in performance. R134, R123 & R22 are used in refrigeration process for better performance.

3)N Soni (ref 12) in her paper showed that Closed loop pulsating heat pipe is very effective tool for removal of heat from very small electronic devices. Numerical model is developed is very helpful in observing the working phenomenon of CLPHP. A parametric study is carried out to find out the effect of various parameters like number of loops, position of CLPHP, Nature of Refrigerant used, filling ratio on the performance of CLPHP. It is been found that gravity plays a very important role in flow of liquid (refrigerant) in the pipe as cooling effect of vertical closed loop pipe is better than horizontal closed loop pipe. It is also observed that the pipe with 50% filling ratio has minimum thermal resistance with comparison with other filling ratios. As the heat input increases in the thermal resistance of the pipe decreases i.e thermal resistance of pipe is in inverse proportion with the heat input. We can modify the study by taking different inclination angles or by vertical arrangements.The filling ratio can be changed also for Numerical Study in CFD FLUENT.

III CONCLUSSION- IMPROVEMENT POSSIBILITIES WITH CFD ANALYSIS

Computational Fluid Dynamics(CFD)-With the help of high speed digital computers, combined with accurate numerical methods for solving physical problems, has drastically changed the way we study and practice fluid dynamics and heat transfer. This approach is called Computational Fluid Dynamics or CFD. CFD is regarded as a zone of study combining fluid dynamics and numerical methods.The development of affordable high performance computing hardware and the availability of user-friendly interfaces have led to the development of commercial CFD packages. Today, well tested commercial CFD packages not only have made CFD analysis a routine design tool in industry, but are also helping the research engineer in focusing on the physical system more effectively.All established CFD software contain three elements: (i) a pre-processor, (ii) the main solver, and (iii) a post-processor .With the help of CFD software we can analyze the performance of Heat Pipe. We can create model of heat pipe on GAMBIT. The simulation work is done on Fluent.During simulation different operating parameters can be set for finding optimum results. The results can be further improved by changing inclination, filling ratio, no. of turns etc. With the help of CFD Analysis we can create models of Closed Loop Pulsating Heat Pipes and analyze the performance of Heat pipe by changing different parameters like no of turns, inclination angle, filling ratios, working fluids.By increasing Filling ratio in the range of 70%-85% there is great chances of improvement in performance. R134, R123 & R22 are used in refrigeration process for better performance. Various graphs can be plotted on FLUENT which show comparative study for different working fluids.

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