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An Investigation of Thermal Performance of Closed Loop Pulsating Heat Pipe

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***Abstract*— Using a mathematical model of a closed loop OHP with two branches, this paper investigates the motion law of internal working fluid and the working of heat transfer enhancement generated by different heat source modes, namely the even pulsing heat source mode (EP-mode) and the alternate heat source mode (AH-mode) (A-mode). The simulation result reveals that both the vapour plug pressure and the liquid slug displacement exhibit varied amplitude fluctuations under the three heating regimes.**

Keywords— closed loop pulsating heat pipe, Gold Coating, Silver coating, CFD Analysis, Thermo hydrodynamics of system

I. Introduction

The operating testing impact on the thermal performance, but to get the maximum thermal performance, it is the research area. As the coating of PHP with silver and Gold is done, at what level it increases the thermal performance is also the area of research. From the literature review, we understand that working fluid is not become fixed, still it is also the area of research to find out exact optimum fluid.[3].

II. Methodology

A. Convection heat pipe

A heat pipe is in two passive types which are capable in transferring large amount heat with minimum temperature.

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In the heat pipe there are three sections:

1. Evaporator section
2. Adiabatic section
3. Condenser section

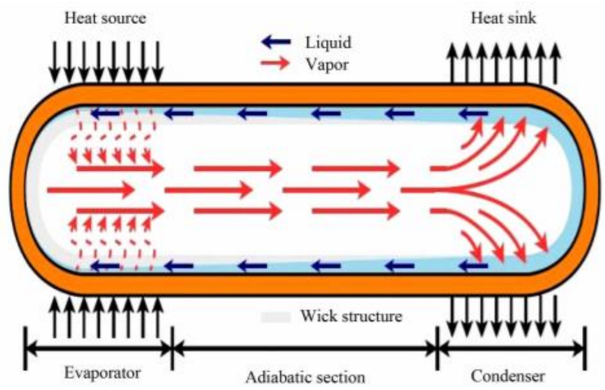

Figure 1. Schematic of convectional heat pipe [1]

"Heat pipes" use thermal and phase-conversion principles in order to efficiently transport heat between two solid surfaces. It's true that in the evaporator part of a heat pipe heat is added, however in the adiabatic region of the system there's no heat addition, and there's heat gain in the condenser section as well. It is a fact that a fluid that comes into touch with a thermally transferrable solid surface absorbs heat from that solid surface and transforms into vapour [4][5].

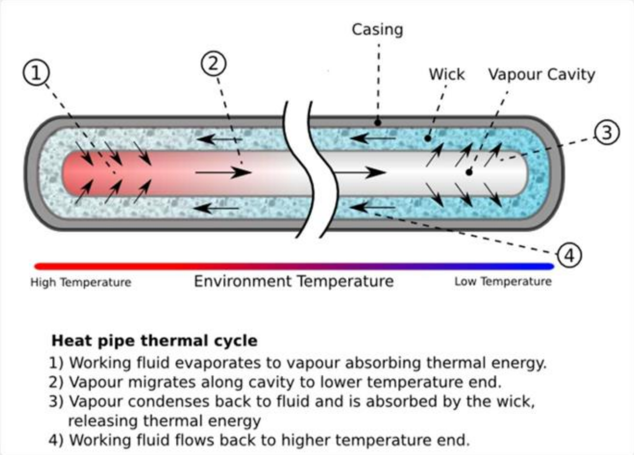

Figure 2. Components and mechanism for heat pipe containing a wick [2]

B. *Pulsating heat pipe*

An oscillating fluid and a phase change in a capillary tube are the basis for this process. Due to its outstanding properties, including as high thermal conductivity, rapid reaction to large heat loads, and ease of assembly, PHP has become one of the most often used technologies in the spacecraft thermal control system. [4].

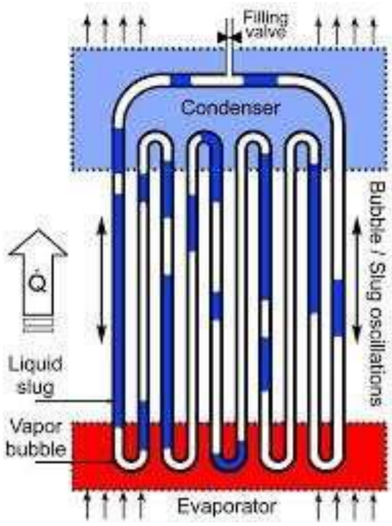

Figure 3. Pulsating Heat Pipe [7]

Pulsating pipes are in two types.

1. Open loop pulsating heat pipe
2. Closed loop pulsating heat pipe

One end of the pipe is sealed and the other is used for both evacuating and charging the system. In a closed looped pulsing heat pipe, both ends of the pipe are linked to liquid and open to circulation..

III. Design and Analytical Work

A. *Selection of Tube Diameter for CLPHP*

$$d \le 2\times\sqrt{\frac{\sigma}{\{(\rho)liq-(\rho)vap\}\times g}}$$

Were,

D = inner diameter of CLPHP

σ = surface tension

g = acceleration due to gravity

$(\rho)_{liq}$ =Density of liquid

For Silver [7][8],

$$d \le 2\times\sqrt{\frac{19.09\times10^{-3}}{\{748.5-2.123\}\times 9.81}}$$

$d \le 3.22$ mm

B. *Experimental Approach*

Six parameters emerge as primary influence parameter affecting the system. These are,

1) Inner Diameter of tube = 2 mm to 4 mm
2) Volumetric filling ratio = 20 to 80 FR
3) Input Heat flux = 10 W to 100 W
4) Operating Orientation = 0 to 90
5) Total no of turns = 5 to 10
6) Working fluid = Silver Nano Particles
7) Coating Material = Silver and Gold metal

Only temperature measurement will be employed for the system analysis, internal pressure measurement will not be done [9], Equipment used for this experiment are [10],

a) Cooling fan for condensation
b) Temperature recorder
c) Thermocouple
d) Copper tube having 2mm to 4mm
e) Working Fluids
f) Data collection circuit
g) Coil Heater
h) Variable AC Supply
i) Temperature Recorder

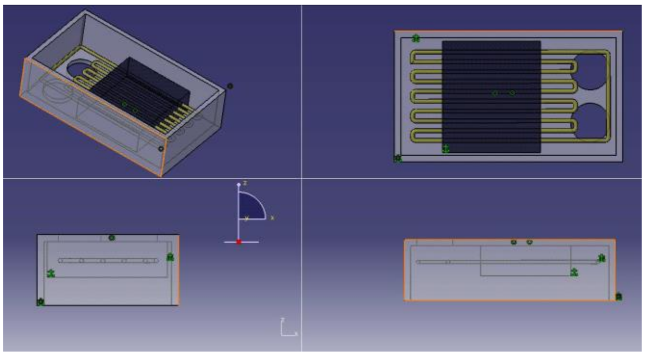

Figure 4. Closed-loop Pulsating Heat Pipe Assembly

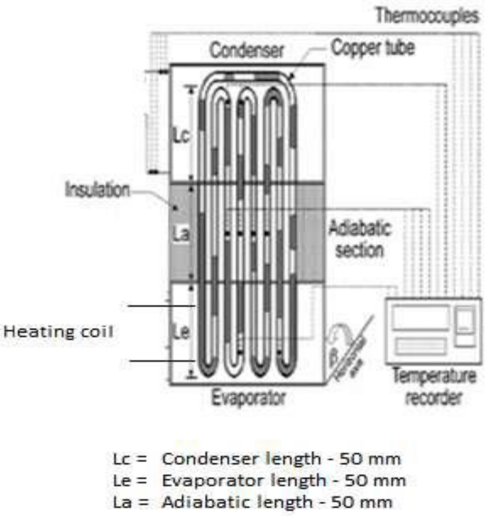

Figure 5. Construction of experimental work [11]

V. CFD Analysis on ANSYS CFX Software

CFD Analysis and Simulation has been carried out in ANSYS software using CFX tool.

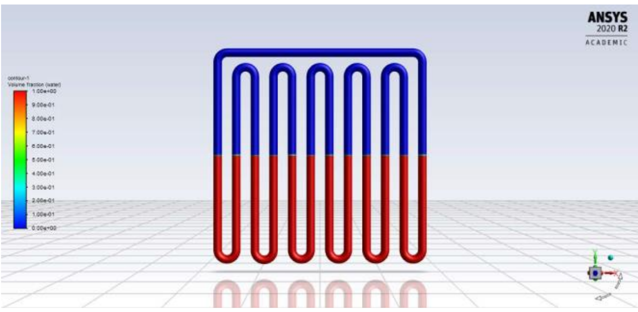

Figure 6. Volume fraction through CFD analysis

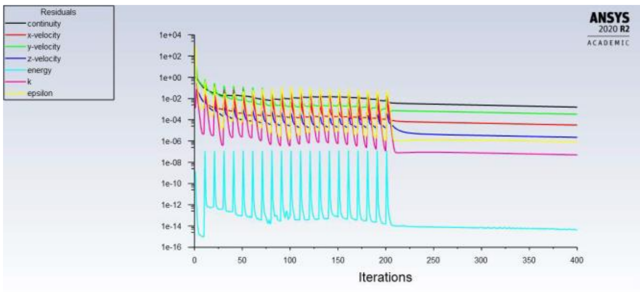

Figure 7. Resudual for 400 iteration

Variation of thermal resistance with heat power for different working fluids.

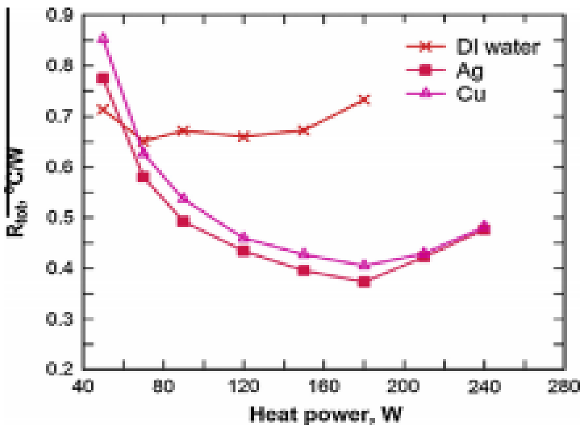

Figure 8. Overall thermal resistance as a function of heat power for different working fluids

Figure 8 represents overall thermal resistance as a function of heat power for different working fluids. In general, the thermal resistance decreases with increasing heat power, and finally increases at dry out. The thermal resistance is slightly lower for Ag compared to that Cu nano fluid [12].

Variation of thermal resistance with heat power for different working fluids.

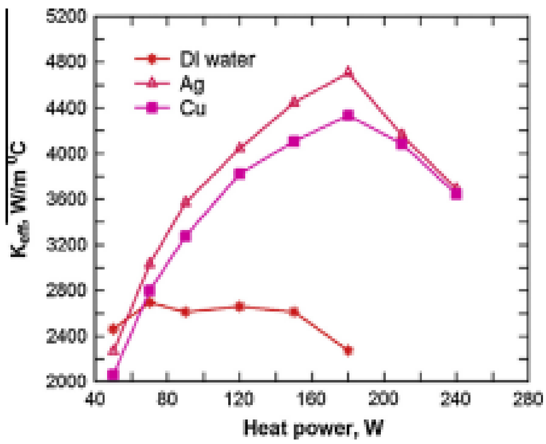

Figure 9. thermal conductivity with respect to heat power for all the working fluids

Figure 9 represents the thermal conductivity with respect to heat power for all the working fluids. The thermal conductivity increases with increasing heat power, and finally decreases at dry out The thermal conductivity value is many times higher compared to that of ordinary copper tube [12].

VI. Result and Discussion

The result of experiment may perform on the basis of finding out the effect of working fluid filling ratio on the different orientation. Also find the reactions of heat flux on CLPHPs and resistance offered by the tube and refrigerant on the working conditions. CLPHP is an example of a closed-loop heat-pump system, and its performance depends on a variety of factors, including its geometry, materials and working fluids. The non-equilibrium nature of the heating and cooling process, the formation of bubbles and bursts, and the combined reaction of the multiphase liquid changes among the multiple channels further complicate its functioning.

VII. Conclusion

Gold and silver metal coating has been experimentally investigated to determine the heat transfer in closed loop pulsating heat pipe with coating of silver metal on evaporator and condenser section and compare with gold metal coating, operating inclination angle, study the effect of internal diameter, number of turns, working fluid. Closed Loop Pulsating Heat Pipes presented in this experiment is one of the first systematic attempts to understand the thermo hydrodynamics of the system. While many aspects of the complex operational characteristics have been covered; it will indeed be very naive to claim completeness in scope of the present research. The future aim should be directed towards making the technology of pulsating heat pipes to become a norm for the industry.

VIII. Scope for the Future Work

Close loop pulsating heat pipe (CLPHP) having different application like heat exchanger, economizer, spacecraft, computer system, solar thermal, ventilation heat recovery.

The project work having a very large scope for future work some of them are:

1. Use of Nano fluid of any binary mixture of fluid
2. Use gold and platinum coating for better thermal performance

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