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Numerical Analysis of Closed Loop Pulsating Heat Pipe Using CFD

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ABSTRACT

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. It was observed that R134a performed better in comparison with all other refrigerants given the same operating conditions.

Keywords : CLPHP, R134a, ANSYS Fluent

I. INTRODUCTION

A heat-transfer device effectively combining principles of phase transition and thermal conductivity to transfer of heat between two solid interfaces called as heat pipe. Thermally conductive solid surface turns into a vapor at the hot interface of a heat pipe by absorbing heat liquid in contact. The vapor then condenses back into a liquid - releasing the latent heat while traveling along the cold interface of heat pipe. Thereafter liquid enters the hot interface due to capillary action, centrifugal force, or gravity, and the cycle repeats. Heat pipes (Figure 1) are very effective thermal conductors, due to the very high heat transfer coefficients available for boiling and condensation. The primary motive of a cooling system is to increase the performance and the reliability of module or package, reliability indeed is a strong function of temperature. The temperature plays an important role in administrating Device functionality, safety and failure [1-6].

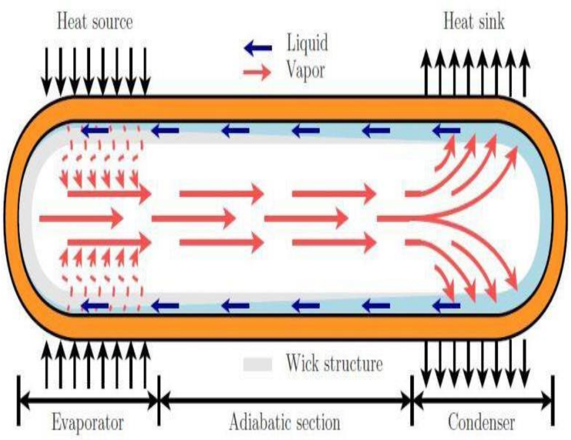

Figure 1. Heat pipe

Closed loop pulsating heat pipe has better performance than open loop devices due to the fluid circulation along with the oscillations within the loop. The performance of the closed loop heat pipe is further enhanced by using the check valve within the loop. But, it is very difficult and costly to install check valve because of the small nature of the device. So, the closed loop pulsating heat pipes without a check valve are mostly used. In this study, a numerical model of the closed loop pulsating heat pipe was created to establish the practical working conditions. Different models were analyzed with different values of heat flux and input temperature and filling ratio to establish various parameters effecting performance of CLPHP [7-9].

II. METHODOLOGY

The first step of a Computational fluid analysis is geometry creation. Analysis of the performance of CLPHPs is done using computational fluid dynamics method. For this geometry is modeled in 2D in Gambit 2.2.30. Number of turns is taken as 10. Inside and Outside diameter of pipe are 3 mm and 4 mm respectively. Length of pipe is 450 mm and 12 mm is the gap between the pipes. Total length of the pipe is taken as 6 m. For achieve better results grid independent study is done, element size .5 mm , 2 mm and 3 mm are selected, Figure 2 . Different kind of mesh has been checked for simulations and 0.5 mm element size mesh is found optimum and selected for further analysis. It is found that the 0.5 mm mesh has 13279 elements, 2 mm mesh has 7495 elements and 3 mm mesh has 3852 elements. Since the number of elements in 0.5 mm mesh is more so it will provide us better results. Different working fluid were used namely R134a, R22, R32 with filling ratio 50%, 70% and 83% respectively.

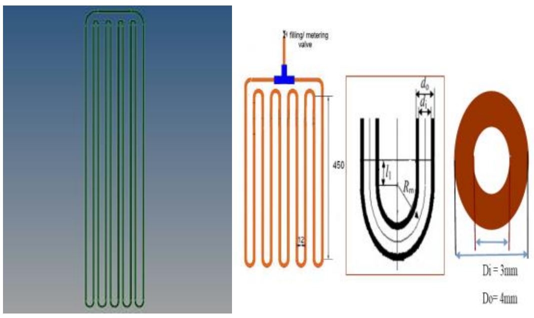

Figure 2. Closed loop pulsating heat pipe

III. RESULTS AND DISCUSSION

The refrigerants properties are set and then used in different phase i.e in both gas as well as liquid form. Initially R134a is taken as a fluid flowing through evaporator in both the phases.

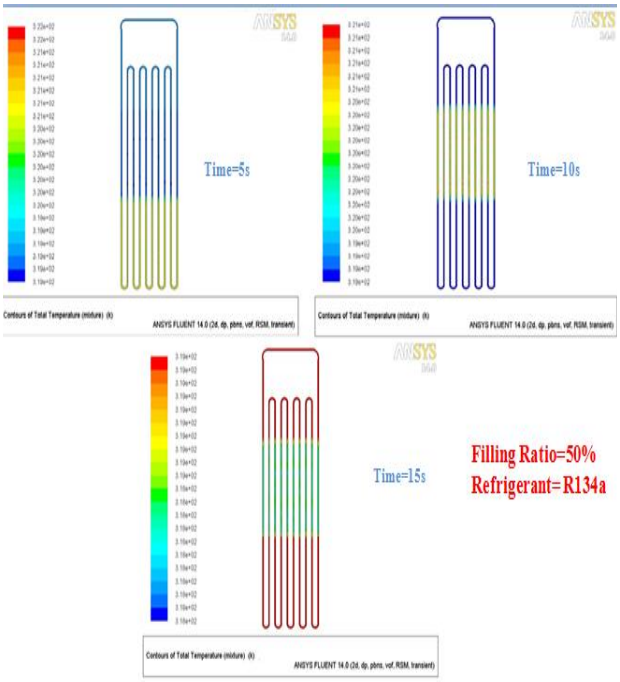

Figure 3. Contours of temperature variation in CLPHP

It was observed that vapour slug were formed in the heat pipe leading to a pulsating action creating heat transfer and subsequently changing temperature were established in different sections Figure 4.

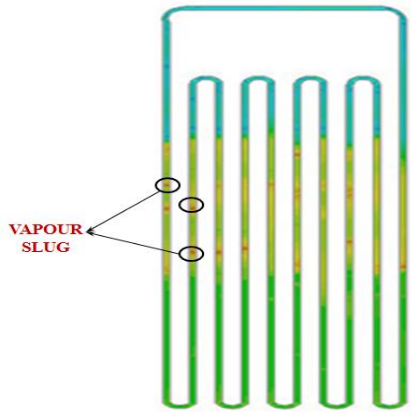

Figure 4. Vapour slug in CLPHP

It is been found that that the heat transfer rate increases with the time. Continuous working of the closed loop heat pipe may also result in the over use of the coolant and the filling ratio will decrease as a result of which only vapor form of the coolant will be left and the R-134a will totally vaporized. This situation obviously needs to be avoided. But obviously it can be used for continuous removal of heat as it starts from the beginning so it remains good in the form of a cycle, see Figure 5. This graph (Figure 5) represents that the variation of heat flux in both R134a and R22 are almost following the same nature. It is been found that that the heat transfer rate increases with the time. It was also observed that as the heat input increases the efficiency of the CLPHP may decrease. The contact thermal resistance is varied with varying heat transfer rate to obtain the variation throughout the flow through the pipe.

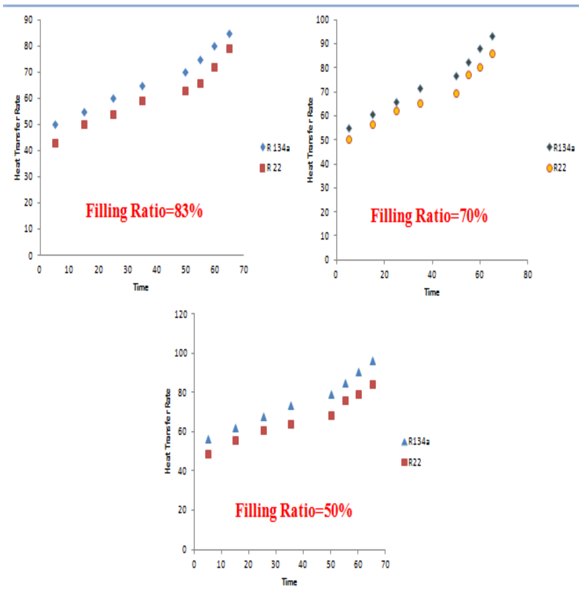

Figure 5. Effect of filling ratio

It was observed that with the increase in heat transfer rate decreases contact thermal resistance and the trend remains same for all three types of filling ratios and refrigerants. It was observed that contact thermal resistance for refrigerant R134a is more as compared to R22, see Figure 6.

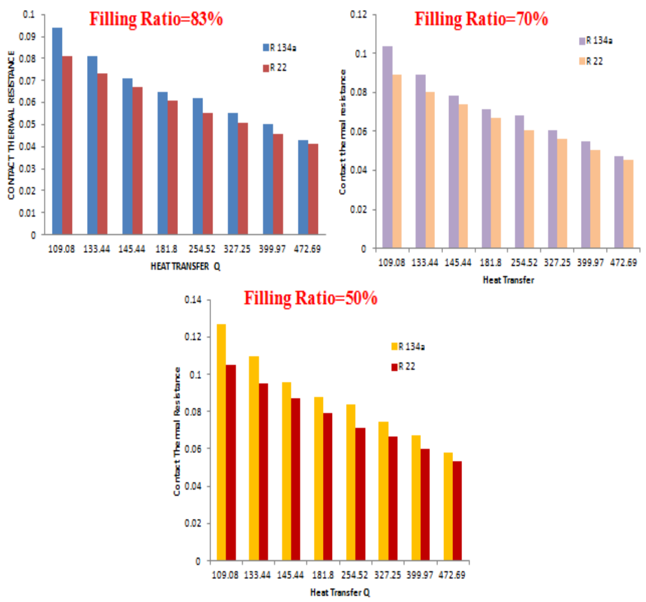

Figure 6. Contact thermal resistance of CLPHP

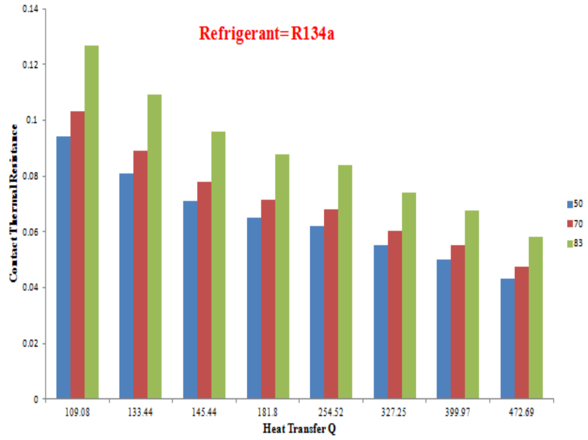

Figure 7. Variation of contact thermal resistance with filling ratio

It was observed that filling ratio plays a significant role in defining the performance and heat transfer characteristics of closed loop heat pipe. It was found that contact thermal resistance at 83% filling ratio is highest while minimum for 50% filling ratio for all configurations and for all different types of refrigerants, see Figure 7. In this figure different heat input flux were taken for refrigerant R134a to determine its contact thermal resistance.

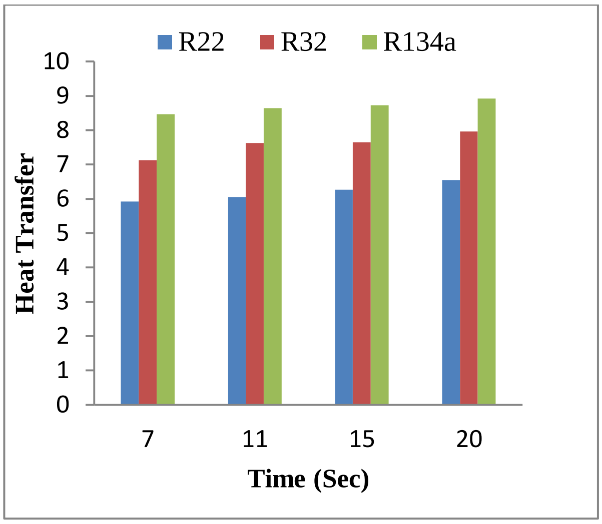

Figure 8. Effect of Refrigerant

It is clearly observed that R134a refrigerant is having better performance as compared to other two refrigerants. The heat transfer is better in R134a is better demonstrates that the performance of the refrigerator system incorporating it will be better than other two refrigerants. Similarly the Coefficient of performance of the Refrigerating systems can be calculated keeping the work input as constant for all the refrigerants by using the heat transfer value obtained from the simulation for each refrigerant, see Figure 8.

IV. CONCLUSION

It was found that: Mathematical model developed using ANSYS Fluent of closed loop pulsating heat pipe in both vertical and horizontal position is validated.

Evaporator and condenser wall temperature variation with respect to heat input is found to be acceding in order

At 50% filling ratio of PHP is exhibit better heat transfer characteristics in all orientations because of minimum resistance offered by it.

Effect of refrigerants on the performance of closed loop heat pipe is also analyzed using different refrigerants namely R22, R32 and R134a. All refrigerants are simulated differently but keeping same boundary conditions and same geometrical parameters.
R134a refrigerant is having better performance as compared to other two refrigerants. The heat transfer is better in R134a is better demonstrates that the performance of the refrigerator system incorporating it will be better than other two refrigerants.

In general, the CLPHPs obtain the best thermal performance and maximum performance limitation when they operate in the horizontal bottom heat mode with 50% filling ratio.

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