CFD analysis of vertical closed loop pulsating heat pipe with 10 turns

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Abstract- **CLPHP is a device which combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces. Geometry of CLPHP with 10 turns was modeled having 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 achieving better results grid independent study is done, element size .5 mm , 2 mm and 3 mm are selected . Different kind of mesh has been checked for simulations and 0.5 mm element size mesh is found optimum and selected for further analysis. Numerical model developed is very helpful in observing the working phenomenon of CLPHP. Mostly analysis of closed loop pipe was performed in vertical position with refrigerants having different filling ratio. When the filling ratio of the CLPHP was marked as 50% highest performance curve was obtained. Thermal contact resistance offered by the CLPHP at this filling ratio was found to be minimum leading to high performance of structure.**

INTRODUCTION

A Heat-transfer equipment competently combining the basic principles of heat transfer and phase transition in order to transmit heat b/w both solid interfaces called heat pipe. A solid surface which is thermally conductive turns into vapor at the higher temperature interface of a heat pipe by absorbing liquid heat in contact. After that by releasing heat the vapor condenses into liquid while traveling along the cold interface of heat pipe. After that liquid enters the hot interface because of capillary action, gravity, or centrifugal force, and the cycle repeats. Heat pipes are regarded as effective thermal conductors, because of its high heat transfer coefficients available for condensation and boiling. The primary motive of a cooling system is to increase the performance and the reliability of module or package, reliability indeed was strongly considered as a temperature function. The role of temperature is very important role in administrating Device functionality, safety and failure.

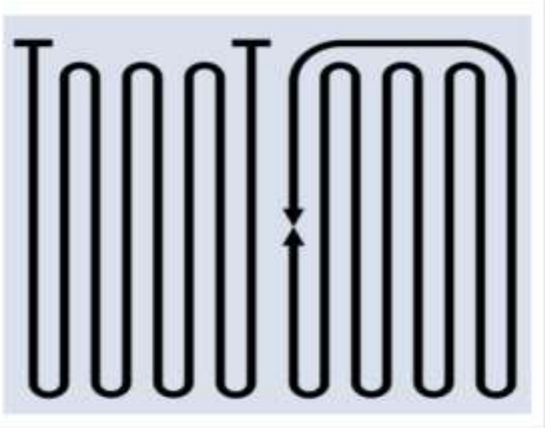

Fig.1. Open and closed loop heat pipe

-hydraulic coupling were termed as closed loop pulsating heat pipes (CLPHPs). Close Loop Pulsating heat pipes (CLPHPs) were very well suited in microelectronics cooling consisting of a plain very thin and delicate capillary tube having many U-turns joined at each ends to each other. The pipe was initially emptied and further was filled partially with working fluid. Due to small diameter of Close Loop Pulsating heat pipe, the fluid distributes itself into an arrangement of liquid slugs and vapor bubbles. This liquid–vapor/slug-bubble system receives heat from one end of tube bundle transferring it to the other end by a pulsating action of the fluid. The type of fluid and the operating pressure inside the pulsating heat pipe decides the operating temperature of the heat pipe. The region between evaporator and condenser was assumed to be adiabatic. The heat was transferred from evaporator to condenser by the means of pulsating action of vapor slug and liquid slug. This pulsation appears as a non-equilibrium chaotic process, whose continuous operation requires non-equilibrium conditions inside the tube in some of the parallel channels. Close Loop Pulsating heat pipes (CLPHPs) doesn't require any external power source for either creating or maintaining the fluid motion or the transfer of heat. The purpose of this project is to understand how CLPHPs operate and to be able to understand how various parameters (geometry, fill ratio, materials, working fluid, etc.) affect its performance. Understanding its operation is further complicated by the non-equilibrium nature of the evaporation and condensation process, bubble growth and collapse and the coupled response of the multiphase fluid dynamics among the different channels. The heat pipes whose thermal performance was governed by its strong thermal

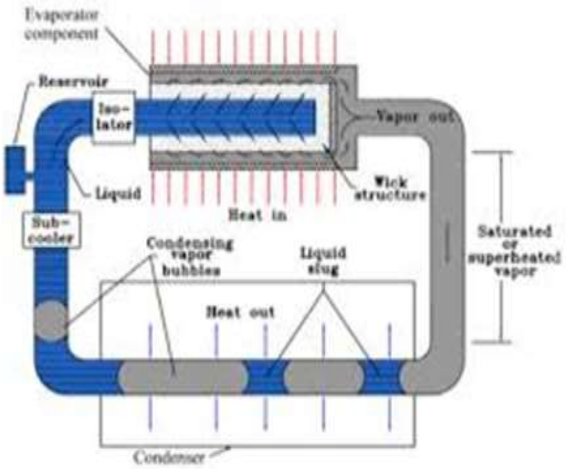

Fig. 2. Principle of CLPHP

II NUMERICAL MODEL

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 . Different kind of mesh has been checked for simulations and 0.5 mm element size mesh is found optimum and selected for further analysis.

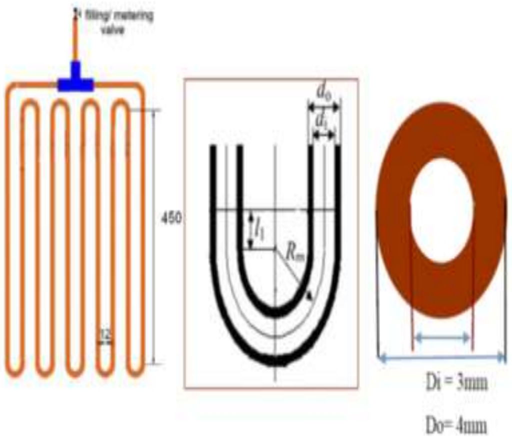

Fig.3. Geometry of CLPHP

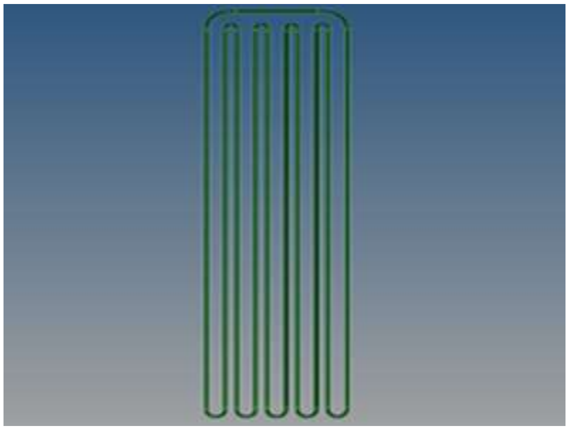

Fig. 4. Meshed model

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.

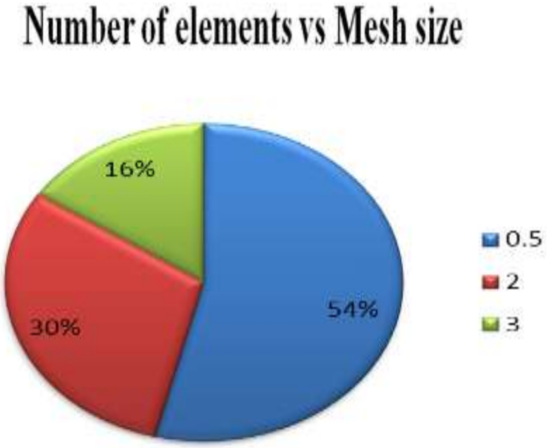

Fig.5. Discretization

III. RESULTS AND DISCUSSION

The closed loop heat pipe which is meshed with 1 mm mesh size is analyzed with ANSYS Fluent software with different boundary conditions and refrigerants. 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. Different filling ratios were used namely 50%, 70% and 83% respectively. Inclination angles are also varied to mainly as vertical to find out the effects of inclination of closed loop heat pipe.

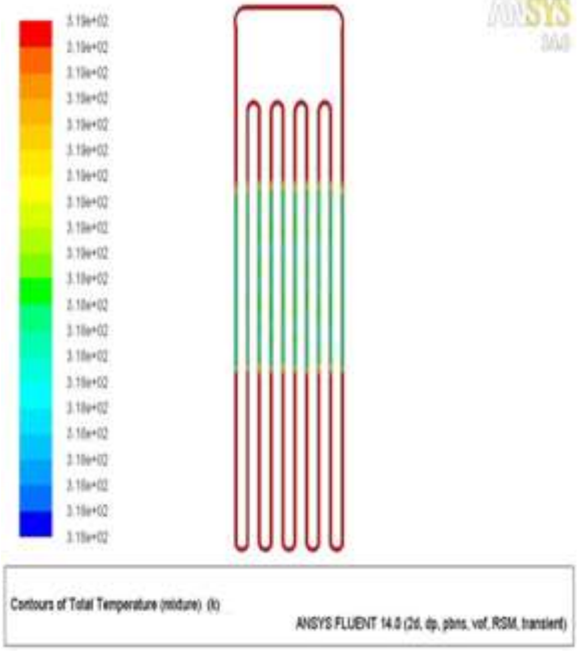

Fig.6. Temperature contours in CLPHP

The below graph represents the comparison between the theoretical heat flux obtained on analysis with 83% filling ratio working fluid R-134a and that with R-22. Theoretical data is obtained from the analysis of the modelling of the closed loop pulsating heat pipe drawn with same dimensions as earlier mentioned and the boundary conditions are the output and input temperature of the fluid is provided. This graph represents that the variation of heat flux in theoretical basis for both refrigerants R134a and R22 almost follow the same nature. Hence it can be concluded that the model obtained from ANSYS FLUENT is very appropriate. It was been found that they heat transfer rate increases with the time. Although the fact remains that the pipe will remain in working condition as the input increases and as the input increases the efficiency of the CLPHP may decrease.

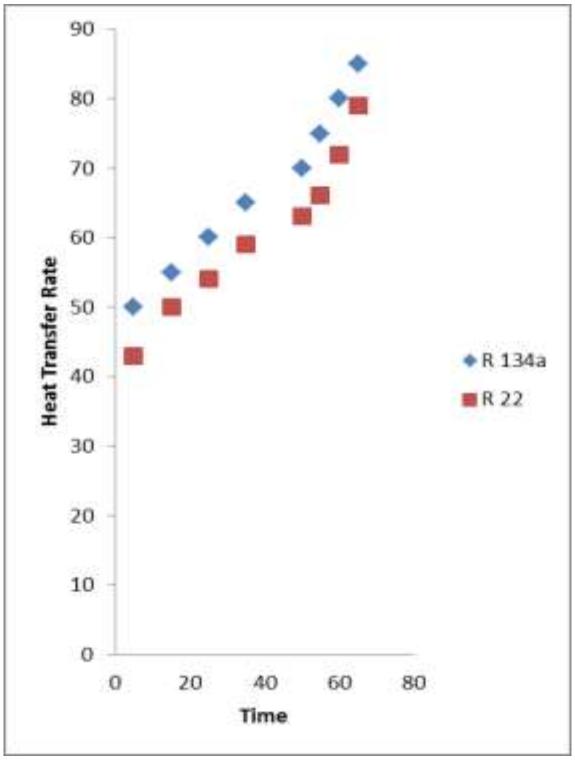

Fig.7. Comparison on Heat Transfer Rate with 83% FR

The below graph represents the comparison between the theoretical contact thermal resistance obtained on analysis with 83% filling ratio and working fluid R-134a and R 22. The theoretical data is obtained from the analysis of the model of closed loop pulsating heat pipe drawn with same dimensions as earlier mentioned and the boundary conditions are the output and input temperature of the fluid is provided. This graph represents that the variation of heat flux in both refrigerants R134a and R22 obtained from theoretical basis and it was observed that they almost follow the same nature. It is been found that that the heat transfer rate increases with the time. Although the fact remains that the pipe will remain in working condition as the input increases and as the 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. The below graph represents the comparison between the theoretical contact thermal resistance obtained on analysis with 70% filling ratio and working fluid R-134a and R 22. The theoretical data is obtained from the analysis of the model of closed loop pulsating heat pipe drawn with same dimensions as earlier mentioned and the boundary conditions are the output and input temperature of the fluid is provided. This graph represents that the variation of heat flux in both refrigerants R134a and R22 obtained from theoretical basis and it was observed that they almost follow the same nature. It is been found that that the heat transfer rate increases with the time. Although the fact remains that the pipe will remain in working condition as the input increases and as the 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.

IV. CONCLUSIONS

A numerical study was done taking into consideration a closed loop pulsating heat pipes (CLPHPs) with aim of investigating various effects of geometrical and performance parameters like inner diameter, operational orientation, and filling ratio on thermal performance of heat pipe. Some of the major findings are:

1. Numerical model developed using ANSYS Fluent of closed loop pulsating heat pipe in both vertical and horizontal position is validated.
2. Evaporator and condenser wall temperature variation with respect to heat input is found to be acceding in order.

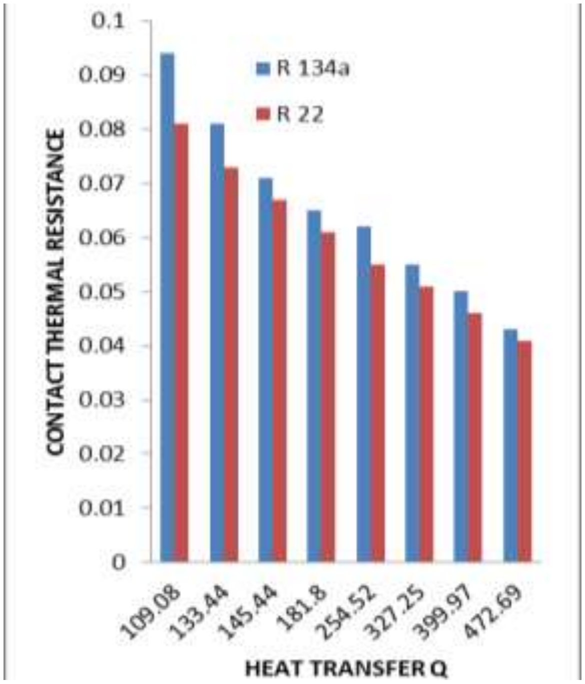

Fig. 8. Thermal contact resistance vs Heat Flux on 83% filling ratio

3. Gravity certainly affects the heat output and evaluation of closed loop heat pipe.
4. The thermal resistance is decreases as the heat input is increases in all orientations.
5. In horizontal mode of operation and 50% filling ratio is found the minimum thermal resistance than any other orientation.
6. At 50% filling ratio of PHP is exhibit better heat transfer characteristics in all orientations because of minimum resistance offered by it.

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