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THERMAL PERFORMANCE OF OSCILLATING HEAT PIPE WITH DIFFERENT WORKING FLUID: A REVIEW

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Abstract - *The rapid rise in electronic components in recent year has led to a rapid increase in concentration of thermal systems. As electronic designs are enclosed in smaller packages dissipating the heat becomes a critical design factor. Electronic devices require more cooling than the capacity of standard metallic heat sinks due to compactness and energy consumption. Heat pipe becomes a major tool for thermal management. Flat plate oscillating heat pipe is passive heat transfer device and has unique advantages due to low cost, no wick structure, easy manufacturing methods. The performance of FP-OHP is influenced by various parameters like radius of channel, heat flux level, numbers of channels, charge ratio, inclination angle and physical properties of working fluids. Out of number of methods to improve and increase the thermal performance of flat plate oscillating heat pipe, the most direct and efficient one is to select proper working fluid. The objective of this paper is to present an overview of literature dealing with improving thermal performance using different fluids like binary fluids, ternary fluids, nano fluids and some important inferences from various papers are also highlighted.*

Key Words: Oscillating heat pipe, Heat transfer performance, Thermal performance, Working fluids.

1. INTRODUCTION

The heat pipe is a passive heat transfer device that effectively utilizes evaporation and condensation to transfer heat over a long distance. A heat pipe consist of a container charged with a working fluid. This sealed container is divided into three sections: Evaporator where heat is added, Adiabatic section where no heat transfer exists, and condenser section heat is rejected. The heat pipe is evacuated and then filled with the working fluid. When heat is supplied to the evaporator section, heat transfer takes place from container walls and heat the working fluid inside. The working fluid vaporizes and vapor is generated in the evaporator section when the saturation temperature corresponding to the local saturation pressure is reached. The temperature of the evaporator section is more than that of condenser section. The saturation pressure in the evaporator is higher than the saturation pressure corresponding to the condensation temperature in the condenser.

Vapor flow from the evaporator section to the condenser section is mainly because of the pressure difference caused due to temperature difference between the evaporator and condenser. The condensate in the condenser is pumped back by the Electrostatic force, gravitational force, centrifugal force & capillary forces. Because of this the heat is transported from the evaporator to the condenser.

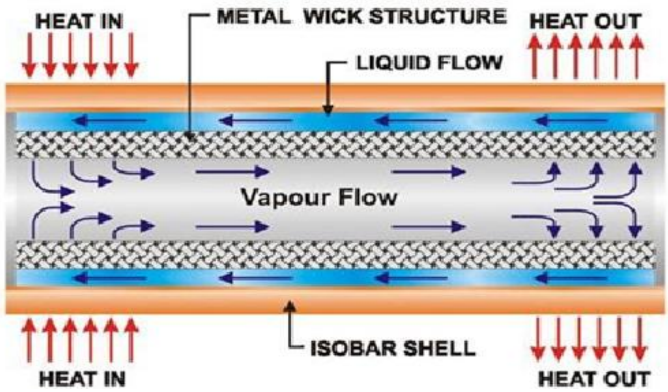

Fig -1: A Basic Heat Pipe Structure

1.1 Classification of Heat pipe

Based upon their conductance.

- Fixed conductance.
- Variable conductance.

Based upon their application & operation.

- Two-phase closed Thermosyphon heat pipe.
- Flat plate heat pipe.
- Capillary driven heat pipe.
- Annular heat pipe.
- Rotating heat pipe.
- Mono-groove heat pipe.
- Micro heat pipe.
- Variable conductance heat pipe.
- Oscillating heat pipe.

Based upon their capillary wick structures.

- Homogeneous heat pipes.
- Composite heat pipes.

Based upon their working fluid temperature ranges.

- Cryogenic heat pipe.
- Low temperature heat pipe.
- Medium temperature heat pipe.
- High temperature heat pipe.

1.2 Oscillating Heat pipe

Oscillating heat pipes are also known as pulsating heat pipes (PHP) & are a relatively new development in the field of heat pipe technology. An OHP is a meandering tube consist of a serpentine channel having capillary dimension which is cooled and heated at various points along its length.

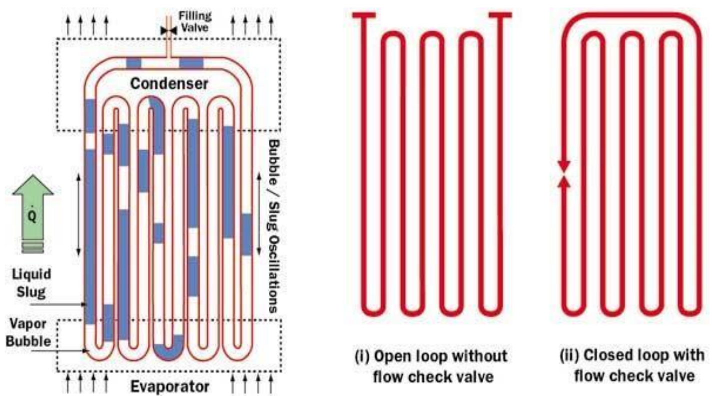

Fig -2:Oscillating Heat Pipe

Operation of Oscillating heat pipe is mainly based on the phase change phenomena in a capillary tube and the principle of oscillation for the working fluid. For vapour & liquid plugs to exist the diameter of the tube must be small enough. Initially, the oscillating Heat Pipe is evacuated and then it is partially filled with the working fluid. The liquid slugs interspersed with vapour bubbles are formed due to the Effects from surface tension.

Working principle of closed loop pulsating heat pipe.

Akachi and Polasek described the basic principle of an OHP such that: "When high temperature is supplies to the one end of the bundle of turns of the capillary tube the working fluid inside starts evaporating and the vapour pressure increases, due to which the bubbles are developed in the evaporator zone. This pushes the liquid column toward the condenser which has low temperature. Due to condensation taking place at the low temperature end there is increase the pressure difference between the two ends. Because of the interconnection of the tubes, motion of liquid slugs & vapour bubbles at one section of the tube along the condenser also cause the motion of slugs & bubbles in the next section toward the evaporator (high temperature end), which works as a restoring force. The Interplay between the restoring force & the driving force leads to cause oscillation of the vapour bubble & liquid slugs in the axial direction. The amplitude and the frequency of the oscillation are expected to be dependent on the mass fraction and shear flow of the liquid in the tube". Heat is transferred through sensible heat transported by the liquid slugs & latent heat of the vapour.

2. FLUID PARAMETERS AFFECTING OSCILLATING HEAT PIPE PERFORMANCE

- Maximum radius of channel.
- Heat flux level.
- Number of channel in FP-OHP.
- Filling Ratio.
- Physical properties of working fluids like Latent heat, surface tension, Specific heat, Viscosity, Thermal conductivity have intense effect on thermal performance of OHP [1].

    1. Fluid with low latent heat help to generate Bubbles quickly, fast oscillation movements & reduces startup time.
    2. High Surface tension will increase allowable radius of channel & pressure drop as radius of channel increases, frictional resistance is reduced & relative increases in thermal performance of heat pipe.
    3. Fluid with high specific heat is preferred.
    4. Low viscosity working fluid in heat pipe will decreases shear stress & reduces pressure drop, hence heat load decreases to start OHP.
    5. Higher value of thermal conductivity of working fluid increases heat transfer.

3. LITERATURE REVIEW

Harshal Gamit et al.(2015) had carried out experimental investigation on CLPHP made up of copper tube with 2.5mm inner diameter with water as working fluid. Experiment was conducted with different filling ratio & Heat inputs. System performs better with Lower FR for same input Heat flux. As Heat input increases, thermal resistance decreases due to chaotic fluid movement. For FR=40% Chaotic fluid movement is observed with condenser temperature. As Heat input is increased with the same FR, larger fluctuations are observed. This is also observed for FR=60% but the amplitude is lower as compared to 40% and 50% FR [2].

K.H.Chien, Y.R.Chen, Y.T.Lin, C.C.Wang, K.S.Yang (2011) had Experimentally investigate Thermal performance of FPOHP. Two Heat pipes were made of copper capillary tubes with uniform & Non-uniform CL-PHPs, and working fluid as Distilled water with filling ratio's 40%, 50%, 60%, 70% respectively and inclination angle of 0˚, 30˚,60˚ & 90˚. And found that for increase in inclination angles Thermal resistance decreases with rise of inclinations due to gravity effect. Uniform channel CLPHP shows poor heat transfer performance at horizontal orientation and to improve this non-uniform CLPHP is used [3].

Samad Jafarmadar, Nazli Azizinia (2016) Had investigated effects of nanoparticle & volume concentration on the flow characteristics, heat transfer & entropy generation of PHPs with different Nano-fluids including Al_2O_3, CuO and silver Nano-fluid as working fluids. Conclusion made that silver Nano-fluids has highest rate of entropy generation & irreversibility because of delay in oscillation & bubble generation. Heat transfer rate remains unchanged by increasing volume fraction of nanoparticles. Reasonable particle volume fraction is about 0.5-1% [4].

Himel Barua et al. (2013) Had investigated Heat pipe at different Heat input, filling ratio & fluid as water and Ethanol. For low Heat water is better working fluid than ethanol at wide range of F.R. But at high heat input (more than 70W) Both working fluid shows nearly same thermal resistance. For water optimum heat transfer is obtain at nearly 30% filling ratio. For Ethanol best performance is obtained at nearly high filling ratio beyond 50% [5].

V.M.Patel et al.(2017) had experimentally investigated influence of eleven working fluids mainly Deionized water, Ethanol, Methanol, Acetone, water based mixture (1:1) of acetone , methanol, ethanol as binary fluids & sodium dodecyl Sulphate is used as surfactant with 30, 45, 60, 100PPM. With FR=50% and heat input varied from 10 to 110W. CLPHP is failed to startup pulsation below 20W heat input for all working fluids. Startup heat flux is observed lower for acetone compared to all other fluids. Water has highest startup heat input. Addition of other pure fluids or surfactant in water reduces surface tension & hence reduces startup heat flux compared to pure water. Among Base fluid acetone gives better performance & among Binary fluids water-acetone gives better performance [6].

X. Cui et al. (2016) had experimentally studied thermal resistance characteristics of CLHPs using methanol based binary mixture with volume mixing ratios 2:1, 4:1 & 7:1. Heat power is varied from 10W to 100W with filling ratio 45%, 62%, 70% & 90%. For filling ratio of 45% adding water to methanol can delay dryout and thermal resistance of CLPHP with methanol-water mixture is lower than other. Adding ethanol & acetone to methanol cannot effectively improve thermal performance. But at high filling ratio addition of water, ethanol & acetone cannot give effective heat transfer performance as compared to low filling ratio (45%) [7].

S. Shi et al. (2016) had experimentally investigated Heat transfer performance of PHP with ethanol-water, ethanol-methanol & ethanol-acetone with mixing ratio of ethanol based mixed working fluids as 2:1 & 4:1, volume filling ratio ranges from 45% to 90% and heat input is varied from 10W to 100W.Experimental results with 2:1 mixing ratio heat transfer performance of PHP with ethanol-water is better than other working fluids. At filling ratio of 45% and 50% PHP with ethanol-acetone shows better performance among all [8].

J. Qu H. Wu et al. (2011) studied thermal performance of OHP with SiO_2-water & Al_2O_3 –water Nano fluids with mass concentrations, 0-0.6wt% for silica Nano fluids, 0-1.2wt% for alumina Nano fluids and volume filling ratio of 50% for alumina Nano fluids. They found that for OHP with alumina Nano fluids there existed an optimal concentration of 0.9wt% at which reductions in over thermal resistance of 0.057°C/W and evaporator wall temperature of 5.6°C. For OHP with silica Nano fluids overall thermal resistance and evaporator wall temperature increased with increase in mass concentration of silica Nano particles [9].

L. M. Poplaski et al. (2017) presented 2-D laminar, steady, compressible heat pipe numerical model to simulate the operation of a conventional cylindrical heat pipe charged with Nano fluid. Nano particle concentration have greatest effect on fluid thermal conductivity and thermal resistance. Increase in nanoparticle concentration of Nano fluid lowered the total thermal resistance of heat pipe to an optimal volume concentration corresponding to capillary limit and was 25% vol. for both Al_2O_3 & TiO_2, and 35% for CuO [10].

4. CONCLUSION

Based on Reviewed researches, Thermo-physical properties of working fluids affect significantly on Heat transfer capability of PHPs. Use of Binary or Ternary fluids also improves thermal performance, startup and prevent dryout. Adding some Nanoparticles to working fluid also improve performance of PHP. Hence by using Binary or ternary fluids, Nano fluids it is possible to increase thermal conductivity & decrease surface tension of working fluid which have favorable effects for heat transfer of PHPs.

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