Effect of Filling Ratio on Thermal Performance of Closed Loop Oscillating Heat Pipe

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Abstract— This paper justifies the effect of filling ratio on the closed loop oscillating heat pipe performance. An experimental investigation has been carried out on the thermal performance of the CLOHP with different filling ratio for water based CuO nanofluid. The thermal performance of the device has been investigated with varying heat power in the range of 30–150W in the vertical orientation. The overall thermal resistance and heat rejected by CLOHP are evaluated to predict the thermal performance of the device. Experimental results show that the CLPHPs filled with 30% filling ratio shows better performance for lower heat loads and 50% filling ratio shows better performance for higher heat loads. While the 70% filling ratio shows poor performance for all heat loads compared to 50% and 30%.

Key words: Oscillating Heat, Pipe Base, Thermal Performance

I. INTRODUCTION

Oscillating heat pipe (OHP) is a passive two phase heat transfer device which does not have wicking structure. It has been invented by Akachi, it exhibits self sustained oscillation of the working fluid and phase change phenomenon leading to enhanced heat transfer. Due to its simple design, light weight, low fabrication cost and very fast response at higher heat loads, OHPs have been considered as one of the compact heat transfer devices for various cooling applications such as electronics cooling, heat exchanger and space application, etc. Since the last two decades, many researchers have investigated its thermal performance experimentally and theoretically. These experiments reveal that the CLOHP performance is strongly affected by many parameters including geometrical, physical and operational parameters. Furthermore, it is mentioned that the problem of two phase flow oscillation in closed loop pulsating heat pipe is very complicated because of many unstable variables and complexity of thermo-hydrodynamic operational characteristics. In the meantime, some visual studies have been performed using glass tube to understand the operational behaviour and considerable progress has been also achieved in these attempts. In recent years, improving thermal performance of CLPHP has become a demanding challenge and hot research topic due to rapidly increasing heat load and miniaturization of electronic devices. Based on existing experimental results, the filling ratio of working fluid is the most important parameter in the CLPHP.

II. EXPERIMENTAL SETUP

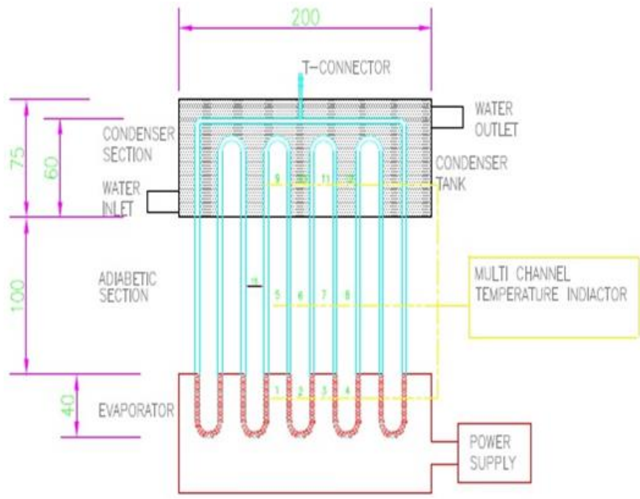

Fig. 1: Experimental Setup

The setup mainly consists of a copper tube with inner diameter 2.3mm and outer diameter 3.1mm. The pipe is bended at several lengths to according to figure sown in experimental setup. The total height of the CLOHP is 200mm with 5 number of turns each in a evaporator and condenser section. The length of evaporation, adiabatic and condenser sections are 40, 100, and 60 mm respectively. The total length of the copper tube is approximately 3.1m. The two end of a pipe are connected bye T-connector and valve. The working fluid is filled inside CLOHP after creating vacuum up to 10-3 torr. The water based CuO nanofluid with 1% volume fraction had been used as a working fluid. The evaporator section is made up of a 0.25mm diameter nichrome wire wounded on pipe surface. The condenser section is made up of thin copper plate with water inlet and outlet section.

Fig. 2: Working Setup

An AC voltage stabilizer, a voltage transformer and a power meter are included in the power supply unit. The condenser section is cooled by running water with temperature around 26° C. The flow rate of cooling water is maintained constant during all the experiments. The 12 numbers of K-type thermocouples are used to determine the surface temperature of CLOHP, 4 in each evaporator, adiabatic and condenser section. The inlet and outlet temperatures of cooling water are measured by digital thermometer. The temperatures of thermocouples are recorded by digital temperature indicator. The evaporator and adiabatic sections were insulated using silver foil enveloped glass fibre tape to minimise the heat loss.

The experiment was performed in vertical position of CLOHP for different heat inputs in the range of 30-150 Watt. Also the CLOHP was investigated for the filling ratio of working fluid as 30%, 50% and 70% respectively.

III. Results and Discussion

A. *Thermal Resistance*

Generally the performance of an OHP is measured in terms of thermal resistance. Lower the thermal resistance indicates better performance of an OHP.

Thermal resistance is termed as, $R_{th} = (T_e - T_c) / Q$

Where, Q = heat supplied (Watts),

T_e = Mean evaporator temperature (°C).

T_c = Mean condenser temperature (°C).

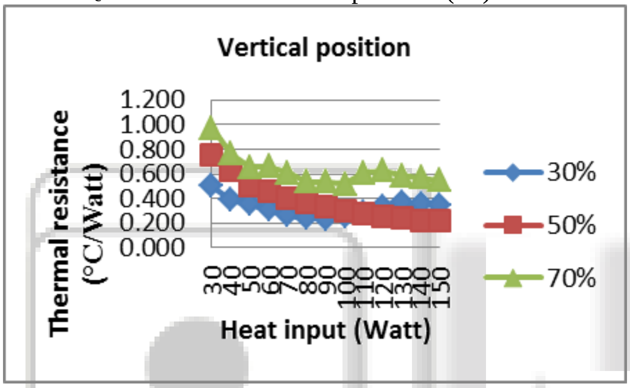

Fig. 3: Thermal resistance of CLOHP for different filling ratio

The 70% filling ratio shows a poor performance compared to filling ratio 30% and 50%. While 30% filling ratio is found to be optimum for lower heat load while at higher heat load filling ratio 50% is found to be optimum. The best performance of an OHP founds at 50% filling ratio for heating load of 150 Watt. At 150 Watt heat load 34.41% enhancement in performance of OHP is registered for 50% filling ratio compared to 30% filling ratio.

B. *Evaporator Temperature*

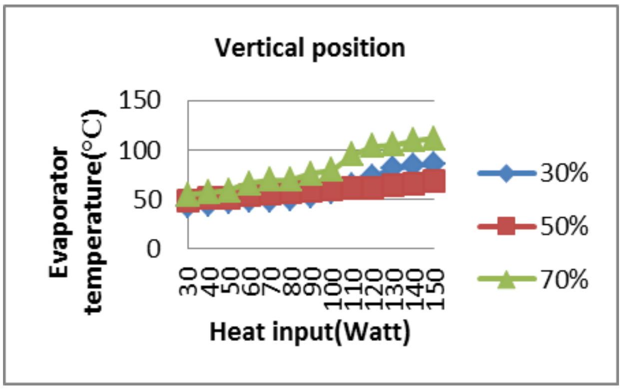

Fig. 4: Evaporator Temperature Of CLOHP For Different Filling Ratio

As seen in figure 4, we can say that the filling ratio affect the evaporator temperature. 30% filling ratio offers lower temperature at lower heat load, while at higher heat load 50% filling ratio offers lower temperature.

C. *Heat Rejected By OHP*

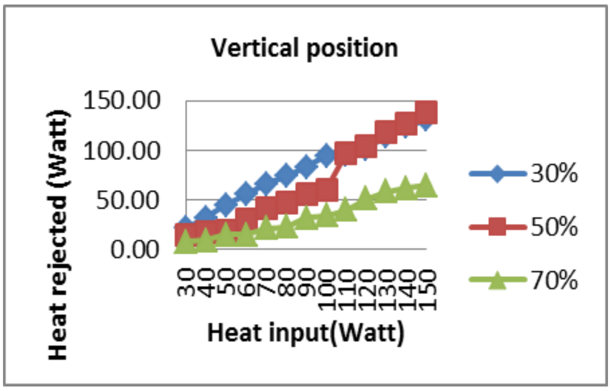

Fig. 5: Heat Rejected By CLOHP For Different Filling Ratio

As seen in figure 5, the CLOHP with 70% filling ratio rejects less heat compared to 30% and 50%, which leads to poor performance of an OHP. While 30% filling ratio rejects more heat at lower heat loads and 50% filling ratio rejects more heat at higher heat loads.

IV. Conclusion

1) The performance of an OHP improves at a higher heat load.
2) The performance of an OHP varies with different filling ratio of working fluid. In present investigation it was found that 30% filling ratio was optimum for lower heat loads and 50% for higher heat load. While, 70% filling ratio shows poor performance compared to 30% and 50%.
3) The CLOHP filled with 30% filling ratio offers lower evaporator temperature at lower heat input and 50% filling ratio offers lower evaporator temperature at higher heat input.
4) The CLOHP should be filled with optimum filling ratio according to applications and heat input for better performance.

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