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EXPERIMENTAL INVESTIGATION ON THERMAL PERFORMANCE OF TWO PHASE THERMOSYPHON CHARGED WITH WATER, ETHANOL, METHANOL AND ACETONE

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ABSTRACT

In this study, thermal performance of a two phase closed thermosyphon was investigated experimentally for various filling ratio from 30% to 90% and with various operating temperature range from 30°C to 70°C in heat input range of 0 to 1200W. Copper tube of 1000mm length with 12mm inside diameter and 16mm outside diameter were employed The series of experiment were carried out to investigate the maximum heat transfer capabilities of water, ethanol, methanol and acetone and compare the maximum heat transfer rate of water, with ethanol, methanol and acetone. The result showed the maximum heat transport capability of water is high compared to other working fluids such as ethanol, methanol and acetone, at all filling ratio and at all operating temperatures. And also the maximum heat transport capability increasing with increasing operating temperature

Key word: *Thermosyphon, Heat transport capability, filling ratio and Operating temperature.*

INTRODUCTION

The two phase closed thermosyphon is a heat pipe which needs no wicks to return the condensate working fluid from the condenser to the evaporator in the heat transport process due to gravity (Park, 1992). The thermosyphon heat pipe can be divided into three sections as shown in the figure 1 (Kannan and Natarajan, 2010). The evaporator which is located near the heat source (bottom), condenser located near the heat sink (top) and the adiabatic section in the middle of the thermosyphon heat pipe. In thermosyphon, the evaporator is partially filled with a working fluid, which is degassed and kept initially at a vacuum. The working fluid in the evaporator section absorbs the heat input in the form of sensible heat and mostly as latent heat of vaporisation. The vapour travels upward to the condenser section where it is converted in to liquid, giving up its latent heat of conduction. The liquid then flows downward on the wall as a thin film under the effect of gravity to the evaporator section. For the past many years considerable experimental and theoretical work have been carried out on the applications and design modification for improving thermosyphon performance. Khandekar *et al*., (2008) investigated the overall thermal resistance of closed tow-phase thermosyphon using pure water and various water based nanofluids (of Al_2O_3, CuO and laponite clay) as working fluids. They observed that all these nanofluids show inferior thermal performance than pure water. Thermal performance of the thermosyphons are affected by several factors such as the type of working fluid, filling ratio, aspect ratio, operating pressure, inclination angle and length of various sections of the pipe (Noie, 2005 and Khazaee *et al*., 2010).

Thermosyphons are suitably applied for energy recovery in HVAC systems especially in tropical countries where incoming fresh air at high ambient temperatures could be precooled by the cold exhaust air streams (Chowdhury *et al.,* 1997). Some other applications of thermosyphons are cooling of electronic components, solar energy systems, space craft thermal control, cooling of gas turbine rotar blades, etc (Faghri , 1995 and Ong *et al.,* 1999). Khazaee *et al*., (2010) was investigated the effect of filling ratio, aspect ratio, heat input and mass flow rate on the heat transfer characteristic of methanol as a working fluid. Chowghury *et al.,* (1997) has developed correlations for water, ethanol and R113. Hussam Jauhara *et al*., (1997) has developed the thermal performance of cooper thermosyphon charge with water as well as three fluorinert liquids FC-77, FC-84 and FC-3283 is reported for small thermosyphon. Donald *et al*., (1977) and Chen *et al*., (1990) investigated the characteristic of two phase closed loop thermosyphon through experimentally method studied the effect of fill ratio of evaporation, condensation and overall heat transfer coefficient. Groll *et al.,* (1980) made an experimental study on the performance of stationary two phase closed thermosyphon with three working mixture (water-glycerine, water-ethanol, water-ethylene glycol). In this research to find out the maximum heat transport capabilities of two phase thermosyphon at various filling ratio and at different operating temperature for different working fluid such as water, ethanol, methanol and acetone were experimentally conducted.

METHODOLOGY

The experimental setup shown in the fig 2 was used for studying the thermal performance of a two phase closed thermosyphon for various filling ratio with different operating temperatures for different working fluids. The test rig consists of a heater, a liquid reservoir for charging, a thermosyphon (wickless heat pipe), a cooling section and also measuring instruments. The upper part of the thermosyphon was equipped with a seal valve for connection to a mechanical vacuum pump and to the working fluid charging line. A mechanical vacuum pump capable of up to 0.5 Pa used for partial elimination of the non-condensable gases (NCG) from the thermosyphon. Complete extraction of NCG was achieved by purging.

In this study the thermosyphon consist of 1000 mm long tube having an inside diameter of 12 mm and outside diameter of 16 mm. The evaporator section has the length of 300 mm and adiabatic section has the length of 200 mm. The condenser section of the pipe consisted of a 500 mm long (50 mm OD) concentric tube acting as a cooling water jacket surrounding the pipe is shown in Figure 3. An electrical resistance of a nominal power range of 0 W to 1200 W was wrapped around the evaporator section, which is used to heat the evaporator. To prevent the heat loss to the atmosphere, the electrical elements were insulated by glass wool having a thickness of 65mm. The heat was removed from the condenser section by the water jacket. The power supplied to the evaporator section was determined by monitoring the applied voltage and current with accuracy of ± 2%. The accuracy of flow measurement was estimated to be around ±2 %. A variable voltage controlled the rate of heat transfer the evaporator. Temperature distribution along the thermosyphon was measured using Ni- Cr thermocouple. Thermocouples were mechanically attached to the surface of the pipe. The vapour temperature was measured by thermocouple T_9 and T_{10} attached to the top and bottom surface of thermosyphon as shown in figure.4. In order to find out the effects of maximum heat transfer capability on the thermal performance of the thermosyphon a series of test were carried out for the following conditions.

Input heat transfer

Rate range : 0W to 1200 W
Filling ratio : 30,40,50,60,70,80,90

Operating

Temperature (°C) : 30, 40, 50, 60, 70.
Working fluids : Distilled water, ethanol, methanol and acetone

Test procedure began by charging a required working fluid. In the first series of experiments, the thermosyphon was filled with distilled water. The thermal performance of the thermosyphon for different working filling ratio and operating temperature was investigated. Maximum heat transport capability was measured by subjecting the thermosyphon to cyclic variation of heat input. The power input was increased linearly from 0 W to nominal power. The maximum power, at which the wall temperature of thermosyphon was high, was recorded. At that condition the maximum heat transport rate was measured. This procedure was repeated for all working fluids.

Performance of two phase closed thermosyphon: Three different types of performance limitations are observed in the investigation of closed two phase thermosyphon.

1. The dry out limitation is observed in low filling ratio. In this case, the returning condensate flow is reduced before reaching the evaporator. Then the level of liquid pool is slowly lowered and finally the evaporator wall gets dried out completely.
2. The boiling limit or burn out limitation is noticed in high liquid filling ratio and high radial heat flux in the evaporator section.
3. The entrainment or the flooding limitation is encountered for high axial heat flow at small radial evaporator heat flux.

The following correlation between the maximum heat transport capabilities and the various influence parameter was used (Groll and Rosler [13]) to verify the measured result.

$$Q_{\max} = \{ f_1 f_2 f_3 L(\rho_v)^{1/2} [\gamma g(\rho_l - \rho_v)]^{1/4} \} A'_E \quad \textbf{(1)}$$

RESULTS AND DISCUSSIONS

The maximum heat transport capability with respect to the operating temperature for different working fluids (water, methanol, ethanol, acetone) at various filling ratio were calculated and the results have been plotted in figure 5-9. The figure 5-9 shows the maximum heat transport capability of water is higher at all filling ratio 30% to 90% and all operating temperature 30^0c to 70^0c because of its high latent heat, heat capacity, high liquid and vapour density. The maximum heat transport capability of acetone is relatively low at all operating temperature for all filling ratio, The maximum heat transport capability of ethanol is found to be higher than acetone, but less than methanol. Comparison between the predicted maximum heat transport rate according to Eq.1 and experimental results was found to be good and the discrepancy was less than ±14%. Groll *et al*., (1980) has studied the maximum heat transport capability at various tilting angles, with water as a working fluid and also studied the influence of surface roughness on maximum heat transport capability.

CONCLUSION

The effect of the different working fluids with various filling ratio on the maximum heat transport rate of a closed two phase thermosyphon under normal operating condition were investigated in this work in the range of heat input of 0 to 1000W. The following results were obtained. The maximum heat transport capability showed a increasing trend with increasing operating temperature. The effect of filling ratio on heat transport capability was only marginal for all fluids. The heat transport limitations were observed in different ways with various filling ratio. For a small filling ratio (FR<20%) it occurred by the dry out limitation. While for the large filling ratio it occurred by the flooding limitation. The maximum heat transport capability of water is higher at all filling ratio and all operating temperature. For acetone it is relatively low at all operating temperature for all filling ratio, the maximum heat transport capability of ethanol is found to be higher than acetone, but less than methanol. Maximum heat transport capability was found to strongly depend on the operating temperature and filling ratio.. As the operating temperature increases from 30°C to 70°C, maximum heat transport capability is also increases from 688 to 1189 W. for water.

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Figure.1 Two phase thermosyphon (Gravity – assisted wickless heat pipe)

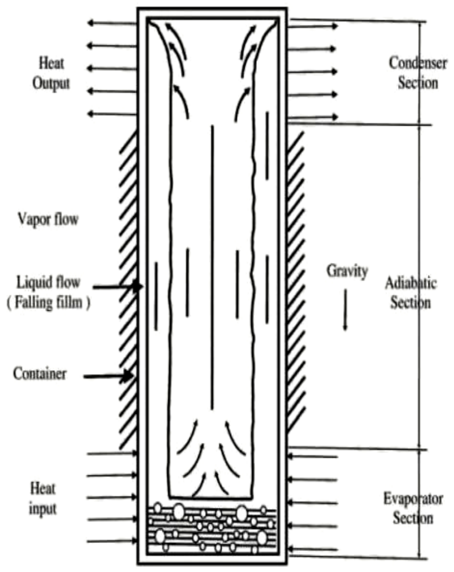


Figure.2 Schematic of the test rig

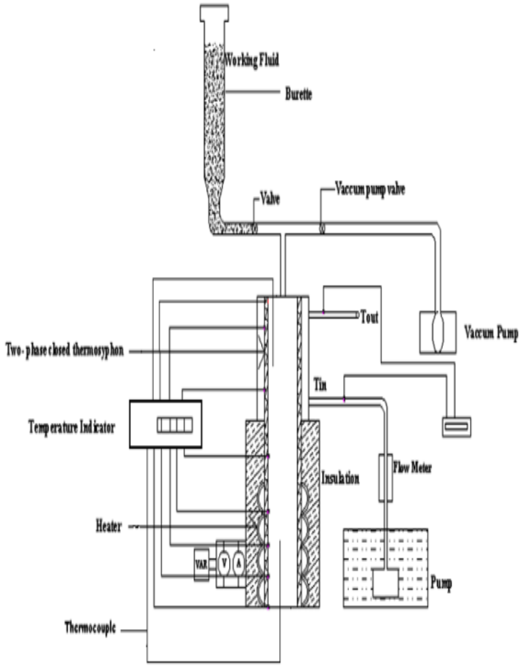


Figure.3 Details of thermosyphon with inner diameter of 12 mm

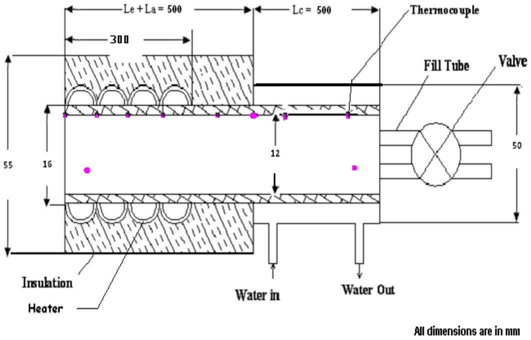


Figure.4 Locations of thermocouples

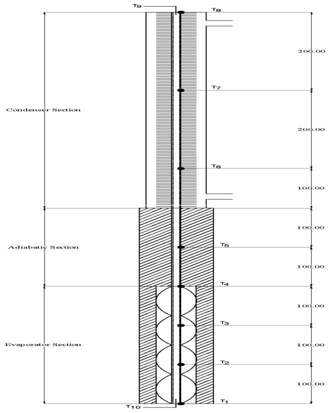


Figure. 5: Maximum heat transport capability Vs filling ratio for thermosyphon for operating temperatures of 30^{o}C.

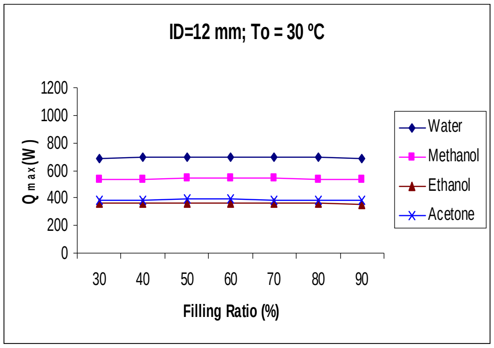


Figure.6: Maximum heat transport capability Vs filling ratio for thermosyphon for operating temperatures of 40^{o}C.

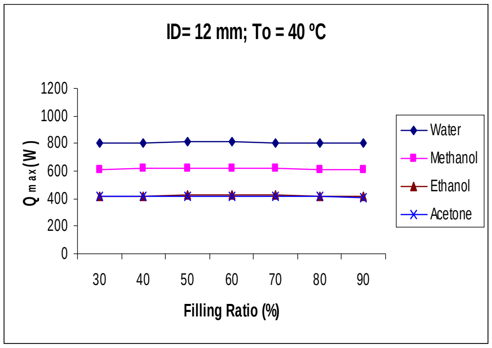


Figure. 7: Maximum heat transport capability Vs filling ratio for thermosyphon for operating temperatures of 50^{o}C.

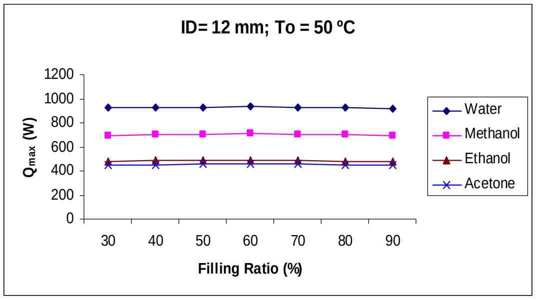


Figure.8: Maximum heat transport capability Vs filling ratio for thermosyphon for operating temperatures of 60^{o}C.

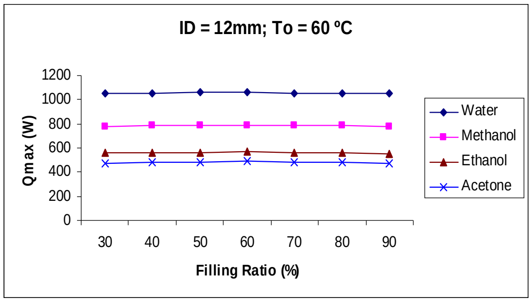
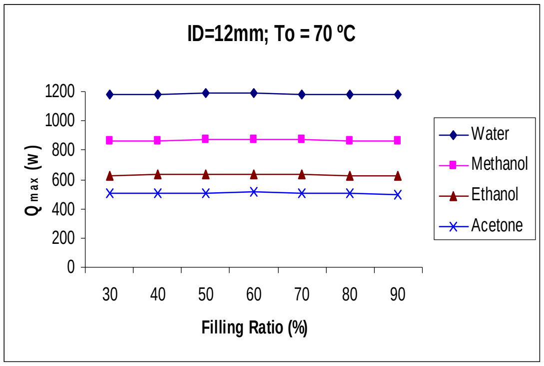


Figure.9: Maximum heat transport capability Vs filling ratio for thermosyphon for operating temperatures of 70^{o}C.



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