THERMAL PERFORMANCE OF A TWO PHASE CLOSED THERMOSYPHON CHARGED WITH DIFFERENT WORKING FLUIDS

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Abstract: *In this study, thermal performance of two phase closed thermosyphon was investigated experimentally for various filling ratio from 30% to 90% and with various operating temperature range from $30^{0}C$ to $70^{0}C$ in heat input range of 0 to 1200W. Copper tube of 1000mm length with 6.7mm inside diameter and 8mm outside diameter were employed. A series of experiment were carried out to investigate the maximum heat transfer capabilities of water, ethanol, methanol and acetone and to 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 that of other working fluids such as ethanol, methanol and acetone, at all filling ratios and at all operating temperatures. And also the maximum heat transport capability increases with increasing operating temperature.*

Keywords: *Thermosyphon, filling ratio, Operating temperature, Heat transport capability.*

1. Introduction

A two phase closed thermosyphon is a heat pipe which needs no wicks to return the condensed working fluid from the condenser to the evaporator in the heat transport process due to gravity [1]. The thermosyphon heat pipe can be divided into three sections as shown in the figure 1 [2]. 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 into liquid, giving up its latent heat of conduction. The liquid then flows downwards on the wall as a thin film under the effect of gravity to the evaporator section.

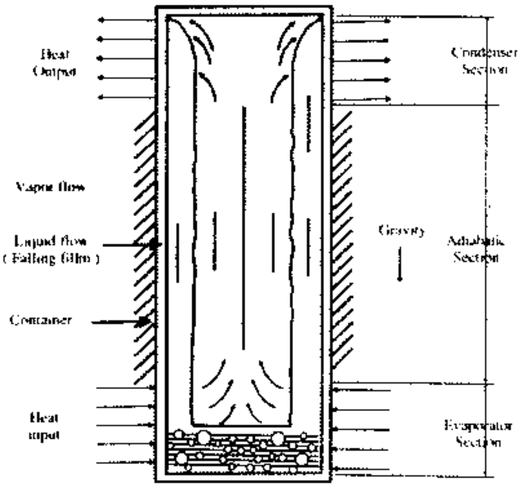

Figure 1: Two phase thermosyphon (Gravity – assisted wickless heat pipe)

For the past many years considerable experimental and theoretical work have been carried out on the applications, design and modification for improving thermosyphon performance. Khandekar et.al [3] investigated the overall thermal resistance of closed two-phase thermosyphon using pure water and various water based nanofluids (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

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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 [4, 5].

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 [4]. Some other applications of thermosyphons are cooling of electronic components, solar energy systems, space craft thermal control, cooling of gas turbine rotor blades, etc [5-7]

Khazaee et.al [4] has investigated the effect of filling ratio, aspect ratio, heat input and mass flow rate on the heat transfer characteristic with methanol as a working fluid. Chowdhury et.al [8] has developed correlations for water, ethanol and R113. Jouhara and Robinson [9] investigated a small diameter and compact thermosyphon with four different working fluids: water, FC-84, FC-77 and FC-3283 and reported that thermal performance of the water-charged thermosyphon outperformed the other three working fluids in both the effective thermal resistance as well as maximum heat transport capabilities. Donald et.al [10] and Chen et.al [11] have investigated the characteristic of two phase closed loop thermosyphon through experimentally and studied the effect of fill ratio of evaporation, condensation and overall heat transfer coefficient. Park and Lee [12] made an experimental study on the performance of stationary two phase closed thermosyphon with three working mixture (water-glycerin, water-ethanol, water-ethylene glycol). Wong *et al.* [13] investigated heat transport characteristics of a cryogenic two-phase nitrogen thermosyphon and found that the maximum heat transfer rate is governed by the interaction between the vapor flow and the returning liquid film flow along the wall in the evaporator section, even near the critical point.

In this research, we tried to find out the maximum heat transport capabilities of two phase thermosyphon at various filling ratios and at different operating temperatures for different working fluid such as water, ethanol, methanol and acetone.

2. Experimental Setup

The experimental setup shown in the fig 2 and fig 3 was used for studying the thermal performance of a two phase closed thermosyphon for various filling ratios with different operating temperatures and 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.

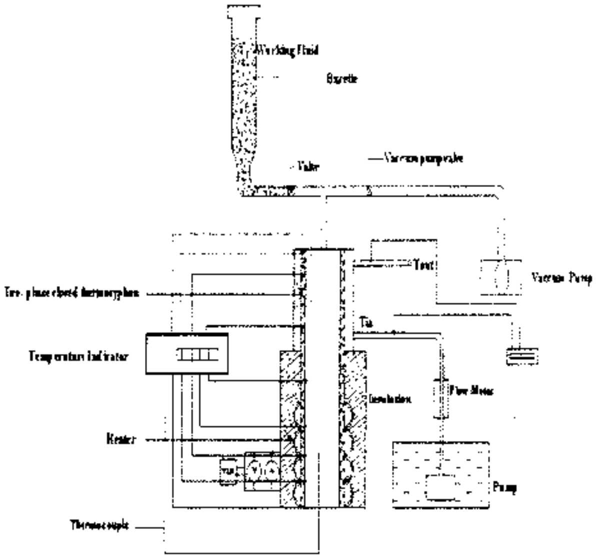

Figure 2: Schematic of the test rig

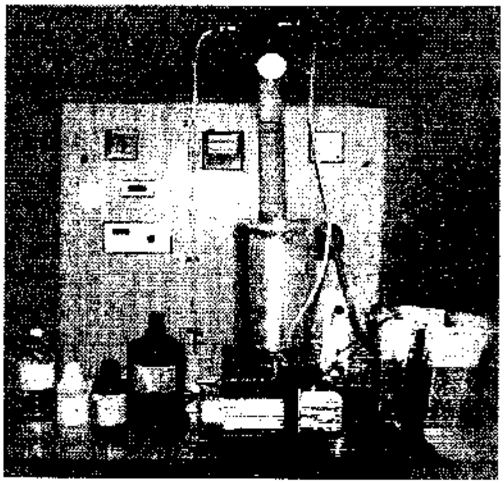

Figure 3: Photographic view of experimental setup

In this experimental process, the thermosyphon consist of 1000 mm long tube having an inside diameter of 6.7 mm and outside diameter of 8 mm. The tube was sealed at one end and was provided with a vacuum valve at the other end. 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 (30 mm OD) concentric tube acting as a cooling water jacket surrounding the pipe.

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 reduced from the condenser section by the water jacket.

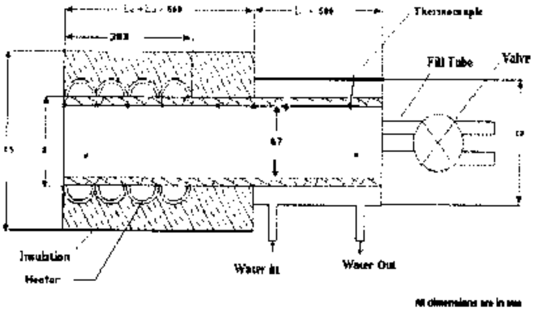

Figure 4: Details of thermosyphon with inner diameter of 6.7 mm

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 controller controlled the rate of heat transfer of the evaporator. Temperature distribution along the thermosyphon was measured using Ni- Cr thermocouple. Thermocouples were mechanically attached to the surface of the pipe.

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.

3. 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°C to 70°C 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 that of acetone, but less than methanol.

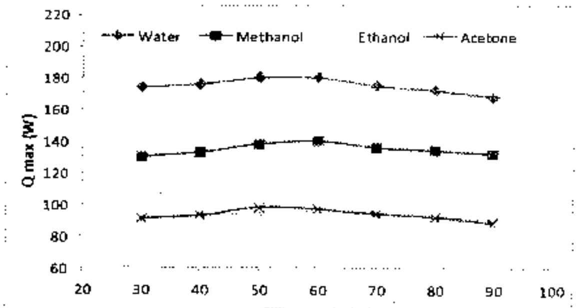

Figure 5: Maximum heat transport capability Vs filling ratio for thermosyphon with operating temperatures of 30°C

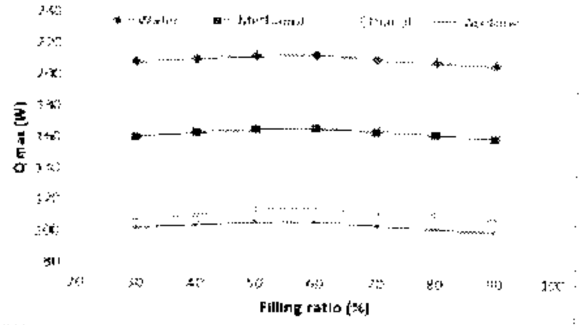

Figure 6: Maximum heat transport capability Vs filling ratio for thermosyphon with operating temperatures of 40°C

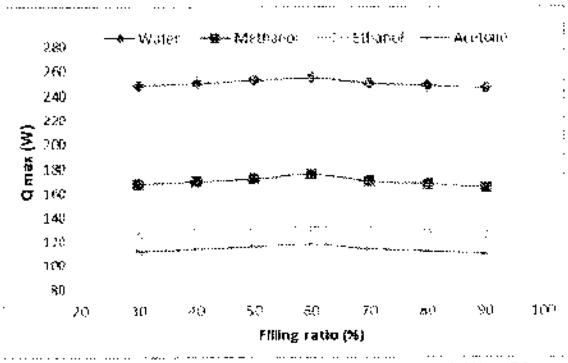

Figure 7: Maximum heat transport capability Vs filling ratio for thermosyphon with operating temperatures of 50°C

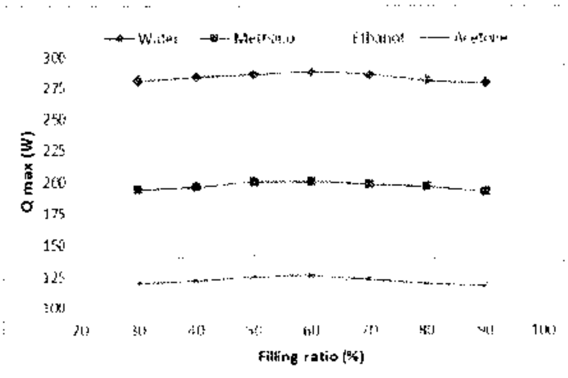

Figure 8: Maximum heat transport capability Vs filling ratio for thermosyphon with operating temperatures of 60°C

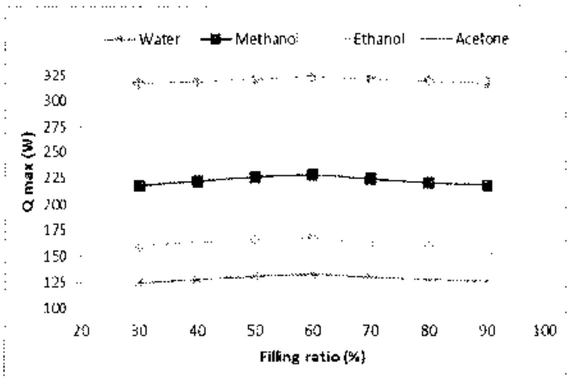

Figure 9: Maximum heat transport capability Vs filling ratio for thermosyphon with operating temperatures of 70°C

4. Conclusions

The effect of the different working fluids with various filling ratios on the maximum heat transport rate of a closed two phase thermosyphon under normal operating condition in the range of heat input of 0 to 1000 W were investigated in this work. The following results were obtained.

- The maximum heat transport capability showed an 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 ratios and all operating temperatures. For acetone it is relatively low at all operating temperatures for all filling ratio, the maximum heat transport capability of ethanol is found to be higher than acetone, but less than that of methanol.
- Maximum heat transport capability was found to strongly depend on the operating temperatures and filling ratios. 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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