Effect of Evaporator Surface Roughness on the Performance of a Two Phase Closed Loop Thermosyphon

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ABSTRACT

A two-phase closed loop thermosyphon has been designed, fabricated and tested. This thermosyphon consists of four components in its loop, an evaporator with boiling enhancement structure, vapor rising tube, condenser and condensate return tube. Evaporator surface is heated by using an electric capsule heater which is connected to the A.C power supply. Heat supply is varied using a voltage regulator which is measured by a precision ammeter and a voltmeter. The condenser section is cooled by natural convection of air. Temperatures at different locations of the evaporator surface are measured using five calibrated K type thermocouples. Three different evaporator surfaces namely semi circular ribbed surface (SCRS), triangular ribbed surface (TRS) & smooth surface (SS) are tested in this study to assess the effects of evaporator surface geometry using three working fluids (acetone, ethanol and methanol). Triangular ribbed surface can dissipate maximum heat flux among all the evaporator surfaces used and among the working fluids ethanol's performance is the best.

Keywords: *Evaporator surface, Two Phase, Closed Loop, Thermosyphon*

NOMENCLATURE

q''	Heat Flux, kW/m^2
T_{sat}	Saturation temperature of working fluids, °C
T_w	Evaporator wall temperature, °C
ΔT	Wall superheat, °C

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1 INTRODUCTION

Thermosyphon has been being studied since the middle of last century due to its high effective heat transfer coefficient. The early studies on thermosyphons were on single phase heat transfer and fluid flow processes. But the latest researches are emphasizing on two-phase thermosyphon. Many studies of thermosyphon show the existence of several operating limits that depend on the heat addition, geometry and liquid filling ratio and fluid characteristics. As the size of the evaporator is reduced, the liquid/ vapor space around the enhanced structure has also been reduced. This could affect the heat transfer performance of the system. Katto et al. [1] examined the effect of placing a plate parallel to the boiling surface at very close distance (0.2 – 10mm) with saturated distilled water as the working fluid. They found degradation in the heat transfer performance with reduction of vapor space. Nowell et al. [2] conducted a similar study with a micro configured heat sink, which was etched in silicon and oriented vertically. Ahmed [3] studied the effects of working fluids and evaporator geometry. Three different working fluids were used in his study (Acetone, Ethanol and Methanol). Boiling heat transfer was studied for three different evaporator surfaces, plain surface, integrated rectangular finned surface and integrated cross-finned surface. Webb et al. [4] has used enhanced surfaces in the evaporator and condenser sections of a thermosyphon for cooling the hot side of thermoelectric coolers. Using a "bent-fin" structure, they have achieved a heat flux of about 18 W/cm^2 for refrigerant R-134a. Ramaswamy et al. [5] investigated the effect of confinement of the evaporator section. Baset [6] studied the effect of three different evaporator surfaces (semicircular ribbed surface, saw tooth ribbed surface and triangular ribbed surface) on the performance of two phase closed loop thermosyphon using three different working fluids named, ethanol, methanol and acetone.

2 EXPERIMENTAL SETUP AND TEST PROCEDURE

The experimental setup of a closed loop thermosyphon as shown in Fig.1 consists of an evaporator, condenser, copper tubing, heat supply system and measurement system. Three working fluids (acetone, ethanol, and methanol) are used to transport heat from evaporator to condenser. Evaporator section as shown in Fig.2 is a stainless steel enclosure made from a circular cross-sectioned hollow cylinder with top and bottom flanges welded there. It has one vapor outlet port, condensed liquid inlet port and two looking windows. All the body of the evaporator section is properly insulated with glass wool. One thermocouple is

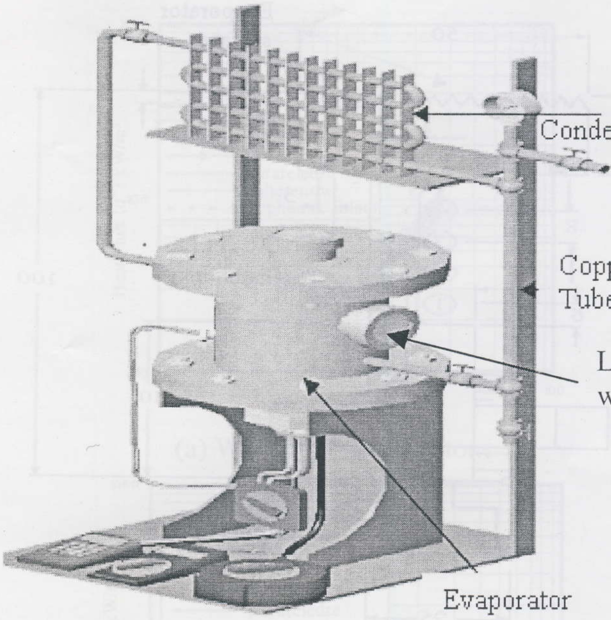


Figure 1: Layout of the experimental rig

embedded inside the enclosure to measure the temperature of boiling liquid. The condenser surface is of tube-in-fin type and is cooled by air. Thus the cooling is done by natural convection. The total number of fins is 40. The condenser section is fixed at higher elevation point as shown in Fig.1. The experimental set up is tested for leak proof in pressurized condition and after that the evaporator section is charged with working fluid. High heat flux is then supplied to the heater. Heat is supplied to the evaporator through Joule heating. A cartridge heater fitted in the evaporator is shown in Fig.2. Vent valves are kept closed during cooling. Initial heat input is 100 W and it is increased at steps of 10W. Regulated electrical energy is supplied to the heater during the experiment. The maximum heater capacity is 350W. During experiment, the power supplied to the heater is measured by measuring voltage and current by voltmeter and Clip-on-meter respectively. At the same time, temperatures at the locations mentioned in Fig.2 are measured using five calibrated K type thermocouples. All the measured data are recorded manually. Using gathered data, heat flux ($q^{//}$) and wall superheat ($\Delta T = T_w - T_{sat}$) are calculated.

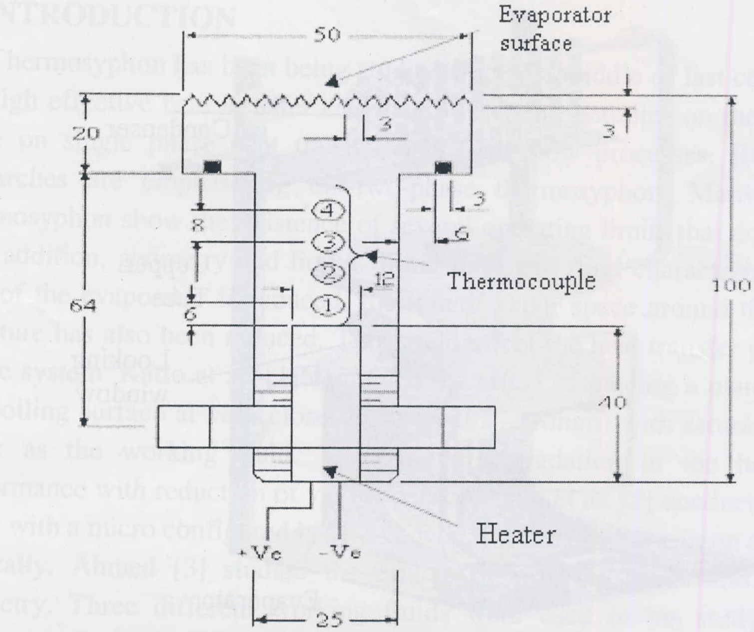
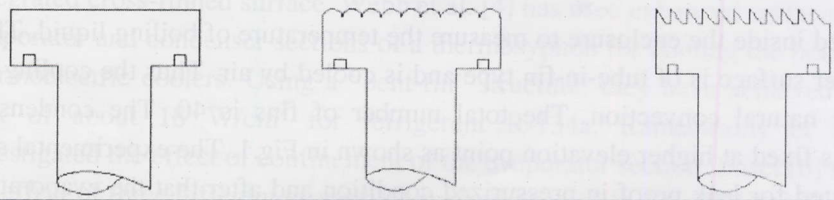


Figure 2: Detail evaporator assembly (All dimensions are in mm)



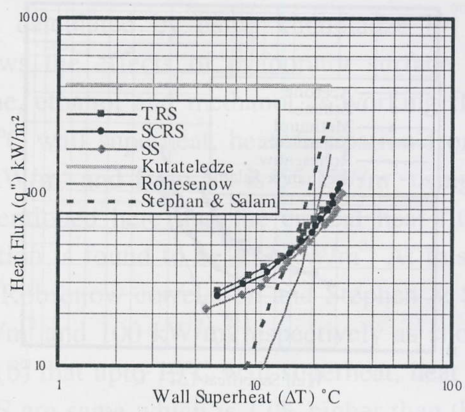
(a) Smooth surface (SS)	(b) Semicircular ribbed surface (SCRS)	(c) Triangular ribbed surface (TRS)

Figure 3: Geometric variations of test surfaces

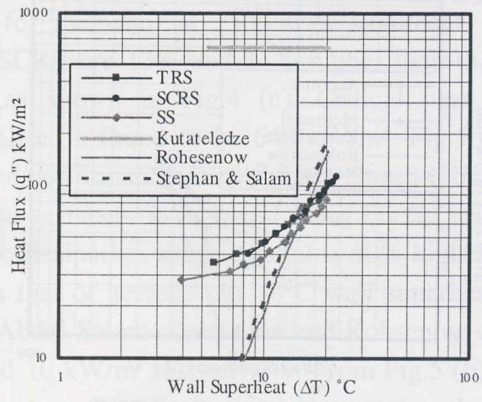
Three different evaporator surfaces namely smooth surface (SS), semicircular ribbed surface (SCRS) and triangular ribbed surface (TRS) as shown in Fig.3 have been tested in this study.

3 RESULTS AND DISCUSSIONS

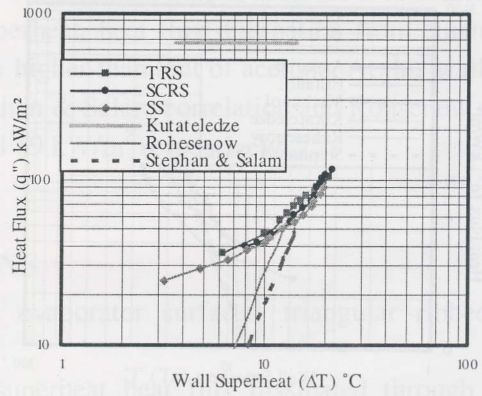
Using collected data, various curves are plotted as shown in Fig.4 and Fig.5. Results from Rohsenow [7] correlation, Stephan and Abdel Salam [8] correlation are included in some of these plots to compare their results with results of the present study. Critical heat flux values for different working fluids at the same



(a) Working fluid: Acetone



(b) Working fluid: Ethanol



(c) Working fluid: Methanol

Figure 4: Effect of evaporator surfaces on boiling curves for different working fluids

3. At 10ºC wall superheat heat flux dissipated through triangular ribbed surface using methanol, ethanol and acetone are found to be 10%, 17% and 35% higher than that of smooth surface respectively.
4. Among the working fluids used, ethanol gives the best performance in terms of heat flux for any evaporator surfaces.
5. For smooth surface, heat flux dissipation using ethanol is 60% higher and using methanol is 42% higher than that of acetone upto 10ºC wall superheat.
6. For triangular ribbed evaporator surface, heat flux dissipation using ethanol and methanol are found to be 42% and 18% higher than that of acetone at 10ºC wall superheat.
7. For semi circular ribbed evaporator surface, heat flux dissipation using ethanol and methanol are same upto 10ºC wall superheat which is 27% higher than that of acetone.

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