THERMAL PERFORMANCE OF LONG EVAPORATIVE SECTION ETHANOL FLUID THERMOSYPHON USED IN SOLAR WATER HEATING SYSTEM

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Abstract: In this study, the aim is to investigate the application of ethanol fluid thermosyphon as a heat transfer tool in a solar water heater (SWH). For this purpose, a long evaporative section thermosyphon (LEST) is designed, constructed and tested at temperatures of 50,60&70˚C In this work the LEST is made of copper tube of 1000mm length of internal diameter 24.4 mm and 1mm thickness. The working fluid employed is ethanol with filling ratio (FR) 40%. The lengths of evaporator, adiabatic & condenser sections are 600, 200 and 200 mm respectively. The LEST placed centrally in 2 inch UPVC pipe. The 2 inch UPVC pipe water jackets are provided in both evaporative & condenser section of prescribed length for hot water circulation. Heat source at 50˚, 60˚ &70˚C temperature of hot water taken during experimentation. Immersion water heater was used for water heating process. The Inclination of the LEST varies between 0˚ to 90˚. Seven different tests were carried out in different orientation angle. The results show that efficiency of thermosyphon mode is in range of 47% to 73%.Experimentally found that the the vertical position as well as 45˚angle are the best for thermosyphon. Long evaporative section ethanol fluid thermosyphon can be used in solar water heating system. **Keywords: Ethanol fluid, Thermosyphon, Solar water heater, Heat pipe, long evaporative section.**

I. INTRODUCTION

Heat pipes and two phase thermosiphons are heat transfer devices whose operating principles are based on the evaporation/condensation of a working fluid using the capillary pumping forces (in case of heat pipe) and gravity forces (in case of two phase thermosiphons) to ensure the working fluid circulation.

Two-phase (thermosyphon) heat transfer involves the liquid-vapor phase change (boiling and condensation) of a working fluid. Thermosyphons & Heat pipes offer high effective thermal conductivities, energy-efficiency, light weight, low cost and the flexibility of many different size and shape options. As passive heat transfer systems, Thermosyphons & heat pipes offer simple and reliable operation, with high effective thermal conductivity, no moving parts, ability to transport heat over long distances and quiet vibration-free operation. Thermosyphons & Heat pipes transfer heat more efficiently and evenly than solid conductors such as aluminum or copper because of their lower total thermal resistance. It transfers heat many times faster than pure copper. The Thermosyphon & heat pipe is filled with a small quantity of working fluid (Ethanol). Heat is absorbed by vaporizing the working fluid. The vapor transports heat to the condenser region where the condensed vapor releases heat to a cooling medium like water. The condensed working fluid is returned to the evaporator by gravity, or by the heat pipe's wick structure, creating capillary action. Solar water heater is one of the devices that have been used in different shape and types since very old times. The use of Thermosyphon & heat pipes offers several advantages regarding flexibility in operation and application, as they are very proficient in transporting heat even under a small temperature difference [1]. Thermosyphon & Heat pipes are currently utilized in many energy systems according to their needs, in industrial areas and aerospace applications, including the solar system considered in the present analysis. The first area that appears most appropriate for heat pipe application is domestic hot water heating systems. The amount of energy required to heat domestic water is significant, even in comparison with the space heating requirement. Moreover, the environmental issues linked to the use of fossil fuels give great incentives to tie together alternative energies where possible. In the current study we are using thermosyphon for water heating application. We were used thermosyphon in three orientations namely horizontal, vertical and inclined. The size of thermosyphon was selected according to the size of casing of test rig. The selected thermosyphon is of length 1000 mm and diameter 25.4 mm. The main aim of this experiment was to find out the performance of thermosyphon which is use in water heating application.

II. EXPERIMENTAL SETUP

The experimental setup is designed and constructed at ICEM, Pune Workshop. The long evaporative section thermosyphon (LEST) is designed and constructed by siddharth solar Technergies, Pune It is made of copper(Cu) tube of 1000 mm length of internal diameter 24.4 mm and1mm thickness. The working fluid employed is ethanol with filling ratio (FR) 40%. The lengths of evaporator, adiabatic & condenser sections are 600, 200 and 200 mm respectively. The maximum heat transfer capacity of thermosyphon is 500 W. The pipe was initially evacuated using vacuum pumps (rotary and diffusion pumps) after a series of cleaning processes to remove possible contaminants, which can affect the performance and life of thermosyphon. The pipe is first pumped down at the ambient temperature: and then, the pumping is continued while the pipe is heated [3, 4]. Since high vacuums were required, this was a time-consuming process. Following evacuation, the working fluid was sucked into the pipe through a special valving arrangement and the filling tube attached at the upper end was flattened by crimping to a thickness of 0.1to 0.2 mm. This process required up to an hour for pipe. UPVC pipes and their fittings like elbow, reducer, ball valves, caps etc are used in manufacturing of test setup.2 inch and 0.5 inch UPVC pipes and their fittings are used. 2 inch UPVC pipe fitting water jackets prepared in work shop and are provided in both evaporative and condensing section of specified length for hot water circulation. Water circulation was done by using 0.5 hp centrifugal pump. Ball valves are used for controlling the mass flow rate of circulating hot water. The LEST placed centrally in 2 inch UPVC pipe. One Cylindrical water tank of diameter 1m was used for storing hot water. Immersion water heater of 2000 Watt capacity was used for water heating process. The role of the adiabatic section is to connect the condenser and evaporator sections together. The length of adiabatic section in this setup is constant which is 200 mm. The wall temperature distribution along the pipe was measured using ten calibrated thermocouples (type K). The thermocouples are inserted in (2) mm grooves, machined in the outer surface of the water circulation jacket pipe wall. An accurate wattmeter is connected to water heater to record the exact power supplied. The temperature was read directly from a digital display. Mass Flow rate of the hot and cold water was determined by measuring the amount of the water over an interval of time. Water inlet and outlet temperatures were measured using two thermocouples. The actual experimental facilities' are shown in Fig.01& 02.

Fig.No-01 Actual test setup image.

Fig No-02 pipe fittings images.

III.FORMULAE USED FOR CALCULATION

Heat performance solution of thermosyphon is based on calorimetrical equation and values from experimental measuring. The same calculations were used at work [5].The following formulae are used for calculation.

$$Q = m.c.\Delta t \qquad (1)$$

$$\Delta t = t_2 - t_1 \qquad (2)$$

$$R = T_{hot} - T_{cold}/Q_{in} \qquad (3)$$

Where Δt is the temperature difference between output and input temperature, m is the mass flow rate of water, c is the specific heat capacity of liquid, R is the overall thermal resistant, T_{hot} & T_{cold} are the average temperature at evaporative section and condensing section, Q_{in} is the total heat input in evaporative section.

IV.RESULT AND DISSCUSSION

The table no-(01) is the performance sheet of ethanol thermosyphon. The maximum thermosyphon efficiency found 73.33% at 70˚C heat source temperature in vertical position. During experimentation 67.85% efficiency at 60˚C also found in 45˚angle of orientation. Figure (3) illustrates the variation of thermosyphon efficiency with mass flow rate at different orientation (0˚, 15˚,30˚,45˚,60˚,75,˚90˚) angle for different heat source(50˚C, 60˚C, 70˚C).Fig No-04 illustrates Heat performance with different orientation angle for different heat source. Best heat performance 365.75 W was found at vertical position for 0.0385 Kg/Sec mass flow rate of water. Fig No-05 illustrates Variation of overall thermal resistance with heat input for different heat source. Thermal resistance decrease with total heat input. Maximum thermal resistance 0.109278˚C/W was found at horizontal position for maximum mass flow rate 0.0417 Kg/Sec. Fig No-06 illustrates Variation of overall thermal resistance with tilt angle for different heat source. It was observed that Maximum thermal resistance 0.109278˚C/W occurs at horizontal position.

Table No (01) Performance of ethanol thermosyphon.

Thermosyphon Working Fluid-Ethanol				
Working Temperature	**Angle**	**Mass Flow Rate(Kg/Sec)**	**Thermosyphon efficiency(% ή)**	**Over all Thermal resistance(˚C/W)**
50˚C	0˚	0.0417	47.61905	0.065345
	15˚	0.0407	47.82609	0.060579
	30˚	0.0400	50	0.053885
	45˚	0.0397	65.51724	0.04719
	60˚	0.0392	62.06897	0.048436
	75˚	0.0388	62.06897	0.048686
	90˚	0.0385	66.66667	0.04691
60˚C	0˚	0.0417	47.82609	0.084315
	15˚	0.0407	52	0.078802
	30˚	0.0400	53.57143	0.070969
	45˚	0.0397	67.85714	0.07073
	60˚	0.0392	64.28571	0.072007
	75˚	0.0388	65.51724	0.069917
	90˚	0.0385	70	0.067592
70˚C	0˚	0.0417	52.17391	0.109278
	15˚	0.0407	54.16667	0.106914
	30˚	0.0400	57.69231	0.098799
	45˚	0.0397	65.51724	0.088456
	60˚	0.0392	65.51724	0.089877
	75˚	0.0388	65.51724	0.090509
	90˚	0.0385	73.33333	0.087237

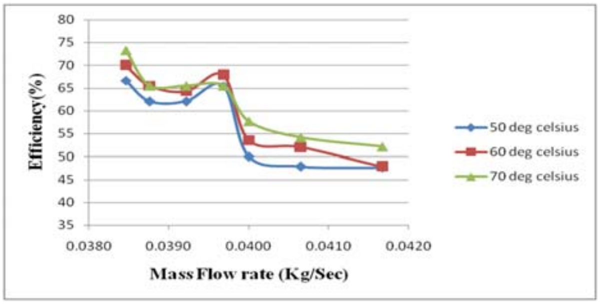

Fig No-03 Variation of themosyphon efficiency with mass flow rate at different orientation angle for different heat source.

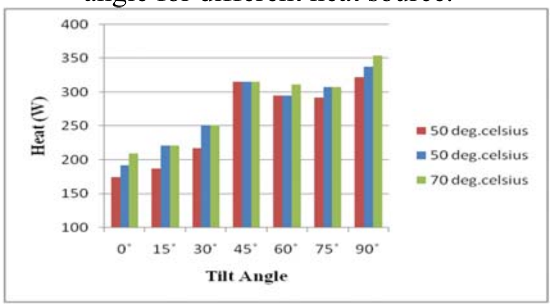

Fig No-04 Heat performance with different orientation angle for different heat source.

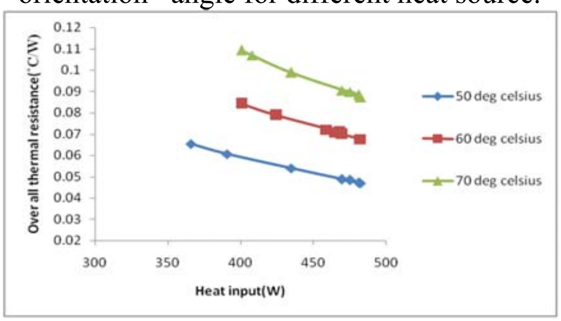

Fig No-05 Variation of overall thermal resistance with heat input for different heat source.

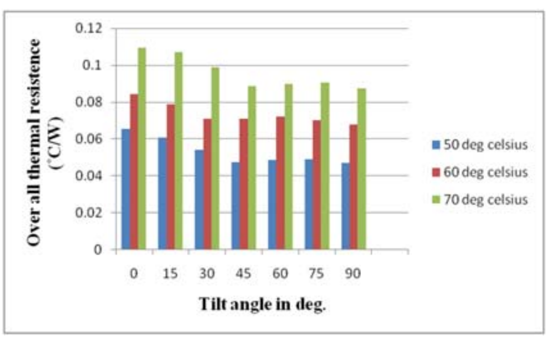

Fig No-06 Variation of overall thermal resistance with tilt angle for different heat source.

V.CONCLUSION

Ideal working position of thermosyphon is vertical position. Thermosyphon operate on maximum performance and maximum mass flow transfer in this position. From experimental measuring performance of thermosyphon is creating graphic dependences average values of thermal performance from working position of thermosyphon. The maximum thermosyphon efficiency found 73.33% at 70˚C heat source temperature in vertical position. During experimentation 67.85% efficiency at 60˚C also found in 45˚angle of orientation. This experiment has testified that the ethanol fluid thermosyphon is able to operate at any other position as vertical and even at the horizontal position. From results measured performances of thermosyphon at various working position discover that the thermosyphon is able to operate at inclined position 45˚and total heat performance transfer is not very different as at vertical position. Due to long evaporative section of thermosyphon the heat absorption capacity at evaporative section also found which is maximum 482.3077 W at 70˚C heat source. Long evaporative section ethanol fluid thermosyphon can be used in solar water heating system.

ACKNOWLEDGMENT

The author would like to thank Prof.S.B.Ingole & Dr.V.M.Kale for his support and discussions. The authors gratefully acknowledge the financial support ICEM, Pune. The authors are also grateful to the anonymous referees who provided detailed and constructive comments.

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