



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 7, July 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

Anodization Effect on the Heat Transfer Performance of Flat Thermosyphon

Ananta G. Mahale¹, Prof. M. M. Khan², Prof. P. A. Rane³

P.G. Student, Department of Mechanical Engineering, Rajarshi Shahu College of Engineering, Buldhana, Maharashtra, India¹

Assistance Professor, Department of Mechanical Engineering, Rajarshi Shahu College of Engineering, Buldhana, Maharashtra, India²

HOD, Department of Mechanical Engineering, Rajarshi Shahu College of Engineering, Buldhana, Maharashtra, India³

ABSTRACT: This paper presents the thermal performance of flat thermosyphon with and without anodized surface. Anodization is to prepare a uniform coating on the inner side of the thermosyphon. Non-anodized and anodized thermosyphons charged with acetone and tested in heat input range of 51–299 W. Testing are takes for anodized and non-anodized flat thermosyphons at various angles (0 °C, 45 °C, 90°C) and fill ratios (40%, 60% and 100%). It is found that fill ratio and inclination angle have a significant effect on the performance of the thermosyphon. The total thermal resistance of the anodized thermosyphon is reduced by 20% when compared to the nonanodized thermosyphon. The pore density of the anodized surface has increased almost 90% than the pore density of non-anodized surface. Both evaporator and condenser heat transfer coefficient of anodized thermosyphon is enhanced, when compared to that of nonanodized thermosyphon. The maximum enhancement in heat transfer coefficients of the evaporator and condenser in the anodized thermosyphon is 9% and 27% respectively, when compared to non-anodized thermosyphon at a heat flux of 49 kW/m².

KEYWORDS: Heat Transfer coefficient, Thermal heat Resistance, Thermosyphon, Heat Flux, Performance Parameters Filling Ratio.

I. INTRODUCTION

Loop thermosyphon is an effective and efficient two-phase heat transfer device that utilizes the evaporation and condensation of a working fluid to transfer heat, and the gravity to circulate the working fluid. Without any pump or capillary action, it provides reliable and cost-saving means for transferring thermal energy in numerous engineering applications, such as in the waste heat recovery, solar water heating, geothermal system, emergency core cooling system in nuclear reactors as well as electronic cooling system. In some cases, loop thermosyphons are expected to function well over the design life, which have to be in operation continuously for a very long time, i.e. ten years or even longer for highly reliable devices such as nuclear reactors and the high performance servers. Due to the increasing challenges in electronic cooling technology, it is necessary to improve the thermal performance of thermosyphons. Many researches have been performed to know the cooling philosophy as well as to improve the performance of thermosyphons. Among them, performance enhancement studies with various working fluids (Water, Acetone, Methanol and nanofluids) and surface modifications in the thermosyphons are emerging.

II. RELATED WORK

In the past few decades, nanofluids have been used as working fluids in thermosyphons due to its superior thermo-physical properties. Noie et al. (2009) studied the thermal performance of thermosyphon using Al₂O₃/water as working fluid. It was found that the efficiency of the thermosyphon was enhanced up to 14.7% when compared to pure water as the working fluid. Huminic et al. (2011) studied the heat transfer characteristics of two-phase closed thermosyphon with iron oxide-nanofluids as working media at different inclinations, operating temperatures and nano-particle concentrations. It was evident that the nano-particles have a significant effect on the enhancement of heat transfer characteristics of thermosyphon. Buschmann et al. (2011) studied the thermal performance of thermosyphon using de-ionized water, previously based on titanium dioxide and gold nanofluids with different concentrations. It was observed that a maximum reduction of thermal resistance of 24% was achieved when nanofluids were replaced with de-ionized water. Lips et al. (2010) studied the thermal behavior of a flat plate heat pipe (FPHP) with micro grooves and it was conformed that the nucleate boiling in the grooves improves the thermal performance of the flat heat pipe.

III. METHODOLOGY

Design Principles of Thermosyphon

The design of a thermosyphon includes the following processes,

Selection of Working fluids, Selection of Container Material, Evaluation of performance limits, Evaluation of the actual performance.

Tube sizes are selected for a lab size system suitable for making reliable measurements. Working fluids acetone is selected because of useful range of operating temperature for waste heat recovery applications in the heat input 50-300 Watt.

IV. EXPERIMENTAL SETUP

COMPONENT FOR EXPERIMENTAL TEST RIG

1. DIFFERENTIAL MANOMETER



Figure 1. Photographic View of Differential Manometer

An instrument for the determination of pressure differences it is also used to determine from pressure gradients the levels of liquids and the flow rates of liquids, vapors or gases. Manometers can be employed to measure pressures in the range of 0.4 Pa to 200kPa. According to the principle of operation, a distinction is made between the liquid types, in which the pressure or vacuum being measured is balanced by a column of liquid. In present experimental set up one differential manometer is installed to measure pressure difference between inner side of thermosyphon and atmosphere. Mercury used as manometric fluid.

2. TEMPERATURE INDICATOR WITH SENSORS



Figure 2. Photographic View of Temperature Indicator

The steady state temperature of the base plate is measured by six K type flexible sensors for temperature 0 to 250°C, All sensors are attached to thermosyphon as shown in figure. The readings of each sensor are recorded using a single point digital temperature indicator of size 96 mm x 48 mm, and the average of all these readings are taken to be the steady state temperature of the test surface. The K sensors and temperature indicator are calibrated to $\pm 0.1^\circ\text{C}$ deviation by using a thermostat before using in the experiments. Duration of 50–60 min elapsed in order to reach a steady state. The steady state inlet and outlet temperature of the Water is taken as reading of two K type flexible sensor of temperature range 0 to 250°C, digital temperature indicator of size 96 mm x 48 mm. Four readings are obtained, and the average of these readings are taken as the steady state temperature of the thermosyphon evaporator. Whenever steady state temperature is achieved, then measured data are recorded.

3. VOLTMETER AND AMMETER



Figure 3. Photographic View of Voltmeter and Ammeter

A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit. In present experimental set up, digital voltmeter is installed and uses numerical display of voltage by use of an analog to digital converter. The display range of voltmeter is selected 0 to 500V AC and it designed from input voltage taking as reference. Ammeter is a measuring instrument used to measure the current in a circuit. Electric currents are measured in amperes (A), hence the name. In present experimental set up, digital ammeter is installed. The display range of ammeter is selected 0 to 5 ampere and it designed by using Ohm's law from input voltage and heater specification (resistance) taking as reference.

4. VARIAC (DIMMER STAT)

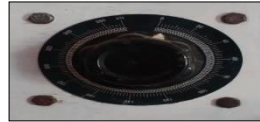


Figure 4. Photographic View of Variac (Dimmer stat)

A variable transformer is an electrical transformer with only one winding it also referred to as dimmer stat. In present experimental set up open type hand operated 5 ampere single phase with input voltage 230V and output 0 to 270 V variable transformers is installed. The amperage of variable transformer is designed by using Ohm's law from input voltage and heater resistance taking as reference.

5. ELECTRIC WATER PUMP



Figure 5. Photographic View of Electric Water Pump

Electric water pump is use to circulate the cooling water through the condenser. In this setup the submersible water pump is utilized with the parameter as follows. 8W Motor, can lift water up to 1.6 meters, Water Output 1100 Liters per Hour.

6. EXPERIMENTAL ARRANGEMENT AND DETAILS

The experimental test setup consists of chilling unit, flow meter, data acquisition system, wattmeter, variable transformer and heating block. The schematic of the experimental set up is presented in Figure 3.10. A chilling unit is used to maintain the coolant at a temperature of $22\text{ }^{\circ}\text{C} \pm 0.5\text{ }^{\circ}\text{C}$. A flow meter is used to vary the flow rate of cooling water. The mass flow rate of the coolant is adjusted, in order to maintain the temperature difference of 3–4 $^{\circ}\text{C}$ between inlet and outlet of the cooling jacket. Eleven K-Type thermocouples with an accuracy of $\pm 0.2\text{ }^{\circ}\text{C}$ are used to measure the temperature response of thermosyphon. One thermocouple (K-Type), each at the inlet and outlet port of the condenser is fixed to measure the temperature response of the coolant. The thermocouple positions of each section are presented in Figure 3.10. The Data Acquisition/Switching Unit is used to monitor and to record the thermocouple signals. The condenser section is made up with inlet and outlet ports. A wattmeter with variable transformer is used to vary the heat load at the evaporator of the thermosyphon. A Nichrome meandering is used as a heating element at the evaporator section. The thermosyphons are tested with heat input range of 50–300 W. The thermosyphon is charged with various fill ratios of acetone. Fill ratio is the volume ratio of charged working fluid to the entire evaporator volume of the thermosyphon. The parameters varied in the experimental analysis are presented in the Table 3.3. The inclination angle of the heat pipe is varied from 0–90°.

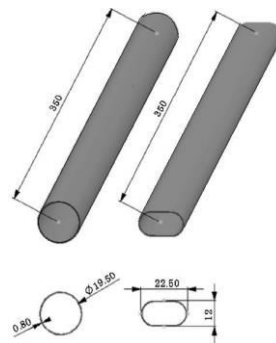


Figure 6. Dimension of circular and flat thermosyphon all dimensions are in MM

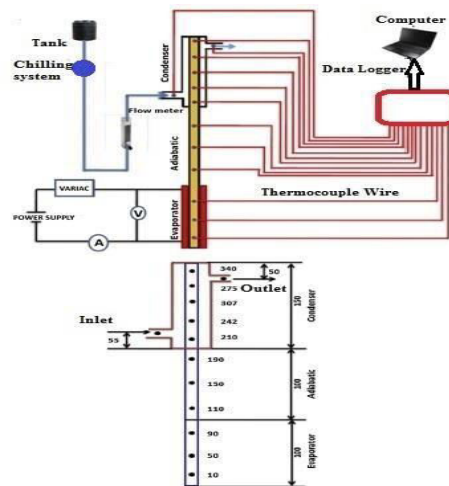


Figure 7. Schematic of the test rig

7. DATA REDUCTION

In order to study the heat transfer performance of flat thermosyphon, heat transferred by the thermosyphon, heat transfer coefficients and the total thermal resistance are calculated. Heat transferred by the flat thermosyphon is calculated by the energy balance equation

$$Q_{out} = m_{cw} * C_{cw}(T_{out} - T_{in})$$

The heat transfer coefficient of evaporator section and condenser section are calculated as

$$h = \frac{q_e}{\Delta T} = \frac{q_e}{T_e - T_v}$$

$$h = \frac{q_c}{\Delta T} = \frac{q_c}{T_v - T_c}$$

Where, $q = Q/A$ and $A = \pi dl$. The vapor temperature (T_v) of evaporator and condenser is assumed as the average adiabatic temperature of thermosyphon.

The total thermal resistance of the flat thermosyphon is calculated as

$$RT = \Delta T / Q_{out} = T_e - T_c / Q_{out}$$

8. VALIDATION OF THE EXPERIMENTAL TEST RIG

Before starting the experimental investigation of heat transport capability of two phase closed loop flat thermosyphon using aluminium pipe with standardization of the experimental setup is done by obtaining the heat transfer capability by using acetone as working fluid and compared present data with known published analytical equations. After confirmation of validity of experimental values of heat transfer capability with standard equations, then experiments are conducted for other liquids as working fluid. From the results the heat transport capability obtained experimentally are



very close to theoretical values calculated from available correlations for thermosyphon. This proves technical feasibility of experimental setup for experimentation in the given range.

V. RESULTS AND DISCUSSION

HEAT TRANSFER PERFORMANCE OF FLAT HEAT THERMOSYPHON

Heat Input (W)	Evaporator Surface Temperature (°c)			Condenser Surface Temperature (°c)			Vapour Temperature (°c)		
	0°	45°	90°	0°	45°	90°	0°	45°	90°
50	56.1	52.8	51.2	32.0	31.6	29.5	44.4	41.5	40.3
75	63.4	61.0	60.3	33.1	31.3	31.1	48.0	44.3	43.7
100	74.6	68.8	67.5	37.3	33.1	32.5	54.1	47.0	46.2
125	81.8	77.3	75.8	38.5	34.9	33.5	57.7	50.5	49.2
150	87.9	85.0	82.9	38.5	35.5	34.0	60.1	53.1	51.3
175	95.1	91.1	89.1	39.4	35.5	34.6	62.9	54.8	53.3
200	109.4	97.3	96.2	40.6	36.0	35.8	67.1	56.3	55.7
225	119.6	105.2	103.3	41.6	37.5	36.3	70.5	59.3	57.7
250	129.7	113.1	110.9	42.4	38.2	36.4	73.3	61.4	59.7
275	142.1	121.0	116.9	43.5	38.7	37.1	77.6	63.7	61.4
300	151.9	127.5	125.5	44.5	39.1	38.2	80.5	65.3	64.1

Table 2. Evaporator, Condenser, and Vapor Temperature of non-anodized flat thermosyphon.

Heat Input (W)	Evaporator Surface Temperature (°c)			Condenser Surface Temperature (°c)			Vapour Temperature (°c)		
	0	45	90	0	45	90	0	45	90
50	60	48.7	48.7	32.8	32.1	31.6	43.7	38.5	38.2
75	59.4	55.7	55.7	34.8	33.4	33.2	47.3	41.1	40.9
100	67.9	65.2	65.0	38.2	36.1	35.6	53.8	45.3	44.7
125	74.8	72.3	71.3	40.5	37.9	36.8	57.2	48.2	46.8
150	82.3	80.2	79.3	43.0	39.3	38.3	58.7	51.0	49.8
175	91.9	86.9	86.7	45.1	39.9	39.7	62.4	53.2	52.4
200	100.9	94.4	92.2	48.1	41.5	40.1	66.1	56.4	54.3
225	109.1	101.1	98.8	49.6	43.3	41.3	68.6	58.8	56.5
250	117.7	107.9	106.7	50.8	44.2	42.7	72.8	61.3	59.2

Table 3. Evaporator, Condenser, and Vapor Temperature of anodized flat thermosiphon

VI. CONCLUSION

According to series of experimental tests and observations as well as analysis the following conclusion comes out.

- [I] Development of Experimental Set-up: In this work design and development of experimental test rig are carried thermosyphon. The components of test rig are designed or selected according to some reference specifications

of the components. It is installed according to the basic laws or standard used for a specific component installation.

- [II] In this dissertation, the effect of anodized surface on the evaporator and condenser heat transfer coefficient of flat thermosyphons is studied. Anodization is performed to obtain a uniform coating with large number of small nucleation sites.
- [III] It is found that the pore density of the anodized surface is enhanced to 90% compared to a non-anodized surface. As a result, the heat transfer coefficients at the evaporator and condenser sections are enhanced.,
- [IV] The total resistance of the flat anodized thermosyphon is significantly reduced compared to the non-anodized one.
- [V] Anodized thermosyphon is very much suitable for electronic cooling applications because of its enhanced heat transfer performance and less weight.

REFERENCES

1. Brusly Solomon a, R. Roshan a, Walter Vincent a, V.K. Karthikeyan b, L. Godson sirvathama -Heat transfer performance of an anodized two-phase closed thermosyphon with refrigerant as working fluid Centre for Research in Material Science and Thermal Management, School of Mechanical Sciences, Karunya University, Coimbatore 641114, India International Journal of Heat and Mass Transfer 82 (2015) 521–52
2. R. Renjith Singh a, V. Selladurai b, P.K. Ponkarthik c, A. Brusly Solomon c Effect of anodization on the heat transfer performance of flat thermosyphona Department of Aerospace Engineering, Karunya University, Coimbatore, India Experimental Thermal and Fluid Science 68 (2015) 574–581
3. Ali Chehade a, Hasna Louahlia-Gualousa, St_ephane Le Masson b, EricL_epinasse-Experimental investigations and modeling of a loop thermosyphon for cooling with zero electrical consumptiona Caen Basse Normandie University, LUSAC, 50000 Saint, France Applied Thermal Engineering 87 (2015) 559e573
4. Zhen Tong a, Tao Ding b, Zhen Li b, Xiao-Hua Liu - An experimental investigation of an R744 two-phase thermosyphon loop used to cool a data centera Department of Building Science, Tsinghua University, Beijing 100084, PR China Applied Thermal Engineering 90 (2015) 362e365
5. M.M. Sarafraz, F. Hormozi, S.M. Peyghambarzadeh Role of nanofluid fouling on thermal performance of a thermosyphon: Are nanofluids reliable working fluid? a Faculty of Chemical, Petroleum and Gas Engineering, Semnan University, Semnan, Iran Applied Thermal Engineering 82 (2015) 212e224
6. Bandar Fadhl 1, Luiz C. Wrobel, Hussam Jouhara-Numerical modelling of the temperature distribution in a two-phase closed thermosyphon School of Engineering and Design, Brunel University, Kingston Lane, Uxbridge, Middlesex UB8 3PH, UK Applied Thermal Engineering 60 (2013) 122e131
7. Matthias H. Buschmann Nanofluids in thermosyphons and heat pipes: Overview of recent experiments and modelling approaches Institut für Luft-und Kältetechnik Dresden, Bertolt-Brecht Allee 22, 01309 Dresden, Germany International Journal of Thermal Sciences 72 (2013) 1e17
8. Jiang He a,b, Guiping Lin a, LizhanBaia, Jianyin Miao b, Hongxing Zhang b, Lu Wang b Effect of non-condensable gas on steady-state operation of a loop thermosyphon, a Laboratory of Fundamental Science on Ergonomics and Environmental Control, School of Aeronautic Science and Engineering, Beihang University, Beijing 100191, PR China International Journal of Thermal Sciences 81 (2014) 59e67
9. Alessandro Franco, Sauro Filippeschi- Experimental analysis of Closed Loop Two Phase Thermosyphon (CLTPT) for energy systems Department of Energy, Systems, Territory and Constructions Engineering (DESTEC), University of Pisa, Largo LucioLazzarino, 2, 56126 PISA, Italy Experimental Thermal and Fluid Science 51 (2013) 302–311



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.423



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 **6381 907 438** **ijirset@gmail.com**



www.ijirset.com

Scan to save the contact details