JOURNAL OF CRITICAL REVIEWS

ISSN-2394-5125 VOL 7, ISSUE 6, 2020

EFFECT OF BINARY MIXTURE AS A WORKING FLUID ON HEAT TRANSFER PERFORMANCE OF THERMOSYPHON

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Abstract

An experimental investigation of the effect of mixture of ethanol-methanol as a binary working fluid with pure fluid on thermosyphon performance is being presented in this project. The thermosyphon has main three components, an evaporator with a boiling enhancement structure, adiabatic section at the center and condenser. Experiment has been done to assess the effects of binary fluid and pure fluid on the performance of the thermosyphon at different inclination. The selected thermosyphon has one in 25.4 mm diameter and 500 mm length designed to dissipate 240 watt heat from the applying. The working fluid will be pure ethanol, pure methanol and mixture of both in (60-40) % by volume and filled by 60% of evaporator section. The method tested by applying heat load to the thermosyphon by four band heater of sixty watt capability as per application and also the condenser section is cooled by vessel with fluid pump and flow control arrangement. The testing of the thermosyphon has done at inclination of 90°, 75°, 60°, 45°, 30° and 15° with respective horizontal axis to study the effect on heat transfer ability of the system. The Properties of Pure Ethanol and Methanol and its (60-40) % mixture are studied and find out maximum heat input for various mixtures by heat transfer limitations correlations. So, heat input of 240 W is supply to evaporator region of 60 % FR. It found the result from the experimental trial is that ethanol fuels (60-40) the mixture proportion of binary fluid offers higher performance of thermosyphon than alternative mixture, at optimum mass flow rate and optimum angle inclination.

Keywords: Angle Inclination, Binary Fluid, Heat Transfer, Mixture Proportion, Pure fluid, Thermosyphon Performance.

1. Introduction

The thermosyphon is works on gravity and has been proved as a heat transfer device with high thermal conductance. In practical, its effective thermal conductivity exceeds 200 to 500 times that of copper. The amount of heat transfer by these devices is can be many times of magnitude more than pure conduction through a solid metal. They are low cost, very effective, and reliable heat transfer devices for applications in many thermal and waste heat recovery systems. Because of its satisfactory heat transfer effectiveness has its own importance in the small temperature difference heat transfer. A two-phase closed thermosyphon (TPCT) is a high performance heat transfer device and transfer the maximum amount of heat at a high rate with less temperature gradient. As it will transfer large amounts of heat over comparatively large distances with minimum temperature differences between the heat source and heat sink it also referred as thermal super conductor. They are used in many applications like heat exchanger devices, in heat recovery applications, water heaters and solar energy systems and are showing some promise in high- performance, anti-freezing, baking ovens, electronicsthermal management for situations which are orientation specific.

The TPCT is empty sealed tube which contains a small amount of working fluid (Phase Change Material). The evaporator section is exposing to band hater and heat conducted across the pipe wall so the liquid in the thermosyphon absorbs the applied heat and it converting to latent heat of vaporization. The vapour in the evaporator region is at a higher pressure than in the condenser section due to this the vapour to flow upward direction. In the condenser region, the vapour condenses thus releasing the latent heat of vaporization that was absorbed in the evaporator section. Then heat exits through the tube wall and into vessel. Within the tube, the flow of fluid is completed by the liquid flow due to gravity back to the evaporator section in the form of a thin liquid film. Thermosyphon not be in operation at inclinations near the horizontal position. Following figure shows the working principal of two phase closed thermosyphon. It is oriented in the vertical position to understand its working principle.

In this paper, the study of various categories research papers on the thermosyphon are studied. Research work includes its completely different input conditions of system i.e. filling ratio, aspect ratio and combination of various operating fluids and angle inclination.

The projected work has been done principally for result of binary mixture proportions, angle inclination and cooling water flow rates. The purpose of following literature survey is to go through the main topics of interest i.e. effect of angle of inclination and mass flow rate of water for cooling process of condenser and binary mixture of TPCT.

Different refrigerants won’t to verify the thermal performance of a two-phase thermosyphon in solar collector. three identical solar water heating systems, using refrigerants R-134a, R407C, and R410A, were tested one by one under varied environmental and load conditions. The performance of the system to examine and investigated through an experiment under clear- sky conditions with and without water load. The experimental results were compared to the results determined within the literature survey and that they showed good agreement (Mehmet Esen, et al., 2005).R11 Refrigerant is employed as a base operating fluid with the Ti nanoparticles of 21 nm diameter and copper heat pipe with the outer diameter 15 mm and length 600 mm. Effects of the charge amount of in operation fluid, heat pipe angle inclination on the efficiency of heat pipe are considered. For pure R11, at 60° angle inclination and 500th fr gives the utmost efficiency and with 0.1% nanoparticles concentration gives 1.40 times higher efficiency than that with pure refrigerant (PaisarnNaphon, etal., 2009).

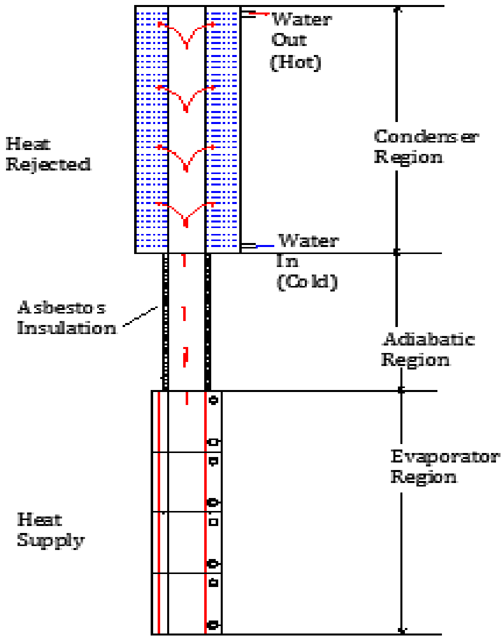


Fig.1 Thermosyphon Working Principle

Also it's the performance verify by charged with water and the dielectric heat transfer liquids FC-84, FC-77 and FC-3283 was through an experiment investigated. The copper thermosyphon of 200 mm length, 6 mm ID, 40 mm evaporator length and 60 mm the condenser length was chosen with water because the operating fluid 0.6 ml and 1.8 ml load of fluid take into account, corresponding to approximate half-filled and overfilled evaporator. Liquid provides thermal performance up to 30–50W once that liquid entrainment compromised their performance (HussamJouhara, et al., 2010).

Nanofluids (less than 100 nm) used for a two-phase closed thermosyphon (TPCT). Nanofluids of liquid Al2O3 nanoparticles suspensions were ready in varied volume concentration of 1–3%. It appears from experimental results that once Al2O3/water nanofluid was used rather than pure water for various input powers, the potency of the thermosyphon will increase up to 14.7% (S.H. Noie, et al., 2009).Also, silver nanofluid used in it. The thermosyphon was created with copper material with 7.5, 11.1 and 25.4 mm ID. The filling ratios of half-hour, 500th and 80th by evaporator length and aspect ratios of 5, 10, and 20 with an inclination angle 90°. The in operation temperatures were 40°C, 50°C and 60°C. The impact of dimensionless parameters on heat-transfer characteristics and appears that fr has no effect on the ratio of heat-transfer characteristics within the vertical position, however operating fluid properties affected the heat-transfer rate (T. Parametthanuwat, et al., 2010), and iron oxide nanoparticles added to water used as a working fluid in thermosyphon. The tested concentration level of nanoparticles is 0%, 2%, and 5.3%. From results it seems that the addition of 5.3% (by volume) of iron oxide nanoparticles in water improved thermal performance compared with the operation with DI-water (Gabriela Huminic, et al., 2011).

N2–Ar binary mixture used in completely different compositions into the cryogenic thermosyphon, including pure N2 and pure Ar. This binary mixture has operational temperature range vary with working fluid. Themosyphon is dry-out limit with Ar fraction below 0.503. The calculated results well similar with the experimental results (Z.Q. Long, et al., 2013).It also charged with the ethanol-methanol binary mixture in thermosyphon of copper tube of 1000 mm length with ID and OD of 24 mm and 26 mm respectively. Experiments were carried out on the different inclination angle, coolant flow rate 3.6 kg/h to 21.6 kg/h, varying heat load 25 W to 200 W, result shows that maximum heat transfer efficiency is 86.39% which is higher at 3.6 kg/h coolant flow rate with 80o inclination angle and 190 W heat loads (N. A. Faddas, et al., 2015).

Robert examined that two-phase thermosyphons of length 2200 mm and OD 15.9 mm used in air to air heat exchangers with operating temperature ranges of -100-50 °C for the ambient (cold) side and 60 0-80 °C for the hot side. From the experiments of water-5% ethylene glycol mixture was used as suitable alternative under certain conditions its performance was less than that of R134a. It also saw that water gives the highest heat transfer rate, although it is not suited to the target temperature range, and methanol and R134anot perform well for most of the experimental range (Robert W. Mac Gregor, et al., 2013).

Water used as operating fluid effectively in the experiments were conducted to evaluate the performance of a two phase closed loop thermosyphon. Finally, from the results show that the optimal fill charge ratio is between 7% and 10%, the cooling system has the optimal performance when control the condenser temperature of jacket water and flow rate at 5 °C and at 0.7 l/min respectively (A.A. Chehade, et al., 2014). Water-filled and 0.01 and 0.03 vol% graphene oxide (GO)/ water nanofluids-filled heat pipes with a screen mesh wick considerably study in order to investigate the effects of nanofluids on the heat pipe operation.

The 0.01 volume % GO/water nanofluid-filled heat pipe showed better boiling heat transfer than 0.03 volume % GO/ water Nano fluids due to the different structures of the deposited nanoparticle layers on the wicks (Kyung Mo Kim, et al., 2016).

In thermo economic analysis study, understand experimentally effects of different three working fluids like methanol, petroleum ether and distilled water in the thermosyphon heat pipes which it heats the air is investigated, at different air velocities, energy and exergy efficiencies of the thermosyphon heat pipes investigated in terms of thermo economic concept. From thermo economic results of this study gives distilled water is more cost-effective than that of methanol and petroleum ether (Mustafa AliErsöz, et al., 2016).From the above information, it observed that many researches is done on different kinds of working fluid solutions like refrigerants R-134a, R407C, R410A andR11and FC-84, FC-77 and FC-3283 etc., nanofluids such as Al2O3-water, silver nanofluid, iron oxide- water, graphene oxide (GO)/ water nanofluids etc., Binary mixtures like N2-Ar, ethanol-methanol, water- 5% ethylene glycol etc., working fluids like methanol, petroleum ether and distilled water. In many investigation of thermosyphon it is observed that water gives better performance as a working fluid than other solutions. Due to its high boiling point it generally not used for cold temperature regions. By using other solutions as a working fluid does not get better thermal performance than water. So it most important to use binary mixture of various solutions to get better thermodynamic property for using operating fluid in two phase closed thermosyphon.

2. Experimental Setup

The experimental setup of two phase closed thermosyphon is illustrated in Fig.2. The main components of the set up are thermosyphon pipes, band heaters, cooling jacket with O-Ring, water tank, beaker, Frame for support and insulation provides to adiabatic section.It consists of an empty closed copper tube having evaporator region at lower side, adiabatic region at middle and condenser region at the upper side.

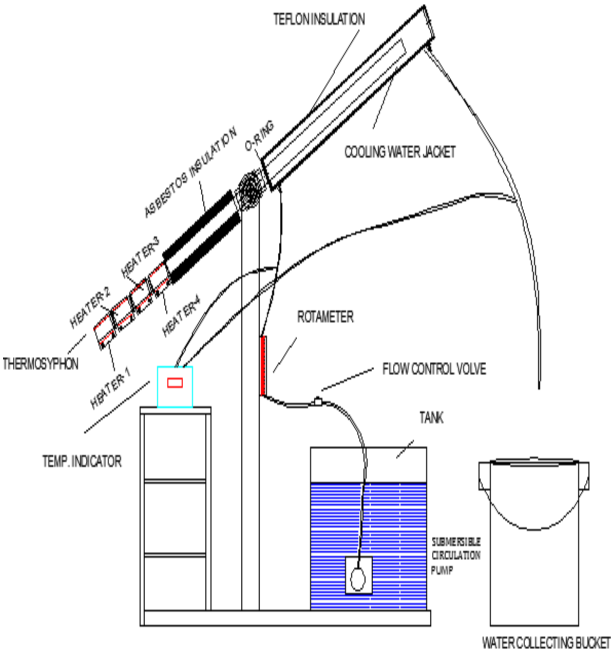


Fig.2 Schematic Diagram of Experimental Setup

The total length of thermosyphon is 500 mm (having 200 mm evaporator, 100 mm adiabatic and 200 mm condenser region) with Diameter is 25.4 mm. The two Band Heaters with 60W capacity are attached to the evaporator and electrical supply to heater with 230V. Ethanol-methanol binary mixture of 60:40% and Pure Ethanol and Methanol is used with 60% filling of evaporation section. For adiabatic region asbestos is used as insulation material to prevent the heat loss.

Condenser section is surrounded by concentric cylinder (water jacket) through which tap water flows. The hot water temperature from water jacket is measured by thermometer. The coolant flow is varied by a controlled valve and for flow circulation submerged pump is used with flow capacity 820 LPH. For initial evacuation of tube arrangement is made to attach vacuumed pump at the top and also to measure the pressure inside the tube, pressure gauge is attached. Evacuation is necessary to eliminate the effect of non-condensable gases. Following Table 1 shows the Design Parameters Table 2 shows the Performance Parameters of experimental setup which can be according to researcher's demand and interest.

Table 1 Design Parameter of Thermosyphon

Sr. No.	Design Parameters	Values
1	Tube material	Copper
2	Outer Tube diameter (mm)	25.4
3	Inner Tube diameter (mm)	24.7
4	Total length (mm)	500
5	Evaporator length (mm)	200
6	Condenser length (mm)	200
7	Adiabatic length (mm)	100

Table 2 Performance Parameter of Thermosyphon

Performance Parameters	Description
Working Fluid	Ethanol-Methanol Mixture, Pure Ethanol and Pure Methanol
Filling Ratio (FR)	60%
Heat Input (Q)	240W
Insulation Material	Asbestos
Aspect Ratio(Le/Di)	8.097
Angle Inclination(θ)	0°, 30° and 60° (wrt. Vertical)
Cooling Water Flow Rate (mw)	0.1 lpm to 0.8 lpm
Inlet Water Temperature (Twi)	Ambient (°C)

3. Experimental Analysis

a. Heat Transfer Rate

The input and output heat transfer rate of the thermosyphon can be calculated from following equation
Heat Input to the evaporator section is given by equation

$$Q_{in} = V * I - Q_{loss} (W) \quad (1)$$

Where, Qloss is the sum of heat losses from the evaporator section by radiation and free convection.

$$Q_{loss} = Q_{rad} + Q_{conv} (W) \quad (2)$$

The radiation heat transfer rate was calculated from Equation

$$Q = \in \sigma A_e (T_{we}{}^{4} - T_{air}{}^{4})(W) \quad (3)$$

Free convection heat transfer was calculated from Equation Thermodynamic properties are useful for the thermosyphon as a working fluid in 0°C to 100°C

$$Q = h_{conv} A_e (T_{ins} - T_{air})(W) \quad (4)$$

Thermodynamic propertie are useful for the thermosyphon as a working fluid in 0°C to 100°C temperature applications. Hence ethanol-methanol In this calculation we neglect the heat loss by evaporator section. So, neat heat supply is given by equationmixture was selected for the experimental assessment of the thermosyphon as a working fluid (N. A. Faddas, et al.,2015).

$$Q_{in} = V * I (W) \quad (5)$$

The heat transmitted from the condenser section is equal to the rejected heat to coolant water in the jacket, and calculated from Equation.

$$Q_{out} = m_w . C_{pw} (T_{wo} - T_{wi}) (W) \quad (6)$$

The quantity of heat transfer to the coolant water can be calculated from inlet and outlet water

3.2 Mass Flow Rate of Coolant (6) temperature difference by considering water mass flow rate and specific heat. So we will see the graphs of temperature difference and mass flow rate of water. Following graphs shows the relation between mass

The Condensation effect of the thermosyphon is depends upon the rate of cooling water flowing through the condenser region. In this project, the range of mass flow rate of water varies from 0.1 LPM (1.6667
* 10-3 kg/s) to 0.8 LPM (0.0134 kg/s) through Rotameter. Where, 0.1 LPM = 0.1/60 LPS = 0.0016667 LPS & 1 kg/s = 1 LPS.

3.3 Binary Working Fluid

Selection of working fluid for thermosyphon is concerned; first go through the various thermodynamic properties of ethanol and methanol. It showed below in the Table 3 (N. A. Faddas, et al., 2015).
In this experiment, various ethanol-methanol mixtures used e.g. 60:40 (by volume); at this ratio these two fluids are completely soluble with each other. . It showed below in the Table 4 (N. A. Faddas, et al., 2015).

Table 3 Properties of Ethanol and Methanol

Sr. No.	Properties	Methanol (CH3OH)	Ethanol (C2H5OH)
1	Molecular Weight	32	46
2	Boiling point (°C)	65	78
3	Melting point (°C)	-98	-144
4	Useful temperature range (°C)	10 to 130	0 to 130
5	Thermal Conductivity at 300K (W/m-K)	0.202	0.171
6	Latent heat of vaporization (kJ/kg)	1100	846

Table 4 Properties of Ethanol- Methanol Mixture

Sr. No.	Properties	Ethanol-Methanol Mixture
1	Boiling point (°C)	72.8
2	Melting point (°C)	-125.6
3	Useful temperature range (°C)	0 to 100
4	Thermal conductivity at 300 K (W/m-K)	0.1834
5	Latent heat of vaporization (kJ/kg)	947.6

4. Result And Discussion

The quantity of heat transfer to the coolant water can be calculated from inlet and outlet waterQout = mw. Cpw (Two - Twi) (W) flow rates (mw) Vs temperature difference (Two–Twi) at various angle inclinations (θ). Different colors are used to indicate difference mixture proportions in the graphs shown in the figures. Blue color indicates the Pure Ethanol, Red color shows pure Methanol and Green color shows the (60:40) % ratio of Ethanol- Methanol mixture by volume.
From figures, it shows that as the mass flow rate of water increases, the temperature difference decreases with the increase in mass flow rate of water. Following graph shows that the result 90^0 inclination angle is better for the thermosyphon.

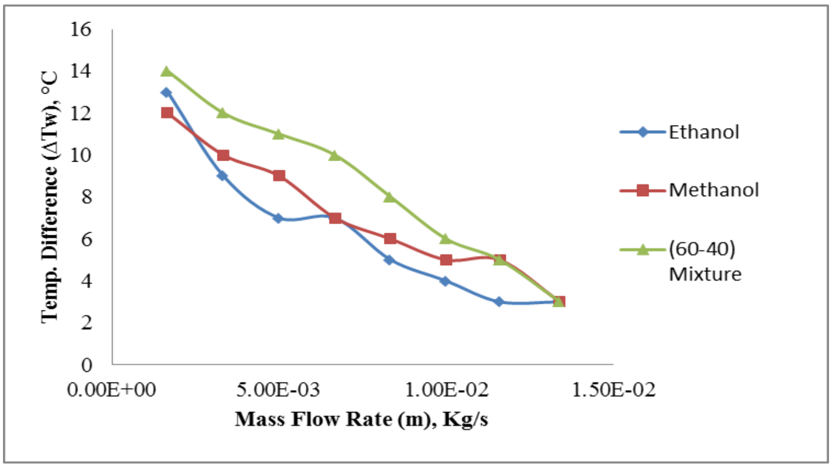
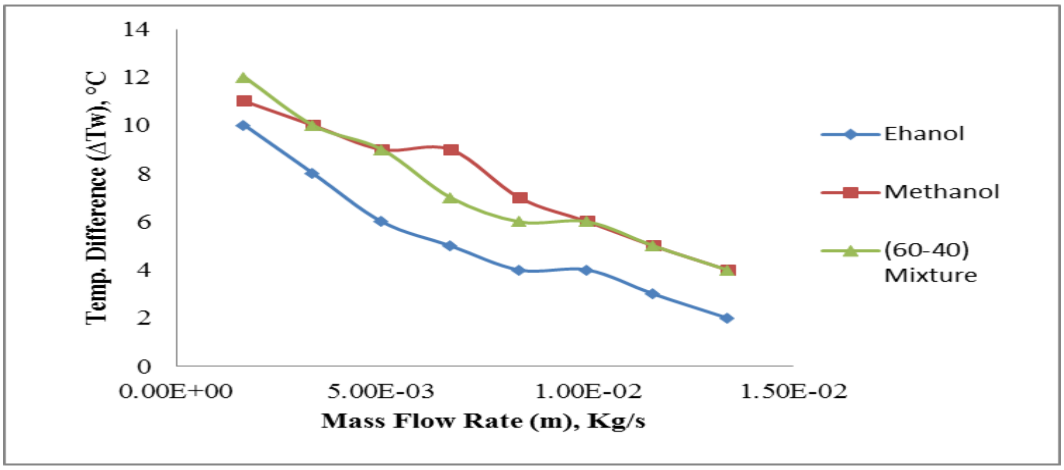


Fig.3 Mass Flow Rate of Water Vs Temperature Difference of Water at Angle Inclination θ = 90°.



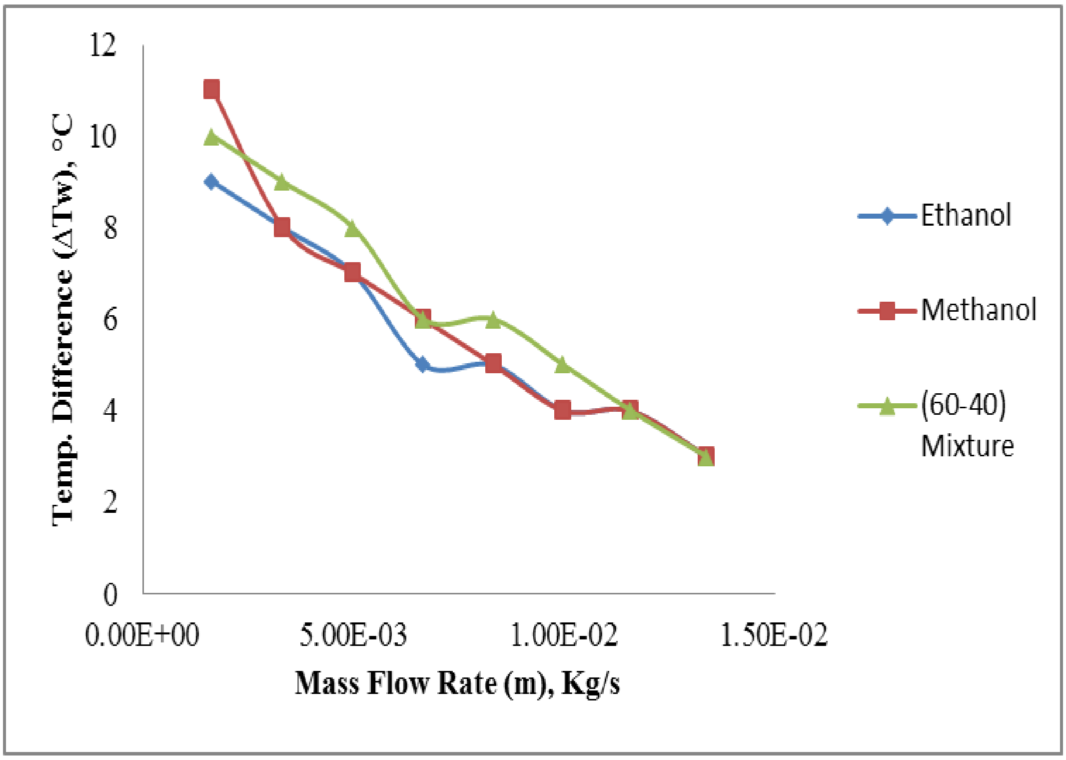


Fig.4 Mass Flow Rate of Water Vs Temperature Difference of Water at Angle Inclination θ = 75°.

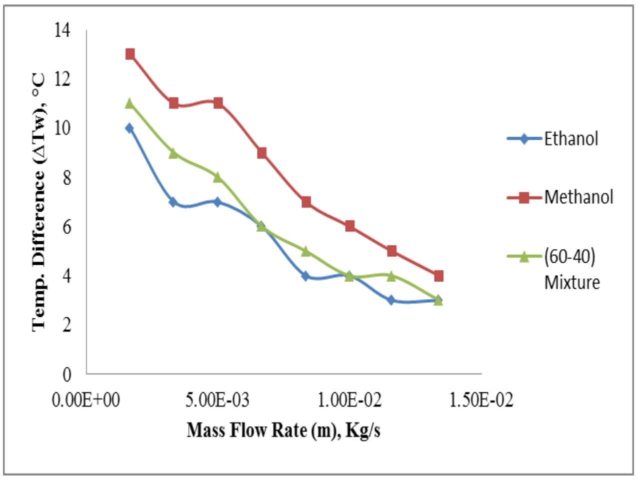


Fig.5 Mass Flow Rate of Water Vs Temperature Difference of Water at Angle Inclination θ = 60°.

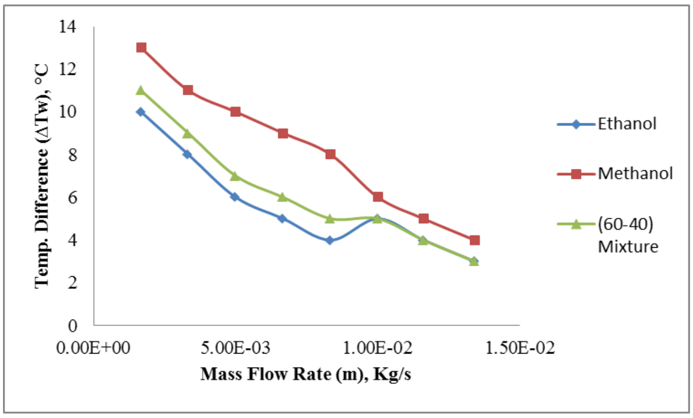


Fig.6 Mass Flow Rate of Water Vs Temperature Difference of Water at Angle Inclination θ = 45°.

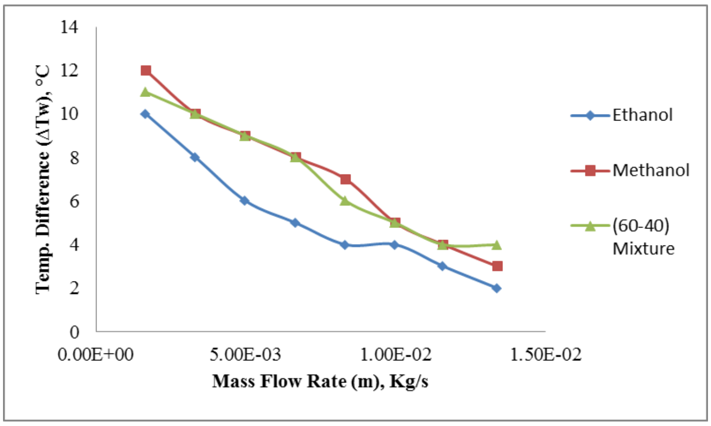


Fig.7 Mass Flow Rate of Water Vs Temperature Difference of Water at Angle Inclination θ = 30°.

Fig.8 Mass Flow Rate of Water Vs Temperature Difference of Water at Angle Inclination θ = 15°.

Conclusion

The experimentation was carried out thermosyphon charged with pure ethanol, pure Methanol and Ethanol-Methanol Mixture. Performance of thermosyphon heat pipe investigated at various inclination angle and coolant flow rate with constant heat load.

1) Thermosyphon has satisfactory heat transfer performance at minimum mass flow rate of water, temperature difference get decreases as mass flow rate increases.
2) The binary mixture (60:40) % by volume gives the best performance as that of pure Ethanol and pure Methanol.
3) From this experiments, it come to know that maximum temperature difference of water at 90° inclination, So we get the best performance of thermosyphon for (60:40) % mixture at 90° inclination and 1.09E-05 kg/s mass flow rate.

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