

Comparative Exploration of Thermal Performance of Methanol & Ethanol Fluid Wickless Copper heat pipes

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ABSTRACT: In this comparative study, the main purpose is to investigate the comparative thermal performance of Methanol & Ethanol fluid wickless heat pipe. For this purpose, a long evaporative section wickless heat pipe is designed, constructed and tested at temperatures of 40, 60 & 80°C. In this work the wickless heat pipe is made of copper tube of 1000 mm length of internal diameter 24.4 mm (1 inch) and 1mm thickness. The working fluid employed is Methanol & Ethanol with filling ratio (FR) 40%. The lengths of Evaporator, Adiabatic & Condenser sections are 600, 200 and 200 mm respectively. The wickless heat pipe 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 40°, 60° & 80°C temperature of hot water taken during experimentation. Immersion water heater of 3.5 KW was used for water heating process. The test position (Horizontal, Vertical & Inclined) of the wickless heat pipe varies between 0° to 90°. Seven different tests were carried out in different orientation angle. Experimentally found that the vertical position is the best performance of wickless heat pipe for maximum mass flow rate of fluid. It was also found that there is no more differences in thermal performance of wickless heat pipe at an angle of 45°, 60° & 90° as compare with vertical position (90°). The overall thermal resistance also calculated in the range of 0.069636 °C/W to 0.109777 °C/W. Experimentally found that overall thermal resistance decrease from horizontal position to vertical position. Less overall thermal resistance causes better performance of wickless heat pipe. Maximum efficiency of Methanol fluid wickless heat pipes was 72.41% found at vertical position after comparison between two wickless heat pipe (Methanol & Ethanol fluid) performances. Maximum heat output performance 498.38 Watt found at vertical position for Ethanol fluid.

KEYWORDS: Methanol fluid, Ethanol fluid, wickless copper heat pipe, Long Evaporative Section, LES.

I. INTRODUCTION

A heat pipe is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces. Heat pipes are the most common passive, capillary-driven of the two-phase systems. Two-phase heat transfer involves the liquid-vapour phase change (boiling/evaporation and condensation) of a working fluid. The heat pipe technology industry leader, Thermacore has specialized in the design, development and manufacturing of passive, two-phase heat transfer devices since 1970. Wickless heat pipes 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 wick less heat pipe) to ensure the working fluid circulation. Two-phase (Wickless heat pipes) heat transfer involves the liquid-vapour phase change (boiling and condensation) of a working fluid. Wickless heat pipes offer high effective

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thermal conductivities, energy-efficiency, light weight, low cost and the flexibility of many different size and shape options. As passive heat transfer systems, Wickless 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. Wickless heat pipes transfer heat more efficiently and evenly than solid conductors such as aluminium or copper because of their lower total thermal resistance. It transfers heat many times faster than pure copper. The wickless heat pipe is filled with a small quantity of working fluid (Methanol & Ethanol). Heat is absorbed by vaporizing the working fluid. The vapour transports heat to the condenser region where the condensed vapour 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. The use of wickless 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]. Wickless heat pipes are currently utilized in many energy systems according to their needs, in industrial areas and aerospace applications, including the solar system 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. Heat pipes transfer heat from the heat source (evaporator) to the heat sink (condenser) over relatively long distances through the latent heat of vaporization of a working fluid. Heat pipes typically have 3 sections: an evaporator section (heat input/source), adiabatic (or transport) section and a condenser section (heat output/sink). In the current study we are using wickless heat pipes We were used wickless heat pipes in three orientations namely horizontal, vertical and inclined. The size of wickless heat pipes was selected according to the size of casing of test rig. The selected wickless heat pipe is of length 1000 mm and diameter 25.4 mm. The main aim of this experiment was to find out the comparative thermal performance of wickless heat pipe.

Literature Review of Related Work:-

Patrik Nemeč, et.al [1] They worked on thermal performance measurement of heat pipe. From experimental measuring thermal performance of heat pipes are create graphic dependences average values of thermal performance from working position of heat pipe. Ideal working position of heat pipe is vertical position. Heat pipe operate on maximum performance and maximum mass flow transfer in this position. This experiment has testify that the wick heat pipe is able operate at any other position as vertical and even at the horizontal position. From results measured performances of heat pipes at various working position discover that the wick heat pipe is able operate at horizontal position and total heat performance transfer is not very different as at vertical position, which capillary structure cause.

Suchana Akter Jahan, et.al [2] They worked on Effect of inclination angles on heat transfer characteristics of a closed loop pulsating heat pipe (CLPHP). They had to study the effect of inclination angle and working fluid on the heat transfer characteristics and performance of CLPHP. The performance characterization has been done using two different working fluids of water and ethanol with inclination angle of 0° (vertical), 30°, 45°, 60°, 75° and 90° (horizontal). The experiment is conducted on a CLPHP made of 148 cm long copper capillary tube of 3.0 mm outer diameter and 2.0 mm inner diameter creating a total of 13 turns. The total length of evaporator section is 39.5 cm and condenser section is 31.5 cm; while the rest is assumed to be adiabatic. The evaporator section is heated by electrical heat input, while the condenser section is cooled by atmospheric air flow. Since a PHP is recognized as a two phase heat transfer device, for comparative studies it is operated as a double-phase system by filling it 70% with the working fluid. The comparative study results in a better understanding of the underlying physics of the PHP operation. The experimental results indicate a strong influence of gravity and thermo physical properties of the working fluid on the performance of the CLPHP. The results demonstrate the effect of the input heat flux, inclination angle and physiochemical properties of the working fluid on the thermal performance of the device.

Thanaphol Sukchana, et.al [3] They worked on Effect of Filling Ratios and Adiabatic Length on Thermal Efficiency of Long Heat Pipe Filled with R-134a. The effect of R-134a filling ratio and adiabatic length on thermal efficiency of the long heat pipe are investigated. An experimental heat pipe is fabricated from the straight copper tube having an inner diameter of 11.3 mm. The evaporator and condenser length are 100 mm. The R-134a used as the working fluids filled in the heat pipe was tested. Filling ratios of the working fluid to heat pipe volume at 10, 15 and 20% and input heat flux rates of 1.97 to 9.87 KW/m² were carried out in order to determine the thermal efficiency and optimum condition. The inlet cooling water temperature was kept constant at 20C. The adiabatic lengths of heat pipe for these experiments were 300, 500 and 700 mm (adiabatic length ratios 0.60, 0.71 and 0.77). The results show that the filling ratios have more

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significant effect on the thermal efficiency than adiabatic length. The optimum filling ratio of 15% and 5.92 KW/m² of heat flux are found to be favorable at shorter adiabatic length.

Leonard L.Vasiliev, et.al [4] They used heat pipes in modern heat exchangers. Heat pipes are very flexible systems with regard to effective thermal control. It is mentioned that heat pipes can easily be implemented as heat exchangers inside sorption and vapor-compression heat pumps, refrigerators and other types of heat transfer devices. Heat pipe air pre heaters are used in thermal power plants to preheat the secondary–primary air required for combustion of fuel in the boiler using the energy available in exhaust gases. Heat pipe solar collectors are promising for domestic use.

II. EXPERIMENTAL WORK

The experimental setup is designed and constructed at Workshop. The long evaporative section wickless heat pipe is designed and constructed by Siddharth Solar Technegies, Pune. It is made of copper (Cu) tube of 1000 mm length of internal diameter 24.4 mm and 1 mm thickness. The working fluid employed is Methanol & 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 wickless heat pipes 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 wickless heat pipes. 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 0.1 to 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 wickless heat pipes placed centrally in 2 inch UPVC pipe. One cylindrical water tank of diameter 1m was used as hot water storage. Immersion water heater of 3.5 KW 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 set up image is shown in Fig.1.



Fig.-1 Actual wickless heat pipe test rig image.

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III. CALCULATION METHOD

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

$$Q = m \cdot c \cdot \Delta t \quad (1)$$

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

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

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 ANALYSIS & DISCUSSION

The table no-01 is the performance sheet of Methanol & Ethanol wickless heat pipe. The maximum wickless heat pipes efficiency found 72.41 % at 80°C heat source temperature in vertical position. During experimentation 60.71% efficiency at 60°C also found in 45° angle of orientation. Fig.-2 illustrates the variation of wickless heat pipe efficiency with mass flow rate at different orientation (0°, 15°, 30°, 45°, 60°, 75°, 90°) angle for 40°C heat source. Fig.-3 illustrates the variation of wickless heat pipe efficiency with mass flow rate at different orientation (0°, 15°, 30°, 45°, 60°, 75°, 90°) angle for 60°C heat source. Fig.-4 illustrates the variation of wickless heat pipe efficiency with mass flow rate at different orientation (0°, 15°, 30°, 45°, 60°, 75°, 90°) angle for 80°C heat source. Maximum efficiency of Methanol fluid wickless heat pipes was 72.41% found at vertical position after comparison between two wickless heat pipe (Methanol & Ethanol fluid) performances. Variation of overall thermal resistance with heat input for different heat source. Thermal resistance decrease with total heat input. Maximum thermal resistance 0.10977°C/W was found at horizontal position for maximum mass flow rate 0.0417 Kg/Sec. Fig.-5 illustrates Variation of overall thermal resistance with tilt angle for 40°C heat source. Fig.- 6 illustrates Variation of overall thermal resistance with tilt angle for 60°C heat source. Fig.-7 illustrates Variation of overall thermal resistance with tilt angle for 80°C heat source. It was observed that Maximum thermal resistance 0.10977°C/W occurs at horizontal position. Fig.-8 illustrates Heat performance with different orientation angle for different heat source. Maximum heat input performance 498.38 Watt found at vertical position for Ethanol fluid. for 0.0385 Kg/Sec mass flow rate of hot water. Maximum heat output performance 337.6 Watt found at vertical position for Ethanol fluid. for 0.0385 Kg/Sec mass flow rate of hot water. The overall thermal resistance also calculated in the range of 0.069636 °C/W to 0.109777 °C/W , experimentally found that overall thermal resistance decrease from horizontal position to vertical position. Less overall thermal resistance causes better performance of wickless heat pipe.

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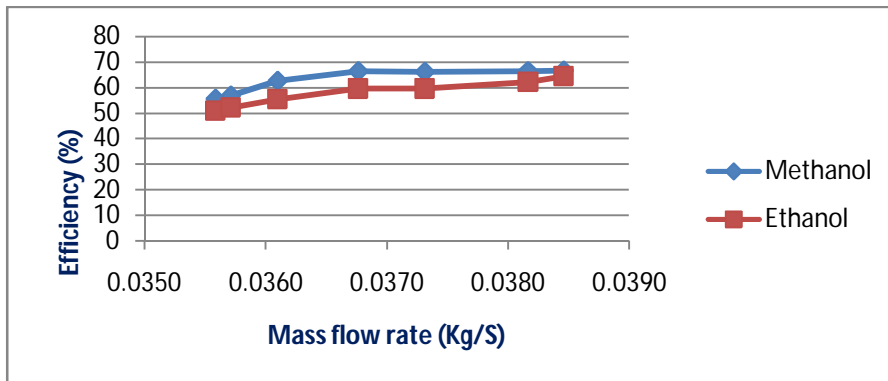


Fig.2.Variation of wickless heat pipes efficiency with mass flow rate at 40°C Heat Source

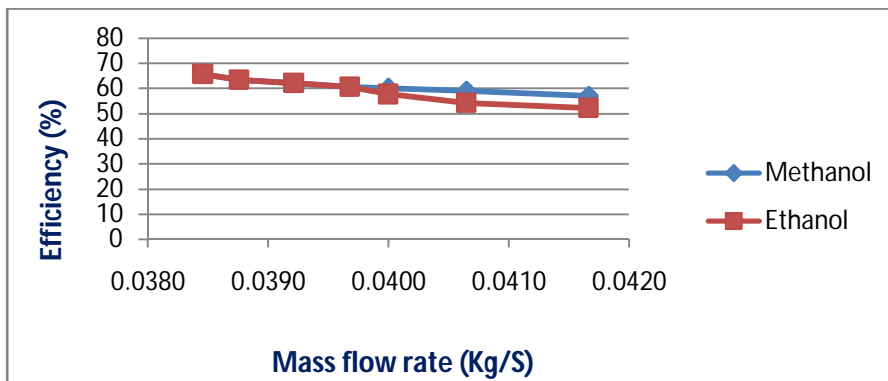


Fig.3.Variation of wickless heat pipes efficiency with mass flow rate at 60°C Heat Source

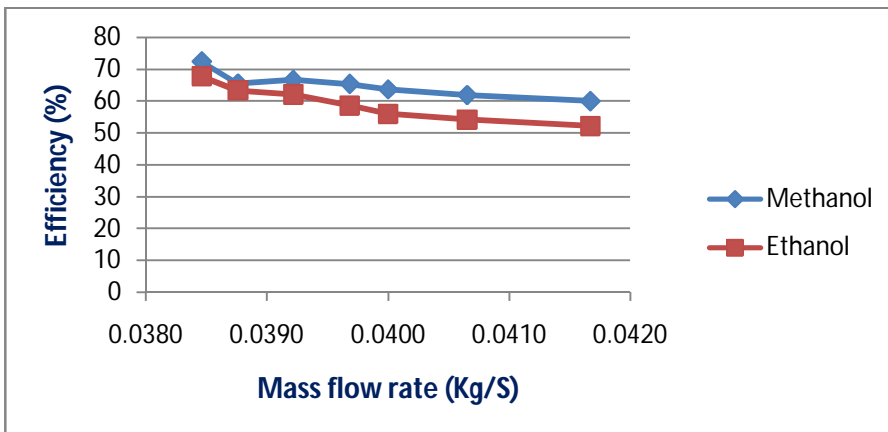


Fig.4.Variation of wickless heat pipes efficiency with mass flow rate at 80°C Heat Source

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Wickless Heat Pipes Performance Table							
Hot Water Working Temperature	Angle	Mass Flow Rate(Kg/Sec)		Efficiency(% η)		Over all Thermal resistance($^{\circ}$ C/W)	
		Methanol	Ethanol	Methanol	Ethanol	Methanol	Ethanol
40 $^{\circ}$ C	0 $^{\circ}$	0.0356	0.0356	55.75397	50.905	0.0696	0.069
	15 $^{\circ}$	0.0357	0.0357	56.91057	52.168	0.0660	0.066
	30 $^{\circ}$	0.0361	0.0361	62.62609	55.400	0.0597	0.059
	45 $^{\circ}$	0.0368	0.0368	66.42247	59.551	0.0509	0.050
	60 $^{\circ}$	0.0373	0.0373	66.17284	59.555	0.0492	0.049
	75 $^{\circ}$	0.0382	0.0382	66.53301	62.240	0.0462	0.046
	90 $^{\circ}$	0.0385	0.0385	66.66667	64.516	0.0453	0.045
60 $^{\circ}$ C	0 $^{\circ}$	0.0417	0.0356	57.14286	52.173	0.0843	0.084
	15 $^{\circ}$	0.0407	0.0357	59.09091	54.166	0.0820	0.082
	30 $^{\circ}$	0.0400	0.0361	60	57.692	0.0764	0.076
	45 $^{\circ}$	0.0397	0.0368	60.71429	60.714	0.0707	0.076
	60 $^{\circ}$	0.0392	0.0373	62.06897	62.068	0.0695	0.069
	75 $^{\circ}$	0.0388	0.0382	63.33333	63.333	0.0675	0.067
	90 $^{\circ}$	0.0385	0.0385	65.625	65.625	0.0632	0.063
80 $^{\circ}$ C	0 $^{\circ}$	0.0417	0.0356	60	52.173	0.1097	0.109
	15 $^{\circ}$	0.0407	0.0357	61.90476	54.1666	0.1058	0.106
	30 $^{\circ}$	0.0400	0.0361	63.63636	56.000	0.1017	0.102
	45 $^{\circ}$	0.0397	0.0368	65.38462	58.620	0.0883	0.088
	60 $^{\circ}$	0.0392	0.0373	66.66667	62.068	0.0896	0.089
	75 $^{\circ}$	0.0388	0.0382	65.51724	63.333	0.0869	0.087
	90 $^{\circ}$	0.0385	0.0385	72.41379	67.741	0.0836	0.084

Table no-01 is the performance sheet of Methanol & Ethanol wickless heat pipes

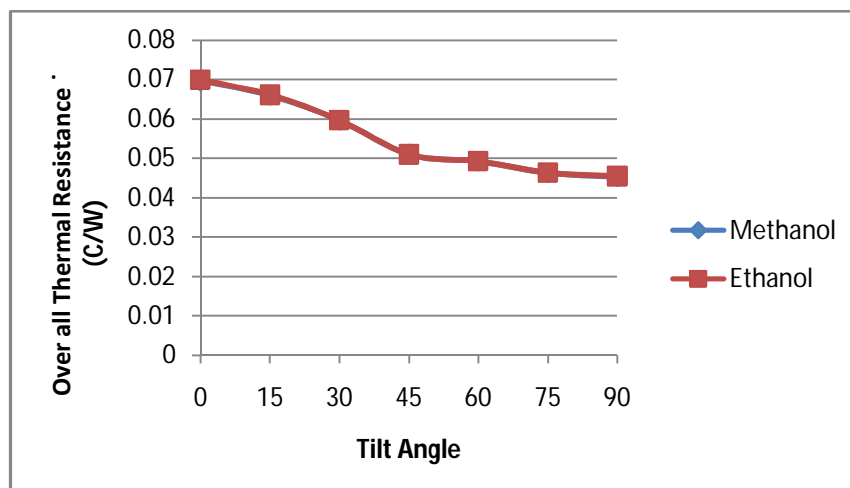


Fig.-5. Variation of overall thermal resistance with tilt angle at 40 $^{\circ}$ C heat source.

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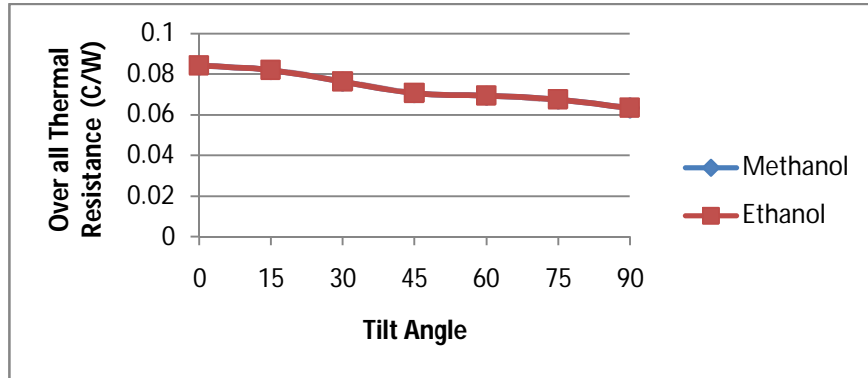


Fig.-6. Variation of overall thermal resistance with tilt angle at 60°C heat source.

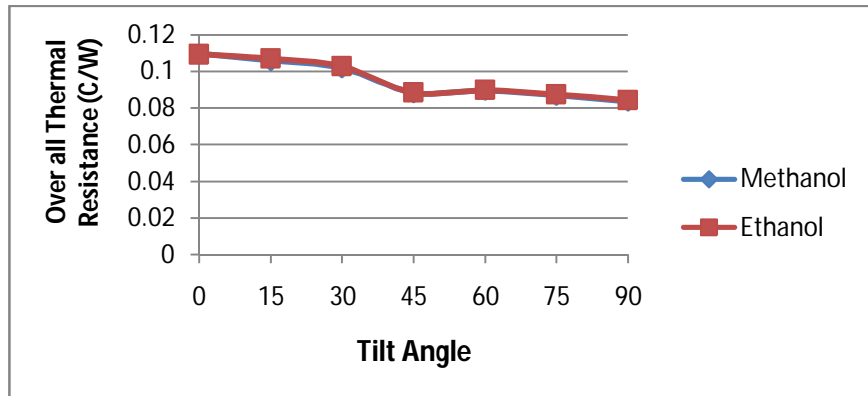


Fig.-7. Variation of overall thermal resistance with tilt angle at 80°C heat source.

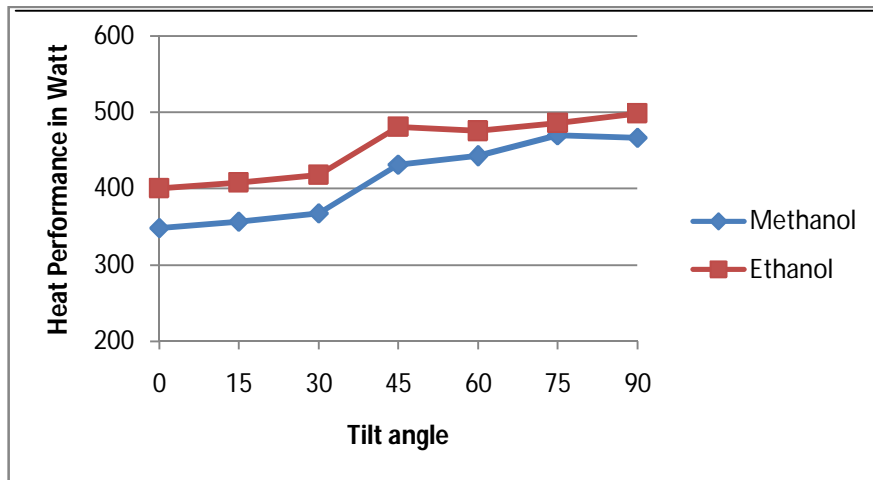


Fig.-8. Heat performance with different orientation angle for different heat source.

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V. CONCLUSION

Due to the very high heat transfer coefficients for boiling and condensation, wickless heat pipes are highly effective thermal conductors. Working fluids are chosen according to the temperatures at which the heat pipe must operate. Wickless Heat pipes contain no mechanical moving parts and typically require no maintenance. Ideal working position of wickless heat pipes are vertical position. Wickless heat pipe operate on maximum performance and maximum mass flow transfer in this position. From experimental measuring performance of wickless heat pipe is creating graphic dependences average values of thermal performance from working position of wickless heat pipe. After comparative study, the maximum wickless heat pipes efficiency found 72.41% at 80°C hot water heat source temperature in vertical position. During experimentation 60.71% efficiency at 60°C also found in 45° angle of orientation. Variation of overall thermal resistance with heat input for different heat source. Thermal resistance decrease with total heat input. Maximum thermal resistance 0.10977°C/W was found at horizontal position for maximum mass flow rate 0.0417 Kg/Sec. The overall thermal resistance also calculated in the range of 0.069636 °C/W to 0.109777 °C/W, experimentally found that overall thermal resistance decrease from horizontal position to vertical position. Less overall thermal resistance causes better performance of wickless heat pipe. Maximum heat output (at Condenser Section) performance 337.6 Watt found at vertical position for Ethanol fluid. for 0.0385 Kg/Sec mass flow rate of hot water. This experiment has testified that the Methanol & Ethanol fluid wickless heat pipe is able to operate at any other position as vertical and even at the horizontal position. From results measured performances of wickless heat pipe at various working position discover that the wickless heat pipes 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 large heat absorption area available of wickless heat pipe the heat absorption capacity at evaporative section also found which is maximum 498.38 W at 80°C heat source for Methanol fluid. Maximum heat output (at Condenser Section) performance 337.6 Watt found at vertical position for Ethanol fluid. for 0.0385 Kg/Sec mass flow rate of hot water.

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