ISSN 2347 - 3983
Volume 8. No. 10, October 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter1558102020.pdf
https://doi.org/10.30534/ijeter/2020/1558102020

Experimental Investigation of Heat Pipe Heat Exchanger with Hybrid Nanofluids

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ABSTRACT:

The heat pipe is a type of heat exchanger, which is widely used for thermal control because it has high possible heat transfer rate over a substantial distance with the low temperature drop. In this research work, the effect of heat exchange between hot and cold mass at different evaporator heat inputs on heat pipe heat exchanger efficiency and it is investigated for different inclination angles, heat inputs and adiabatic heat pipe lengths. Hybrid Nano-fluid, a mixture of 70 per cent of AL_2O_3 and 30 per cent of TiO_2 Nano-fluidis used as working fluid with deionized water as the base fluid. The hot water mass flow rate (mh) of 0.2, 0.4, 0.6 and 0.8 litres per minute is used in the evaporator section. The cold-water mass flow rate (m_c) is maintained as 50% of m_h throughout the experiment. The experimental tests are conducted for adiabatic lengths of 0 mm, 100 mm and 200 mm of Heat pipe oriented at inclination angles of 0°, 15°, 30°, and 45° at various heat inputs of 40, 60 and 80 W. The experimental findings showed that increasing adiabatic length reduces the heat pipe effectiveness. With increasing inclination angles for the whole hot water mass flow rate, the effectiveness of the heat pipe was increased. Compared to two other mass flow rates of 40 and 60 watts heat inputs at all the inclination angles, 0.2 and 0.4 ml water mass flow rate showed higher effectiveness. Whereas the heat input of 80 W had similar characteristics of efficiency except at angle of inclination of 45 °.

Keywords: Hybrid Nano fluids, Heat pipe, Effectiveness; wick structure.

1. INTRODUCTION

The operation of various systems such as Internal combustion engine, power plants, process industries and heat recovery [1] units is made up of heat exchangers. A heat transfer device that delivers heat energy from one region to another region under the principle of thermal conductivity and phase transition is called a heat pipe. In heat pipe heat exchanger of the hot surface of the working fluid was in liquid form and it was converted into vapor by absorbing the heat when in interact with a thermal conductive solid. This vapor transport into the cold region by traveling along the heat pipe. This cycle is repeated by the return of the liquid back to the hot region by capillary action.

Research will be conducted in this study on shell and tube heat exchangers, which are commonly used for the thermal control of electronic devices. The heat pipe heat exchanger is known to be used to measure the performance of the evaporator in order to improve the thermal efficiency and maximize the heat pipe heat exchanger fluid flow.

The significant amount of heat from the heat pipe evaporator to the adiabatic section and condenser section with relatively small temperature difference is transferred. The heat pipe is focused on the effectiveness of working fluid heat transfer characteristics. We will analyze heat pipe heat exchangers by adjusting the heat pipe distance, internal and external heat pipe diameter and the different kinds of nano fluids are used. We are using the Agilent data logger to record the various temperatures. Experiments will be conducted by varying the mass flow rate of hot and cold water, the angle of inclination of the heat pipe heat exchanger at different heat inputs.

1.1. Nano Fluid

The commonly used Nanofluid are metals – e.g., Au, Ag, Cu; metal oxides –e.g., Al_2O_3, CuO, SiO_2, TiO_2; carbon materials like graphite and nanotubes; metal carbides, metal nitrates. Hybrid Nanofluid is also a working fluid in heat pipe and it is mixing Nano fluids adapted each other in single solution form. Hybrid Nanofluids are classified as water-based hybrids Nanofluids, oil-based hybrids Nanofluids and glycol-based hybrids Nanofluids. Based upon these classifications hybrid Nanofluids was prepared. When some amount of nano-Al_2O_3 was added and the thermal conductivity of microcapsules increased in an experiment to find out characterization and thermal properties of paraffin microcapsules modified with nano-Al_2O_3, and the melting and crystallization enthalpy was 93.41 J/g and 92.43 J/g, respectively this shows that nano-Al_2O_3will increase the heat transfer[2]. Tio_2 has melting point of 1800°C and good thermal conductivity. In this article, using CFD software to analyze the fluid conditions of the heat pipe.

Based on the performance were going to carry out to improve the thermal efficiency and optimize the volumetrically fluid fill in the solar heat pipe. In this article, using CFD software to analyze the fluid conditions of the solar heat pipe and take the ambient temperature conditions and volumetric fluid fill in the solar heat pipe for optimization based on the tests. There are two significant elements in the longitudinal direction of the thermal tube, one is a section of the evaporator and the other is a section of the condenser. The output of the solar heat pipes is put at an inclination of 30 ° to 90 ° observations were made that heat transfer occurs effectively for various processes for the above inclinations. Venkat and Bhramara [3] The heat exchanger device generates a heat pulse that absorbs the heat from the evaporator region to the condenser field. CFD modeler is carried out in ANSYS CFX with a pulsing thermal pipe with a single turn and acetone is used as an operating liquid of 60 per cent filling. At evaporator heat input 9W to 15W, heat flux range 7945 w/m^2 and adiabatic heat flux are zero with CFD analysis of evaporator and condenser wall temperature is calculated. It is noted that due to chaotic fluid motion, the thermal resistance decreases and the coefficient of heat transfer increases with an increase in heat flux. And 60 percent of three filling ratios, 70 percent, 80 percent of acetone is found to be the more appropriate 60 percent filling ratio is better for heat transfer features in this paper we are considering the multiphase fluid and filling ratio also so I am decided to taken the multi phase nanofluid is AL_2O_3 and TIO_2. Huang and Chen [4] The numerical model in this document will be assessed on the basis that the simulation performance of heat pipes is effective. The wick is modeled as a fully thawed porous medium in which the impacts of fluid flow and fluid non-flow are known. In the Boltzmann thermal lattice algorithm, the combination of fluid flow and thermal conduction equations between the heat pipe components is resolved. Due to the proposed treatment analysis of conductive processes, fluid flow in wick, evaporator and condensation, much less computational resources are required for the LVPM implemented with the Boltzmann lattice technique. It is shown that both the temporary process pipes and the steady state conduct are capable of precise simulations of the model works around 50 times faster for transient simulation in the test in this paper we are considering the porous wick so I decide the porous wick material is chosen for my experimental work. Saber and Ashtiani [5] evaluate the dynamics of computational fluids used to analyze its evaporator output and attempt to increase the thermal efficiency of the fluid flow style heat exchanger. According to the results, although an increase in the cross-region entry may help to improve the distribution, the large scale of the distribution may improve the operating costs of a drop in pressure. The findings indicate that using a 1/5 diameter ratio imperfect cone can optimize the HPHE performance of these techniques can result in greater effectiveness. By this method, the best distribution of flow and temperature with a minimized pressure drop will be reached and so operation cost may decrease. The above observations and assumptions would increase the thermal efficiency of the heat exchanger in the evaporator and condensing device. Huminic [6] used professional CFD software to present the improvement of heat pipe effectiveness with water Nanoparticle mixtures of copper tube is made up of heat pipe has an outer diameter is 8.9mm and length is 200mm. Water is used as a working fluid, whereas nanoparticles used in this study are three-fold copper oxide nanoparticles with a volume fraction of 0, 1%, and 4 percent CuO. The numerically modelled DI water with copper oxide particles showed that the heat pipe's thermal efficiency was improved. Nano fluid's critical heat flux and convective heat coefficient is greater than that improved by the DI- water with the heat pipe thermal efficiency. The higher thermal efficiency of the Nano fluid will be proven to be traditional for DI water in the heat vessel. it shows the base fluid is de-ionized water will be high efficiency so it can produce the high effectiveness in heat transfer so I am taken the deionized water is the base fluid. Rashmi et al [7] Nano stabilized by 1.0 weight% gum Arabic was utilized as refresher liquid for the concentrated tube laminar heat exchanger with a cold liquid flow rate from 10 to 50 g / s to discuss a carbon nanotube (CNt) Nano fluids 0,01 percent wt. Using fluent software, both experimental and numerical simulations of heat transfer improvement using CFD Nano liquids. The findings showed an improvement in thermal conductivity of 4 to 125 percent and heat transfer of almost 70 percent, with an increase in flow rate. Compared with experimental tests, numerical findings are strong agreement variance would be ± 3.0%. CFD simulations using a single-phase strategy in excellent agreement with the experimental outcomes at distinct flow rates and heat transfer improvement numerical simulations using CNT Nano liquids in this paper we are considering the nanofluids so I consider my experiment work also taken by nanofluids. Senthilkumar et al [8] In this paper, we will investigate the experimental performance of the heat pipe using the combination of copper Nanofluids and different types of heat inputs, inclination angles with working fluids of the long-chain heat pipe alcohol solution. In this experimental study, the thermal efficiency of copper Nanofluid heat transfer coefficient with an aqueous solution of long-chain alcohols is greater than copper Nanofluid and thermal resistance is always less than long-chain alcohol aqueous solution. In this aqueous solution of long-chain alcohols, nanofluid replacement for pure water as a working fluid in heat pipes in elevated thermal efficiency features of nanomaterials results. In this paper we investigate the heat input, inclination angles and T-type thermocouples are considered so for my experimental work also same input as taken. Air to water thermal exchanger fitted with six wickless thermal pipes loaded with water as a working liquid was performed by Mroue et al [9] Here six thermosyphon is made from the carbon steel measured by 2m length, the different temperatures 100-250ºC and the flow rate is 0.05-0.14kg/s. These results are provided by 10% of experimental values. Heat transfer is high for inlet temperature and the efficiency of the air inlet mass flow rate is inversely proportional to the mass flow rate. An average difference between the experimental and numerical results on the evaporator side and 5 percent on the condenser side is achieved by 3 percent. In this article, Peters et al [10] will design a new high-performance heat exchanger capable of transmitting 1000W while consuming less than 33W of electrical input and with a total heat resistance of 0.05K / W. In order to achieve low thermal resistance, a loop heat pipe with a single evaporator and various condenser plates in the array of fins is used. Permanent magnetic synchronous motor with 0.1 * 0.1 * 0.1 m volume to maximize the area of heat transfer by reducing the rate of air flow with electrical power. Modeling of the evaporator and condenser geometry in COSMOL. These results are based on the design and production of air-cooled heat exchangers with high performance in this paper we are considering the air heat exchanger so I am taken as shell and tube heat exchanger. In this study, Yanxin Hu et al[11] will examine the improvement of heat transport by self-rewetting liquid of the micro oscillating heat pipes. For this experiment, the heat transfer range of 100,250 and 200 mm is approved, and the inner diameter is 0.4, 0.8, 1.3 mm for self-rewetting fluid, and de-ionized water is used as working fluid. The 0.1 percent capillary strength of the heptanol solution is much lower than that of the de-ionized water. A much better thermal output is the micro oscillating heat pipe (MOHP) using self-rewetting fluid, which reduces thermal resistance and extends MOHP's efficient variety. in this paper deionized water has better thermal performance so it can produce the higher effectiveness in heat transfer so I decided to take the deionized water. In this study, Raveendiran et al [12] will explore the thermal efficiency of water to be used as a working liquid by the water heat exchanger in methanol and this assessment is based on the efficacy of the NTU strategy. The evaporator section mass flow rate is 30 litre per hour to 60 litre per hour, while the evaporator section condenser ratio is 1:1, 1:1.5, 1:2, 1:2.5 and 1:3. The thermal input working situation is 1KW to 4 KW and the temperature range is 50-80°C. M_c = 50 percent M_h is acquired for the optimal efficiency of the puzzled heat pipe thermal exchanger. From the experimental outcomes, the optimum efficiency range of the Baffled heat-pipe thermal exchanger ranges from 61% to 68% of 1KW to 4KW thermal input. In this paper we considered the baffled pipe heat exchanger so I am taken the shell and tube heat exchanger. Senthilkumar et al[13] considered thermal performance filling of the heat pipe to be thermal efficiency as experimentally studied as a copper nanofluid, De-ionized water is 40 nm particle size with different 25mg / lit, 50 mg / lit, 100 mg / lit, and 125 mg / lit concentrations with various heat loads and working fluid angles. The temperature variation of heat pipes is evaluated in the experimental system and the thermal efficiency of copper Nano fluid is calculated under distinct concentrations. The experimental findings indicate that for all orientations, the heat pipe's greater effectiveness was achieved at a concentration of 100mg / lit than concentration. in this paper deionized water has better thermal performance so it can produce the higher effectiveness in heat transfer so I decided to take the deionized water. In the current research, Alizadehdakhel et al [14] have been modeling the gas / liquid stage flow in thermo syphon evaporation and condensation in the current research. The amount of fluid method is used to model the interaction of distinct heat input 350 to 500 and filling percentage of working circumstances between these experimental stages. The thermo syphon CFD temperature profile was contrasted with excellent agreement experimental readings. In this paper ae are considered the thermosiphon method without mechanical pump but I am taken heat pipe heat exchanger with considering the mechanical pump. Gavtash et al [15] This study seeks to model and simulate the impacts of Nano liquids on cylindrical heat pipes of ANSYS-Fluent CFD commercial software thermal efficiency Temperature of the exterior wall heat pipe, thermal strength, liquid pressure, and Nano particle axial speed (copper, aluminum oxide, and titanium dioxide) within the fluid (water) are examined. It is found that the reduction in particle size leads to an increase in heat pipe efficiency by increasing the concentration level of particles and the thermal conductivity of the thermal resistance of the heat pipe. The magnitude of the velocity was found in the concentration level of the particles is increased even in the studied liquid pressure. It shows Tio2 and AL_2O_3 has higher thermal heat pipe performance and higher thermal conductivity so it can produce higher effectiveness in heat transfer so i have decided to mix 70 % of AL_2O_3 30% of tio2 in hybrid nano fluid. Yerrennagoudaru et al [16] Nano fluids are produced by Nano particles with an ordinary size of less than 100 nm in heat transfer liquids such as water, oil, diesel, ethylene glycol, etc. The objective of this project is evaluated for four distinct Nano liquids in CFD analysis and the result is evaluated, two liquids are chosen for experimental job and lastly compared to the outcomes of CFD. Magnesium oxide-water, copper oxide-water, titanium oxide-water and iron oxide-water are the various Nano materials used for CFD evaluation Nano particle sizes vary in the range of 70 to 230 NM for the preparation of Nano fluids and for thermal conductivity observation in experiments [17,18] it shows Tio2 has higher melting point and higher thermal conductivity so it can produce higher effectiveness in heat transfer so i have decided to mix 30% of tio2 in hybrid nano fluid. Arul Selvam et al [19] discussed a 1 m long heat pipe with an outer diameter of 0.031 m and studies are performed to determine the surface temperature and vapor temperature in the evaporator section and the air condenser section at constant and temporary circumstances with two distinct input energy. A computational fluid dynamics is also conducted and findings are compared with findings obtained from experiments under steady state conditions. With convective resistance in the condenser region, the heat pipe temperature also improved as the surface heat flux in the evaporator rises. The condenser surface is high with flowing water, or the condenser region fins need a greater heat transfer field.

In the present analysis, nanofluids have a better performance of conventional working fluids like silver, graphene, methanol, etc. The concentration of aluminum oxide and titanium oxide in the deionized water is 4.4g/ lit and 2.6g/lit. Nanofluids were prepared using an ultrasonic homogenizer for aluminum and titanium oxides with aluminum and titanium particle sizes of 45 nm and 32 nm. The tests are conducted with various heat inputs for specific inclinations of the heat pipe to the horizontal. The goal of this work is to research the effect of concentration of hybrid nanofluid in improving the effectiveness of heat exchanger for heat pipe.

2. EXPERIMENT SET UP AND PROCEDURE

The schematic diagram of the experimental setup is shown in Figure 2. The experimental system has Heat pipe heat exchanger consists of three sections, namely the evaporator (heat) section, the adiabatic (transport) section and the condenser (cooling) section.There are three copper pipe of in same diameter and length.Each copper pipe is fitted with two layers of porous wick stainless steel structure on their inner surface. The diameter of porous is 0.3 mm and the heating pipe has 2400 holes/porous per metre. The wick is used to transport the working liquid by using capillary action from the condenser section to the evaporator section. Each copper tube contains 18 ml of working fluid. The working fluid used for the study is a hybrid Nanofluid, it has a combination of 70 per cent of aluminum oxide and 30 percent of titanium oxide nanofluids.The concentration of nanoparticles was taken as a concentration of 0.2 percent of the base fluid volume .The De-ionized (DI) water was used as base fluids. Before the hybrid nanofluid is filled the copper tube has to be evacuated using vacuum pump in order to remove the dissolved gases present in the copper tube .The details of shell and tube heat exchanger are given in table (1).The wall temperature distribution of heat pipe heat exchanger is measured using eight T type thermocouples of copper constantan with uncertainty of ±0.1°C. In addition, evaporator inlet and outlet temperatures, atmospheric temperatures, condenser inlet temperatures and outlet temperatures and condenser surface temperatures are also measured with coresponding T-type thermocouples fitted in respective parts.The condenser tube is made up of galvanized iron (GI) pipe with an outer and inner diameter of 24 mm and 22 mm respectively. The 230 V AC electrical power supply is applied to the water bath using heating filament to produce hot water. The water flow rate is measured by means of a rotameter on the inlet line of the jacket with an uncertainty of ±1 per cent and the flow rate varies with the heat pipe heat exchanger. Glass wool is coated in the adiabatic portion of the heat pipes in order to restrict heat loss. There is negligible amount of heat loss from the evaporator and condenser. In the evaporator and condenser section, the mass flow rate of the water was controlled and varied by a rotameter.

Figure .1Schematic diagram of shell and tube Heat Exchanger

The heat pipe transfers the heat through the internal structure.In Heat pipes, the adiabatic length and evaporator length are changed by manual adjustment. The power input of the heat exchanger heat pipe is gradually increased to the desired power level. Once the heat input for desired level of hot fluid flow rate is set in evaporator. Nanofluidis heated and it is transferred to the vapour, then it is cooled through the condenser of the heat pipe, after that Nanofluid is moved through the capillary force in wick structure. The experimental procedure is repeated for different heat inputs (40,60 and 80 watts) and different angles of the heat pipe (0°, 15°, 30°, and 45°) to the horizontal plane and the observations are noted and tabulated. The temperatures of T- type thermocouples are monitered with the module through an Agilent data logger. The vacuum pressure inside the heat pipe is controlled through a vacuum gauge, which is connected to the heat pipe's condenser end.

The first thermodynamics law therefore governs the heat transfer rate of hot water to cold water.

$$Q = m_h c_{ph} \Delta T_h = m_c c_{pc} \Delta T_c \qquad 1$$

Effectiveness is defined as the ratio of the condenser difference between the heat exchanger and the hot and cold water inlet rate of the water streams, given that the heat loss from the heat exchanger to the surrounding area is negligible.

$$\epsilon = \frac{\Delta C}{m_{hi} - m_{ci}} \qquad 2$$

where
Q = Heat Transfer
M_h and M_c= Mass flow rate of Hot and Cold water
Cp_h = Specific heat of hot water
Cp_c = Specific heat of cold water
ΔT_h= Hot water difference temperature
ΔT_c =Cold water difference temperature

ϵ = Effectiveness
ΔC = Cold water temperature difference
m_{hi}= Hot water flow rate of inlet temperature
m_{ci}=Cold water flow rate of inlet temperature

Table1. Specifications of heat pipe heat exchanger

Specifications	**Dimensions**
Outer diameter	19 mm
Inner diameter	17 mm
Shell diameter	620 mm
Shell length	850 mm
Evaporator length	600,700, 800 mm
Condenser length	200 mm
Adiabatic length	0,100 and 200 mm
Total length of HPHE	1000 mm
Wick mesh size	2400 holes per meter
Wick porosity	0.60
Wick permeability	$4.426*10^{-4}mm^2$
Capillary limit	0.092 kW
Sonic limit	60 kW
Entrainment limit	58 kW
Boiling limit	17.5 kW

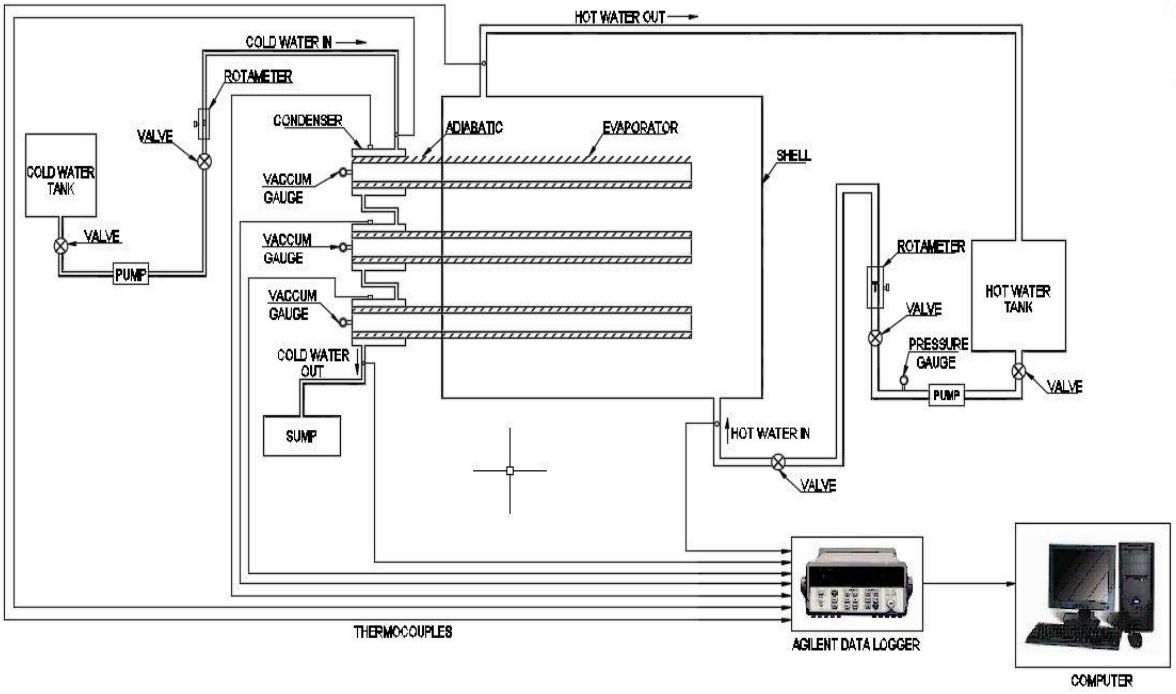

Figure. 2 Experiment set up of shell and tube heat exchanger

3. RESULTS AND DISCUSSION:

In pipe 1figure 3-6 shows the variation of effectiveness for aluminum oxide and titanium oxide was used as the hybrid Nanofluid with different heat inputs (40,60 and 80 Watts) in intervals of 20 W with various inclination angles (0,15,30and 45 degree) are taken. By comparing with figure 1, it is observed that the effectiveness was increased with decreasing hot water mass flow rate for all the heat inputs at the inclination angles of 0, 15 and 30. A similar trend was observed at a 45° inclination angle except for the heat input of 80W. At 0° inclination, the hot water flow rate of 0.2 & 0.4 ml showed high effectiveness at the heat inputs of 40, 60, and 80 W compared to the high flow rate of (0.6 & 0.8). In the horizontal position of the 0 ° inclination angle of the heat pipe, the movement of the working fluid through the wick structure from the condenser to the evaporator section occurs only due to capillary action and the flow of the fluid is very slow. Fluid slow motion takes longer to move from the condenser unit to the evaporator unit. This behaviour would minimize the amount of heat transfer from the hot water to the working fluid at low angles of inclination. As the angle of inclination increases, the effect of the gravitational force on the working fluid increases, acting together with the capillary action to move the condensed fluid towards the evaporator section. The additional gravitational effect helps the working fluid to move quickly towards the evaporating section, which results in the absorption of heat by the working fluid through the evaporator side. Hence, the effectiveness of the pipe increases with an increasing inclination angle. At 45° inclination, the efficiency of the heat pipe heat exchanger with 0.2 ml of hot water mass flow rate with 80 watts of heat input is suddenly reduced because the hot water mass flow rate is slow and also due to heat dissipation in the evaporator section. The optimum inclination angle to achieve higher effectiveness with 0.8 ml hot water flow rate is 30°.

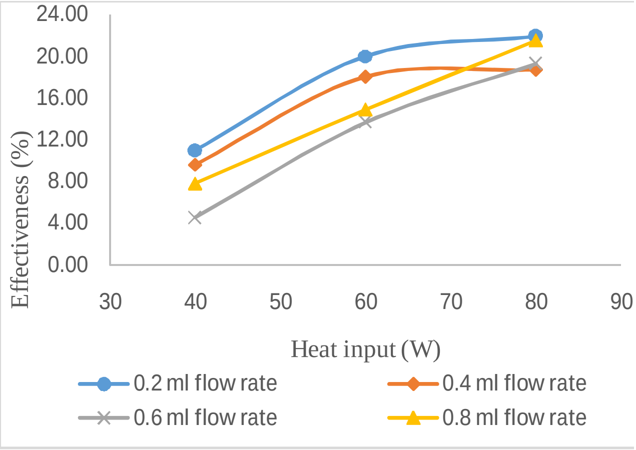

Figure .3 Effectiveness of Heat pipe with Hybrid Nano fluid of 0-degree inclination

Figure 7-10 and figure, 11-14 show the effectiveness of heat pipe having an adiabatic length of 100 mm and 200 mm for the same heat input and inclinations angles. The curved trend shows that increase in adiabatic length decrease the effectiveness in heat pipe heat exchanger. This is because an increase in adiabatic length reduced the evaporator section pipe length which turn to reduced the heat transfer surface effect in the evaporator section.

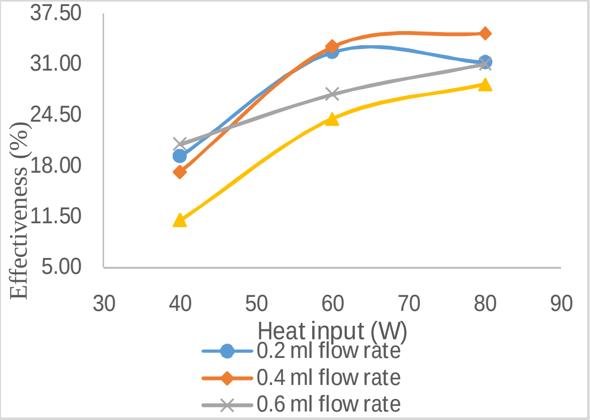

Figure. 4 Effectiveness of Heat pipe with Hybrid Nano fluid of 15-degree inclination

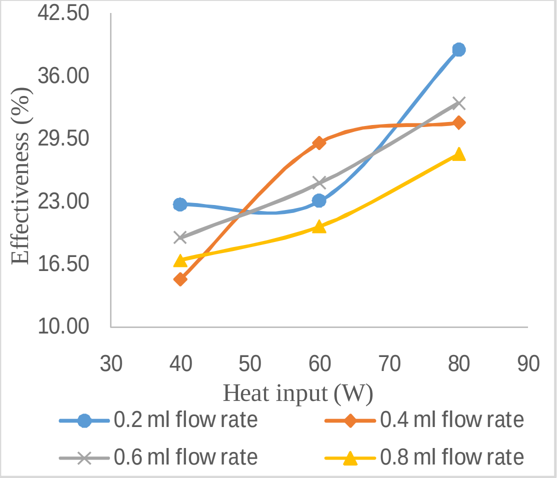

Figure .5 Effectiveness of Heat pipe with Hybrid Nano fluid of 30-degree inclination

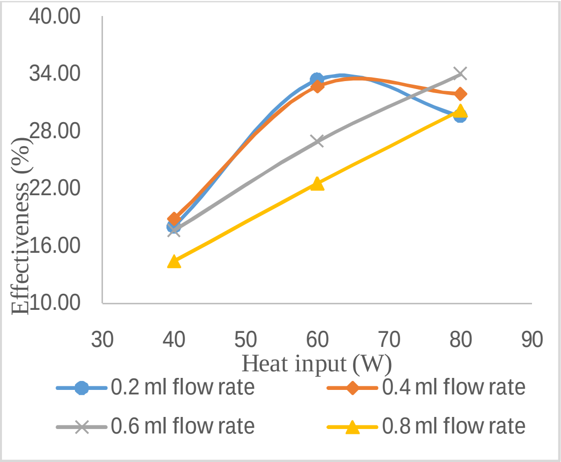

Figure.6 Effectiveness of Heat pipe with Hybrid Nano fluid of 45-de inclination

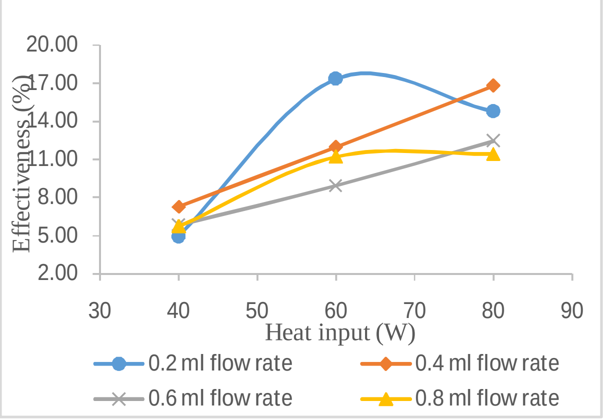

Figure.7 Effectiveness of Heat pipe with Hybrid Nano fluid of 0-degree inclination

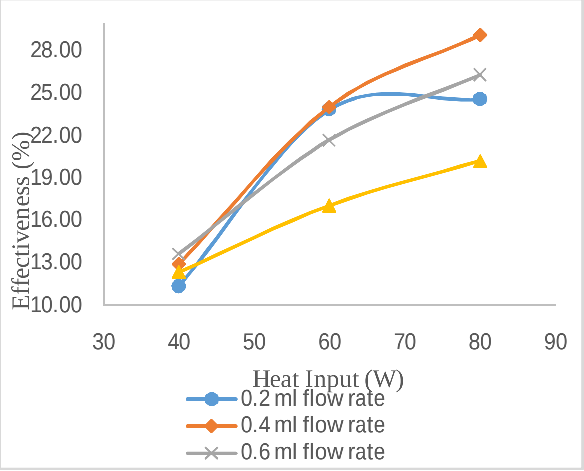

Figure.8 Effectiveness of Heat pipe with Hybrid Nano fluid of 15-degree inclination

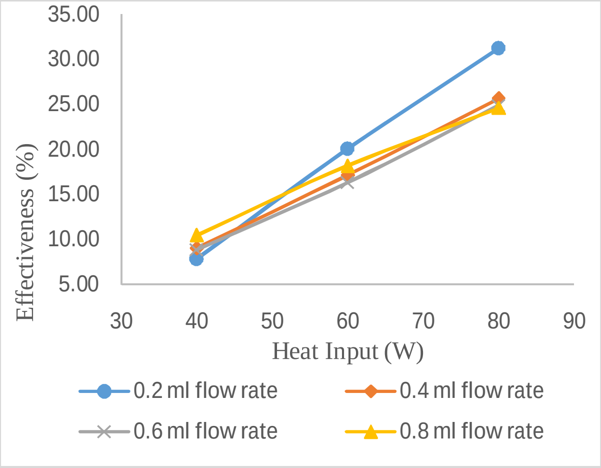

Figure.9 Effectiveness of Heat pipe with Hybrid Nano fluid of 30-degree inclination

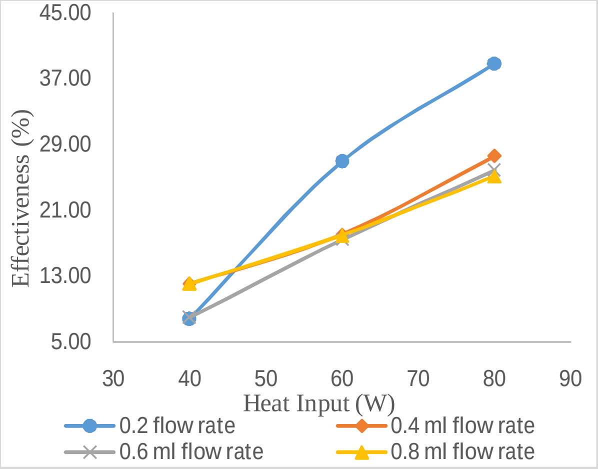

Figure.10 Effectiveness of Heat pipe with Hybrid Nano fluid of 45-degree inclination

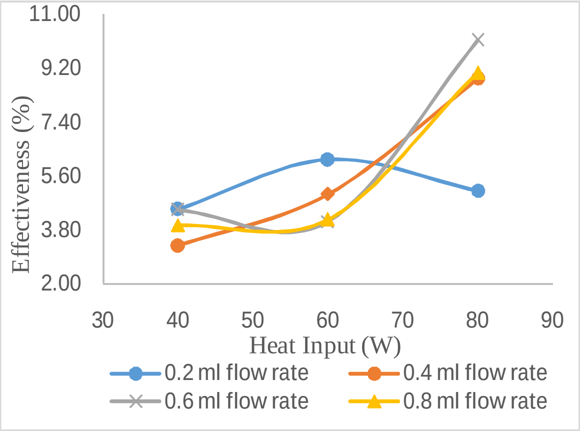

Figure.11 Effectiveness of Heat pipe with Hybrid Nano fluid of 0-degree inclination

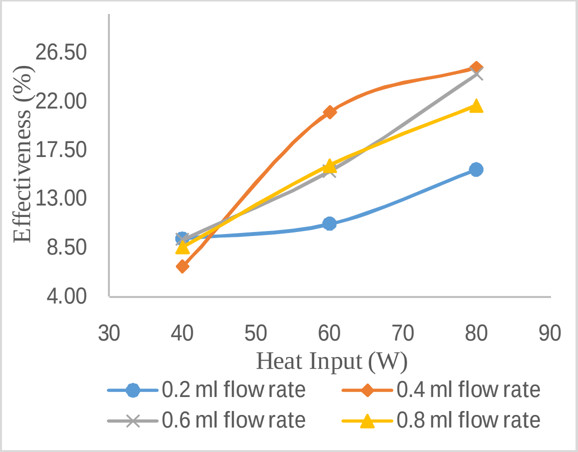

Figure.12 Effectiveness of Heat pipe with Hybrid Nano fluid of 15-degree inclination

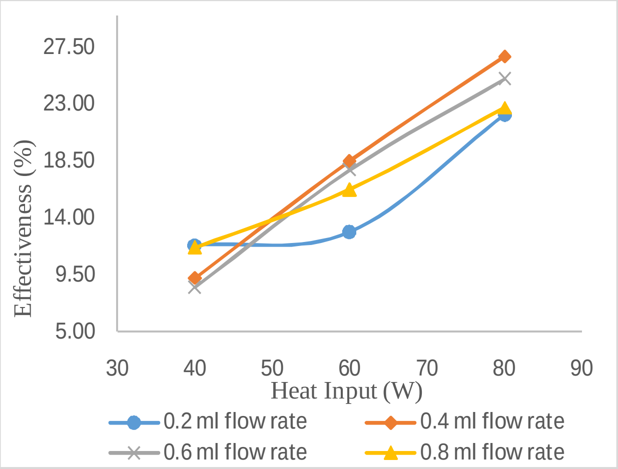

Figure.13 Effectiveness of Heat pipe with Hybrid Nano fluid of 30-degree inclination

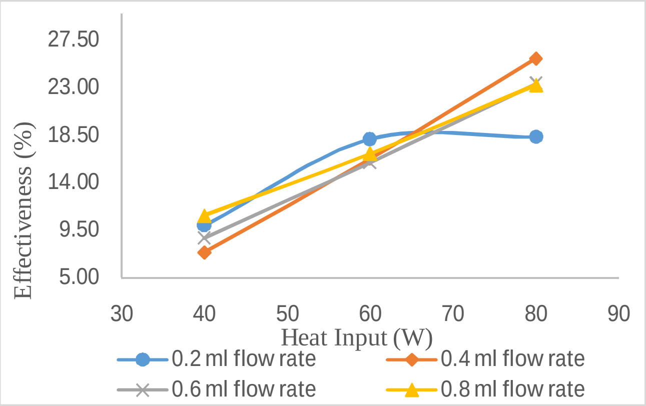

Figure.14 Effectiveness of Heat pipe with Hybrid Nano fluid of 45-degree inclination

Figure 7-14 This behaviour reduced the amount of heat transferred from the evaporator segment to the working fluid. Consequently, the volume of heat transfer from the operating fluid vapour transferred to the cold water in the condenser segment has also been decreased, leading to a decrease in the heat exchanger's effectiveness. For 0 and

100 mm adiabatic length the low mass rate showed higher effectiveness at all heat inputs whereas, at 200 mm adiabatic length, a higher mass rate showed higher effectiveness. Because the length of the heat pipe decreased in the evaporator section at an adiabatic length of 200 mm. This will increase the amount of heat transfer to the working fluid at a higher mass rate compared to a low mass rate. In 0° inclination, 80 Watts heat input was suddenly decreased in effectiveness at 0.2 ml flow rate because of condenser flow rate was low but the heat transfer operation take place in the horizontal of the heat pipe heat exchanger. In pipe two 45° inclination angle of 80-Watt heat input was better effectiveness at 0.2 ml flow rate. In pipe three 30° inclination angle of 80-Watt heat input is better effectiveness at 0.4 ml flow rate. The comparison of all three-heat pipes in the heat exchanger pipe 1 resulted in improved effectiveness.

4. CONCLUSIONS

The objective of this study is to explore the benefits of Nano hybrid fluids in the heat pipe heat exchanger. The major findings of this experimental work are summarized as follows:

In adiabatic length of 0 mm, 200 mm at 30° inclination, the heat pipe heat exchanger gives better effectiveness. Adiabatic length of 100 mm at 45° inclination delivered maximum effectiveness. When the adiabatic length increases, the heat transfer surface of the heat pipe decreases at the evaporator section, which lowered the effects of effectiveness.

In low flow rate the heat pipe heat exchanger gets is increased whereas in high flow rate of heat pipe heat exchanger is decreased in effectiveness. At all heat inputs the 0.4, 0.6 and 0.8 ml flow rate gives better effectiveness in all the combination of heat pipe exchanger. On 0.2 ml flow rate for all the combination of heat pipe heat exchanger the effectiveness was decreased only at 80 Watts heat input at 15 °and 45° inclination in 0 mm adiabatic length.

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