Effect of Titanium oxide nano-fluid with base fluid (R134a) on multi tube heat pipe heat exchanger

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Abstract. Heat pipes are traditionally used in exchange heat, because of higher effectiveness of miniature heat pipe, combined heat pipes are used as heat exchanger commercially. Titanium oxide nano-particles were used to enhance the effectiveness and overall performance in this experimental investigation. Nanofluid with refrigerant R134a is used as working fluid for heat pipe heat exchanger. Inside the heat pipe working fluid gets boiled, vaporised and condensed during heat exchanging process. In these process chances of forming of vapor bubble is high due to nucleate boiling. The study aims To reduce or eliminate the vapor forming process of R134a refrigerant by adding titanium oxide as nano particles. This nano particles of titanium oxide, thereby, reduces the formation vapour bubble and decreasing the thermal resistance of R134a refrigerant. From Experimental study it has been revealed that nano-particles also enhance the thermo-physical properties of the R134a refrigerant when compared with non-added nano-particles in R134a refrigerant.

Keywords *Nano particles, R134a, heat pipe heat exchanger(HPHE)*

1 INTRODUCTION

Heat pipe heat exchanger (HPHE) is two phase heat transfer devices which are broadly used for multiple application just because of their effective thermal conductivity. Heat Exchanger used with heat pipe can be categorized based on their structure and alignment of heat pipe[1]. The effective heat conductivity of HPHE is much better in comparison with metal due to their multi phase heat transfer mechanism. It consist number of tube with wire mesh inside the tube for smooth flow of working fluid. The tubes are arranged in zig zag manner with mesh fin due to zig zag pattern the contact of air to the pipe is more[2]. The construction of heat pipe heat exchanger have evaporator and condenser section, in addition adiabatic section can be exist in case required distance between condenser and evaporator section. The vapour of working fluid converts into liquid by heat dissipation in the condenser section. heat pipe exchanger is passive heat transfer unit so that pressure instability in tubes are the main reason of fluid motion. Several factor affect thermal performance of heat pipe heat exchanger such as inclination angle of heat pipe, numbers of heat pipe, geometry of heat pipe operating condition and working fluid. Fluid with unique thermo-physical properties such as high heat conductive and lower dynamic viscosity can perform better in HPHE [3]. To change thermo physical properties the heat pipe charged with adding nano particles on working fluid and introducing as a new working fluid [4]. Low dynamic viscosity allow to flow fluid smoothly in tube and high thermal conductivity enhance heat transfer of HPHE. Ther are various method to change thermo-physical properties of working fluid and obtain more appropriate working fluid such as nano-fluid and surfactants. Nanofluid have a base fluid and particles or sheets which are nano in scale. The particals is used in nanofluid may are basically made of metals oxide, carbon nano tubes are used, base fluid include DI water, ethylene glycol and alcohol [5]. adding nano particles to the base fluid mainly influence improve heat conductivity of fluid and heat transfer ability while adding surfactant to the base fluid maily for surface tension.

In this investigation effect of adding titanium oxide nano-particles with base fluid on HPHE as working fluid was conducted. Thermo-physical properties of nano fluid are experimentally investigated. Effect of nano-particles with different concentration i.e. .25, .5, 1 and 1.5 g/lit Tio_2 are measured.

2 Experimental setup

In order to investigate the thermal performance of Heat Exchanger, a setup has been designed with two duct for condenser and evaporator separately and four row of copper tubes are used 17 tubes are in each row. The schematic diagram of experimental setup is shown below in fig1. Refrigerant134a used as a base working fluid and titanium oxide, graphite and copper nano-particles are used as additive individually in all 68 heat pipe present in heat exchanger. While charging refrigerant in heat pipes were evacuated with a vacuum pump and maintain pressure inside the heat pipe approximately 40 Pascal in next step heat pipe filled with working fluid. The filling ratio in all test by considering of the total volume. In this paper performance of refrigerant 134a and titanium oxide nano particles were investigated. Wire meshed is used inside the full length of tube on the account of smooth flow of working fluid from condenser to evaporator section. Cotton and sponge were used in adiabatic section to prevent heat transfer from ambient to system and vise-versa. The duct were also insulated with foam sponge of 50 mm thickness to minimize the heat transfer to surrounding air, for controlling flow rate on both duct blower were used and flow rate of both duct were measured with pitot static tube. The ratio of flow rate is kept between 1.1-1.8 kg/m^3.

Fig 1 schamatic diagram of experimental setup

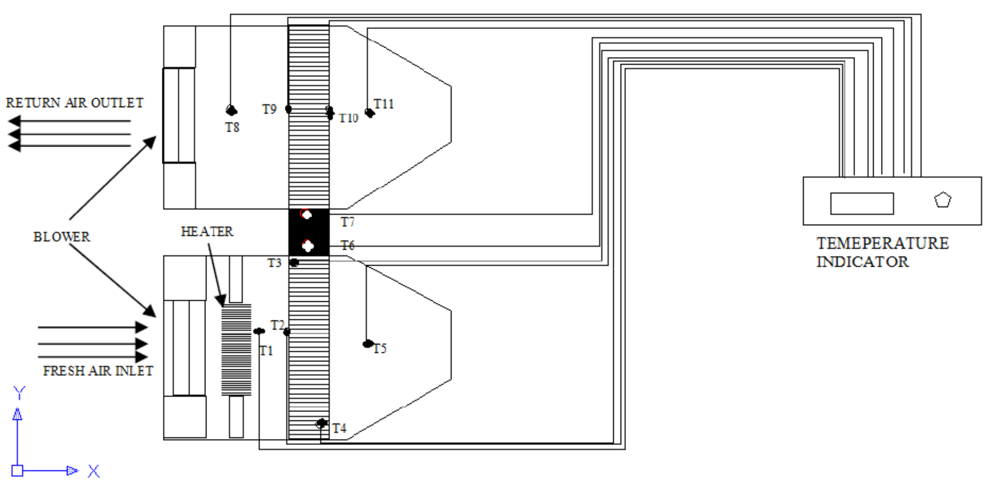

Fig 2 Line diagram of experimental setup

In order to achieved different heat input, electrical heater were used in evaporator section and for measuring condenser section temperature two thermocouple were used, all thermocouple were connected with temperature data logger device. The location of thermocouple are shown in line diagram fig 2 Total eleven number of K-type thermocouple were located in different section of HPHE.

3 Result and discussion

As discussed in introduction thermo physical properties like dynamic viscosity and thermal conductivity of fluid have specific role in performance of heat pipe heat exchanger. In this paper, effects of thermal conductivity, heat input and nano fluid concentration of Titanium oxide with base fluid 134a investigated experimentally. To evaluate the improving rate of Thermal performance Ɛ is defined as following equation

$$\mathcal{E} = \frac{T_{ei}-T_{eo}}{T_{ei}-T_{ri}} X100 \qquad (1)$$

Ɛ = Effectiveness of the system

T_{ei} and T_{eo} = The temperature of inlet and oulet of the evaporator section respectively and

T_{ri} = Temperature of return air

Figure 3 shows the effect of inlet temperature and titanium oxide nano particles to the overall effectiveness of heat exchanger. Fig clearly shows that while inlet increase then the effectiveness of the heat exchanger is gradually increase and less while concentration of titanium oxide concentration and inlet air flow rate is low.

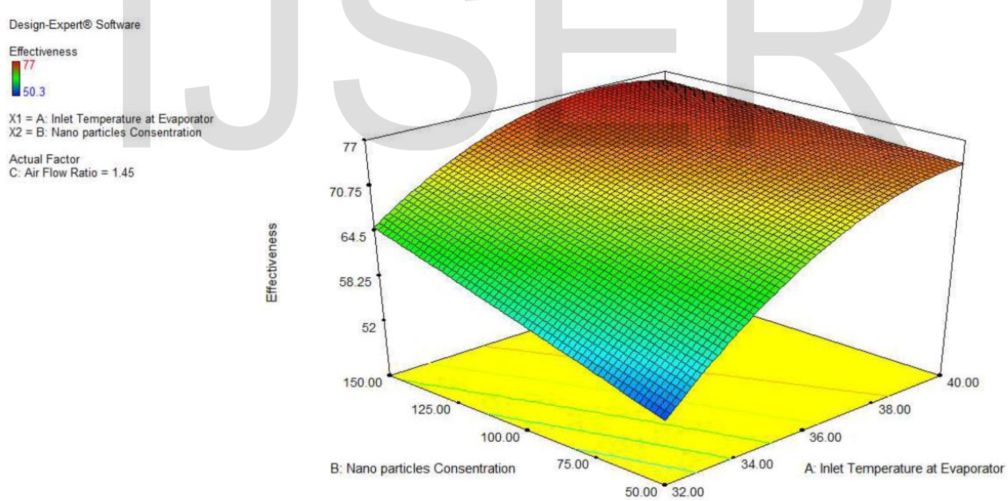

Fig 3 Effect of nano fluid concentration and inlet temperature to effectiveness

Figure 4 shows the change in effectiveness of air flow ratio which is controlled by mechanical blower and inlet temperature at evaporator section. The result found that while air flow ratio is high then the effectiveness of the working system is gradually increased. Both air flow and inlet temperature are equally contributed to increase the effectiveness of the system while alone air flow with minimum temperature shows not more effective.

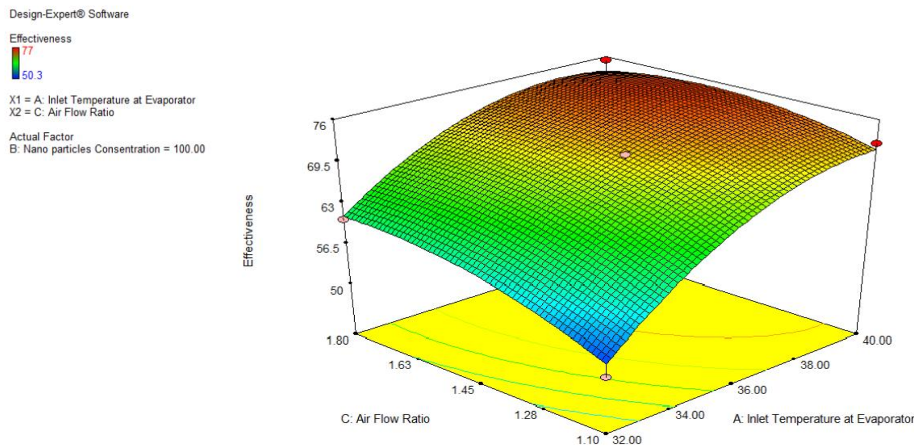

Fig 4 Effect of air flow and inlet temperature to the effectiveness

Figure 5 shows that the effect of rate of air flow ratio and contribution of titanium oxide nano particles concentration to the overall effectiveness of the HPHE. In figure green gradient shows low effectiveness when both air flow ratio and nano particles concentration is low and While rate of air flow and nanoparticles concentration is increase then the effectiveness of the heat exchanger in increase

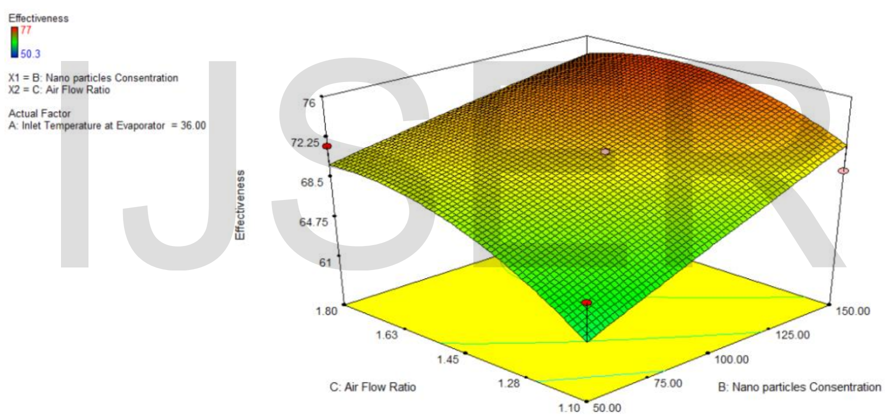

Fig 5 effect of nano particles and air flow to the effectiveness

The varying of effectiveness with respect to air flow ratio, nanofluid concentration and inlet temperature is just because of thermo physical properties thermal conductivity and dynamic viscosity of working fluid. Thermal conductivity of working fluid is ability to conduct heat through the heat pipe and it is depend on thermal resistance of the HPHE. Thermal resistance of the heat exchanger can be calculate by equation (2)

$$Rth = \frac{T_{ei} - T_{eo}}{Q_{evp}} \qquad (2)$$

Heat transfer at evaporator section can be calculated by using general equation for heat transfer which is mention bellow.

$$Q_{evp} = mC_p\Delta t \qquad (3)$$

Where m shows the mass flow ratio at evaporator section Cp is specific heat of air and Δt is temperature difference by shown in temperature indicator. Higher heat input facilitate boiling phenomena and higher air flow rate is use to increase the heat transfer by forced convection in the tube due to higher rate of heat transfer reduced thermal resistance of heat pipe.

3.1 Effect of nanofluid

A Nanofluid is a colloidal mixture it contain of nano scaled particles scatted in a base fluid with amended thermo-physical properties which play a critical role in the heat transfer performance of a heat pipe.

Effect of concentration or filling ratio

To determining the effect filling ratio by volume of working fluid nanofluid has been charged by .25, .5, 1 and 1.5 g/lit. means that as the volume fraction is increased nano particles concentration also increased simultaneously then the surface tension between the nanofluid will increased. As the concentration of nano particles increase in base fluid more nano particles are driven to the base fluid surface and particles will try to get closer to other particles, as a result more inter molecular cohesion force occurs between the molecule and resulting the surface tension of nanofluid will increase. Surface tension is generally known as force per unit area that is surface energy per unit length dominates the transportation of liquid ant it show a very significant in heat transfer.

Effect of size of nano particles

The size distribution of titanium oxide is shown in fig 6 the nano particles size is 30 nm. Apart from the volume concentration size of nano particles also influence in surface tension. Size of particles change the density of working fluid when density change the attraction between the nano fluid and base fluid molecule changes, thereby the van der waals force of liquid surface also were change and resultant variation of surface tension is there.

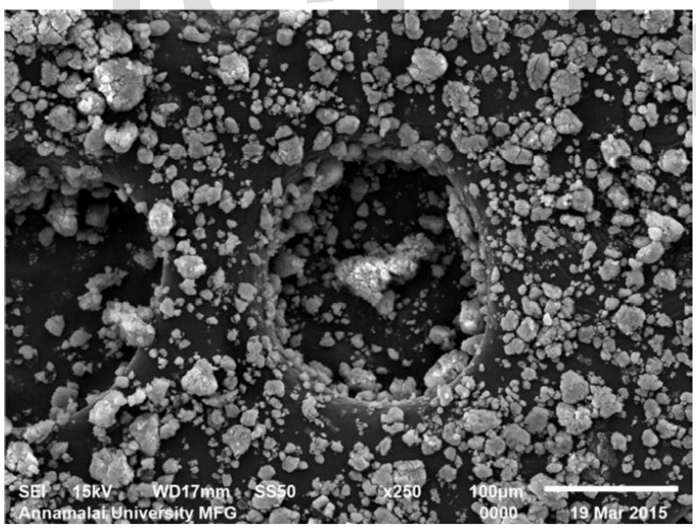

Fig 6 SME image of titanium oxide nano particles

Inside the heat pipe at evaporator section working fluid start to boiling and vapour bubble create inside the heat pipe due to vapour bubble create higher thermal resistance between working fluid and heat pipe wall. Nano particles are tends to use bombard that vapour bubble inside the heat pipe because of no formation bubble inside the pipe thermal resistance is reduced, for this investigation 30 nm TiO_2 particles are used less size of nanoparticles can be show more effective as compared to higher size.

4 Conclusion

In this study, effect of TiO_2 nano-fluid in thermal performance of a HPHE is investigated. Nanofluid in three concentration (50 mg/lit, 100mg/lit and 150mg/lit) were used as working fluid in HPHE. The filling ratio in all test was 25% of total volume is kept constant for HPHE. By adding TiO_2 to the base working fluid enhancement in thermal conductivity and dynamic viscosity of the working fluid was observed. In addition obtained result shows that by adding nano particles to the base fluid can lower the thermal resistance of the HPHE more than 45% at low heat input and low concentration of nano particles as compared to base fluid without adding nano-particles.

5 References

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