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EXPERIMENTAL ANALYSIS ON HEAT TRANSFER OF ABSORBER/RECEIVER OF PARABOLIC TROUGH COLLECTOR

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ABSTARCT:

This Study presents the improvements in Heat Transfer Performance of Absorber/Receiver of Parabolic Trough Collector. The Absorber is tested for Heat Input in four Steps which is Suitable for removing heat from Solar System, Process Industries, Power Plants, Automobile system etc. The effect of various Operational Limits and Test Parameters such as heat input, Volume fraction, Fluid Temperature, Heat transfer coefficient are Experimentally Investigated. The nanoparticle is tested for volume concentration experimentally with average diameter. The experimental results are evaluated in terms of performance matrices by direct measurements of fluid temperature and surface temperature in the absorber. A substantial reduction in thermal resistance is observed for concentration of nanoparticle. The Nussult Number for Absorber increases in comparison that with water.

Keywords: Heat Transfer, Twisted tape Inserts, Nanofliud, Absorber Performance.

1. INTRODUCTION

A method to enhance liquid thermal conductivity is the dispersion of highly conductive solid nanoparticle within the base fluid. This new generation of conductive fluid with nanoparticle is referred to as nanofliud. Taehyau Cho et.al [1] investigated thermal conductivity of fluid suspended with silver nanoparticle .The observations conclude an important in thermal conductivity by 10%,16% and 18% for concentration of 1000,5000and 10000 ppm. Paison Naphen et.al [2] experimentally investigated titanium nanofliud on heat pipe thermal efficiency .The heat pipe with de- ionized water ,alcohol and nanofliud (Alcohol and nanoparticle) are tested. The titanium nanoparticle with diameter of 21 nm are used in the present study. The effect of % charge of amount of working fluid ,heat pipe tilt angle and % nanoparticle volume concentration on thermal efficiency of heat pipe are concluded for the heat pipe with 0.1% nanoparticle volume concentration .The Thermal Efficiency is 10.60% higher than that with base fliud. Tsaisa et.al [3] investigated the influence of heat pipe.

This study is based on structural characteristics of Gold nanoparticle of various sizes dispersed in aqueous solution on heat pipe thermal resistance .The thermal resistance of heat pipe ranges from 0.17 to 0.215 ˚C/W with different nanoparticle solution. Furthermore the thermal resistance of heat pipe with nanoparticle solution is lower than that with DI water. King et.al [4] used dilute dispersion of silver nanoparticle in pure water as working fluid in a circular heat pipe. The diameter of nanoparticle used is 10 and 35 nm respectively. The results showed that the nanofliud as working fluid in heat pipe can transport heat up to 70 W and is higher than pure water by about 20W. Park et.al [5] and Shang Wen Kang et.al [6] also observed in another study that silver nanofliud grooved heat pipe thermal performance was higher than that for conventional grooved heat pipe water as working fluid. Zhan Hua Lin, Yan Li et.al [7] studied compositive effect of nanoparticle parameter on thermal performance of cylindrical micro grooved heat pipe using nanofliud. L Godson et.al [8] studied experimental investigation of thermal conductivity and viscosity of silver deionized water nanofliud.. .Lazarus Godson Asirvatham et.al [9] studied heat transfer performance of screen mesh wick heat pipe using silver water nanofliud.Pak et.al [10] studied hydrodynamic and heat transfer of dispersed fluid with sub micron metallic oxide particle. K.S.Reddy and K.Ravikumar [11] studied numerical simulation of energy efficient receiver for parabolic trough collector. Balbir Singh [12] had studied simulation of convective heat transfer coefficient in receiver tube of parabolic trough collector. It is found from above mentioned literature that all the researcher have observed on enhancement in thermal performance using nanofliud. It is obvious from above literature review that case of forced convective heat transfer in absorber utilizing nanofliud under uniform heat flux boundary condition seems not to have been investigated in past .

2. EXPERIMENTAL ANALYSIS

2.1 Experimental Arrangement

The schematic layout of test facility to measure effect of nanoparticle concentration on the performance of absorber is shown in fig.3. In the present Research work the solar parabolic trough collector receiver tube with heat transfer fluids for various geometries (with and without inserts) is analyzed and compared with experimental results. Experimental set up consists of a test section, pump and flow meter to circulate fluid at constant flow rate through test section, heating arrangement. The temperatures of fluid circulating through test section are recorded by two k-type thermocouple fixed at inlet and outlet of absorber. A total eight thermocouple sensor (with K-type thermocouple) are fixed on test section these thermocouple directly measure fluid and wall (surface) temperature. The heat input to absorber is applied using a Wattmeter connected to an electrical heater. A 230 V AC supply is used to energies the heater. The test section of absorber is completely insulated using asbestos tape to minimize heat losses. The insulating material also helps to reduce radial losses The temperature reading of test section are recorded by connecting thermocouple of test section to data logger or temperature indicator .The entire data acquisition system is monitored and controlled by a P.C. or laptop. The plain absorber/receiver (test section) is made up of copper.The twisted tape tapes are in turn inserted into the plain absorber/receiver. A band heater is used as electrical heater which is wounded over plain absorber/receiver.

2.2 Preparation of nanofliud

Several studies, including the earliest investigations of nanofluids, used a two-step method in which nanoparticles are first produced as a dry powder and then dispersed into a fluid in a second processing step. In contrast, the one-step method entails the synthesis of nanoparticles directly in the heat transfer fluid. The two-step and one-step methods are discussed in more detail in further subsection 2.2.1 and 2.2.2.

2.2.1 Two Step Method

A two step method is used to prepare Nanofluid. Nanoparticle are mixed with De-ionized water without addition of any surfactant [9]. The size of nanoparticle is measured using the particle size analyzer and shown in fig 1 and fig 2. It is clearly observed from fig 2 that the majority of nanoparticle has average size of 10nm- 400 nm and it is also seen from peak in fig 2. This justifies the average size of nanoparticle used for the present study.

2.2.2 One Step Method

In present work, The Method selected for synthesis of nano-particles is as follows:

The nanoparticle colloidal was prepared by using chemical reduction method according to the description of Lee and Meisel. All solutions of reacting materials were prepared in distilled water. During this process the solution was mixed vigorously. Solution was heated until color change is observed .Then it was removed from the heating element and stirred until cooled to room temperature.

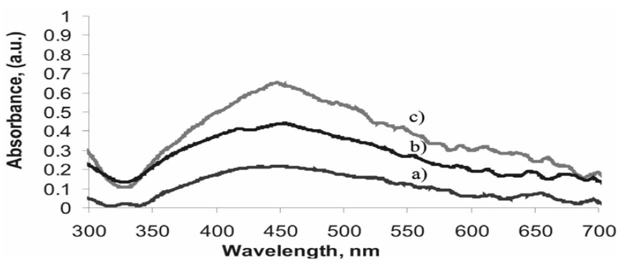

Fig. 1: Absorption Spectrum for Nanofluid

2.3 Experimental Approach

The experimental arrangement (installation) consist of the testing receiver/absorber, Heat transfer fluid tank, pump, heater, temperature control system, data acquisition systems, valves, pipes etc. The heat transfer fluids (water and Nanofliud) are pumped through the flow meter into receiver /absorber and continued to be heated to the required experimental temperature. The receiver is heated by electrical heater. The heat flux on testing receiver/absorber can be changed to the required value by changing the output of electrical heater. The Experimental setup is as shown in fig 3. The analysis of Nu vs. Re, and other parameter for experimental data is carried out .As per experimental data a generalized correlation function for convective heat transfer and friction factor is investigated. The experimental procedure is as follows: At first the fluid pump is switched on and fluid is allowed to flow for few minutes. Then the electrical heater is switched on and allowed to heat for few minutes. The electrical power is adjusted with the help of Dimmer stat to the required value (uniform value). The flow rate of fluid through the test section is set to desired value and kept constant with the help of flow control valve. First the variations in wall temperature at all location are observed until constant value is attained at all eight locations. Then the outlet bulk temperature of fluid is monitored. The steady state condition is attained when outlet fluid temperature did not fluctuate over some duration of time. At the steady state condition thermocouple readings are monitored with help of selector switch/data logger and then recorded. The manometer reading are observed and taken from digital micro manometer. The fluid flow rate is changed with the help of flow control valve after each experimental run, hence changed the Reynolds number. Electrical power supply is kept constant/uniform for change of fluid flow rate. Different data are taken in similar way in each experimental run at steady state condition.

2.4 Uncertainty Analysis

A detailed systematic error analysis is made to estimate the error associated with experimentation by Beckwith .The uncertainties of Nussult number, Convective heat transfer coefficient and heat rate are ± 10 %, ± 10 %, and ± 11 % respectively.

3. RESULTS AND DISCUSSION

The experiments are conducted for various heat loads with absorber in horizontal position .The surface and fluid temperature using thermocouple connected to data logger system. The experimental results are compared between base fluid and nanofliud for all concentration and the enhancement in heat transfer performance with respect to concentration, heat load, and thermo physical properties etc are discussed in following subsection. Many day to day experiments have been conducted with base fluid to check the repeatability in the experimental reading and found that the deviation between day 1 and day 2 reading .It is found that at low heat load, the Nussult number ratio of absorber is more. The reason is that the temperature difference (ΔT) between the wall surface and fluid in absorber is high at low load and the temperature difference fluid and wall surface is less. This increases the heat transfer coefficient in the absorber which is directly proportional to the Nussult number ratio at the load. Fig 4 shows that the convective heat transfer coefficient is a function of heat flux. The convective heat transfer coefficient is low. The reason is that the temperature difference (ΔT) between wall surface and fluid in absorber is low at low heat flux As the heat flux increases, ΔT increases .This increases heat transfer coefficient. A similar trend of result has also been observed and reported in published literature [7]. Meantime an average enhancement of the convective heat transfer coefficient is also quite similar for the same nanofliud. On the other hand ,the convective heat transfer curve has similar trend for both water and nanofliud at the present operating pressure condition that describe actually a heat transfer characteristics of the convective mode. The main reason for the enhancement of heat transfer coefficient of nanofliud based absorber are:(i) The highly conductive nanoparticle in base fluid will increase effective thermal conductivity of nanofliud.(ii)During absorber operation, the working fluid travels through twisted tape inserts and the nanoparticle present in it forms a coating layer on inserts and on the heating surface. This enhances the heat transfer effect of absorber. (iii) The random motion (Brownian motion) of nanoparticle in base fluid causes the particle to collide with each other and with particle of DI water. This will enhance the heat transfer effect by convection. This Brownian motion is significant at higher temperature. The effect of using twisted tape inserts in absorber /receiver on heat transfer characteristics is shown in fig 5, fig 6 and fig 7 .It shows that the Nussult Number obtained from absorber with inserts is higher than plain absorber. It is depicted that the effect of tape inserts increased at high Reynolds Number due to the intensive mixing of fluid which increased the heat transfer rate and high flow velocity. Thus the increase in Nussult number is low at smaller Reynolds Number while it became greater at the higher Reynolds Number. It could be attributed that the tape inserts caused swirl flow or secondary flow and pressure gradient being created along the radial direction. The heat transfer rate is also changed with the helix angle of the tape inserts. It is higher with minimum helix angle. The experimental data for comparison of Nussult Number and friction factor are not available in literature for nanofliud with twisted tape inserts. Hence, the present data for flow of water and Nanofliud in absorber and with twisted tape inserts is subjected to regression and the correlation function is obtained.

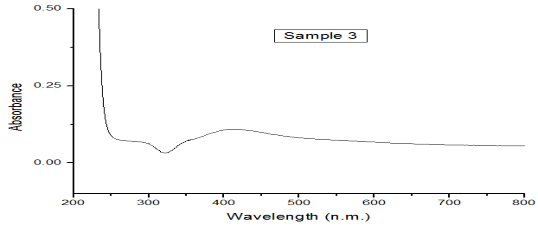

Fig. 2: Absorption Spectrum for Nanofluid[sample3]

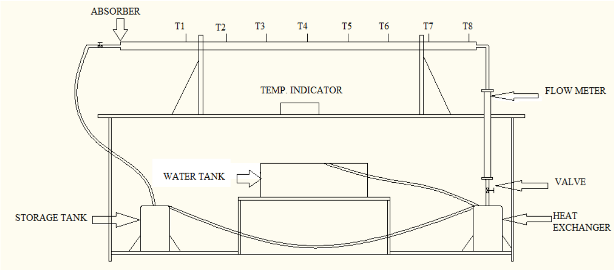

Fig. 3: Experimental arrangement

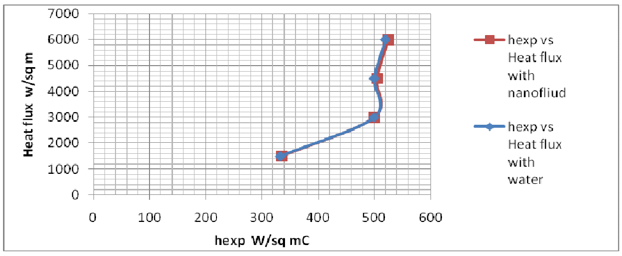

Fig. 4: Heat Flux Vs hexep

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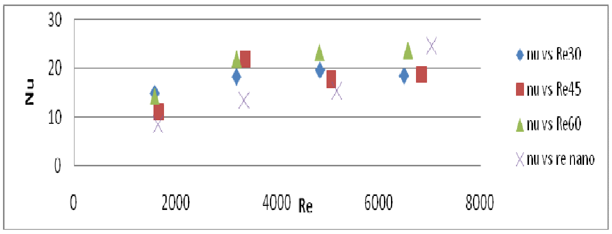

Fig. 5: Re Vs Nu

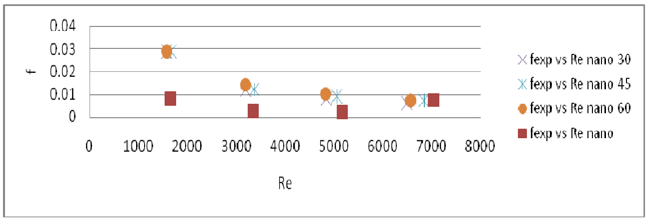

Fig. 6: Re Vs f

3.1. Experimental Analysis

We have investigated the influence of heat transfer fluid properties, receiver geometries (with and without inserts) and (heat flux) on overall heat collection. We have examined the influence of various geometrical parameters for heat flux condition with working fluids (water and Nanofliud) and analyzed with experimental results. The balance between energy supplied by heating and energy absorbed by the flowing fluid is established using equation and for every set of data and experimental heat transfer coefficient is estimated. The experimental Nussult number of fully developed laminar flow and turbulent with water and nanofliud are investigated. The reason for heat transfer enhancement is the effect of thermo physical properties comparatively are greater for Nanofliud . Experiments with twisted tape inserts are conducted with water and nanofliud following the similar procedure for the flow in plain absorber without tape insets. The experimental Nussult number of water for flow in an absorber/receiver is presented in fig 5. However no literature is available for comparison with Silver nanofliud .From fig 5 it can be observed that higher heat transfer rate are obtained with twisted tape inserts than plain absorber/receiver. A generalized regression equation is developed for estimation of Nussult number and friction factor of water and Nanofliud under fully developed flow condition.

4. CONCLUSION

It is observed that convective heat transfer coefficient increase with increase in concentration of nanoparticle. An experimental study is conducted to investigate heat transfer enhancement in an absorber by means of twisted tape inserts. The study reveals that tape inserts caused an increase of heat transfer at the cost of increase of pumping power. From the experimental results the following could be concluded:

i) The Nussult Number for absorber with tape inserts increases in comparison that of plain absorber.

ii) There is no significant increase in pressure drop or friction factor for Nanofliud in comparison to water at the same twist ratio.

iii) *A substantial reduction in thermal resistance is observed for concentration of nanoparticle*

5. ACKNOWLEDGMENT

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