Comparison of Performance of Parabolic Trough Solar Collector (PTSC) using Water and Nanofluid (TiO_2 + Water)

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Abstract

Parabolic trough solar concentrating collector system has proficient usage in all solar applications such as power generation, steam, heating of water, air heating etc. This thesis work is conceded for the study of Nano fluids which are emergent fluid that has shown the development in the thermal properties over the past decade. Nano fluids had made great potential in the field of nanotechnology for the thermal engineers. The present work deals with the investigation into the effects of variation of titanium oxide nanoparticles concentration on the efficiency of a nanofluid based parabolic trough solar collector with the use of high reflective mirror trough. Nanofluids are the mixture of mainly the base fluid with the nanoparticles of the size micro or millimeter and shows characteristic features than that of conservative fluids used. At 110lph mass flow rate the percentage change in overall thermal efficiency was found to be 59.17% at 0.1% of TiO_2 nanoparticles and at 160lph mass flow rate the percentage change in overall thermal efficiency was found to be 41.06% at 0.1% of TiO_2 nanoparticles in comparison to the water.

Keywords: *PTSC, Nanofluid, TiO_2 + Water, Solar collectors, etc.*

1. Introduction

With over utilization of fossil fuels, every day we are edging closer to onlooker the destruction of natural resources which can grounds inequity in nature. Non-conventional energy ascertained minority in this situation of energy disaster. Sources like, solar, wind, hydro powers are profuse in nature and can be coupled to any extent. Among those many thoughts sun is most abundant and significant source of renewable energy. The use of solar energy is safer to the environment and living beings. A Solar energy collector is the heat-exchanging system that consumes solar radiation energy to produce thermal energy. The essential utility of a solar collector is to charm the solar radiation that transforms it into heat and handovers this heat to the functioning fluid circulating right through the whole system.

1.1 Solar Energy Collectors: - There are two types of solar energy collectors available. These are as follows:-

- **Non-Concentrating type Collector: -** The non-concentrating type collector area has the same area as absorber area. They are constrained for low temperature applications (<120^0C).
- **Concentrating type Collector: -** A concentrating type collector is a collector in which the region of the intercepting solar radiations is larger than that of absorber region. Concentrations can be accomplished by the optical device such as mirror or lens, through the reflection or refraction of solar radiation. The different type of concentrating collectors are as follows: -
  1) **Parabolic trough solar collector: -** A parabolic trough solar collector procedures a reflector in the shape of a parabola which is typically a mirror or an anodized aluminium sheet provisional on the prerequisite presentations to reflect and concentrate the solar radiations in the direction of a receiver tube positioned at the focus line of the parabola. The absorber tube may be made of copper or mild steel and also smeared with the heat resilient

black paint for the better presentation. The receiver engrosses the entering radiations and changes them into thermal energy, which is being conveyed and collected by a fluid medium flowing within the receiver tube. The heat transport fluid flows throughout the absorber tube, gets heated and hence transmits heat. This type of collectors can attain the temperature till 400°C.

2) **Parabolic Dish Collector:** This type of collectors can attain the temperature till 1500°C. They utilize parabolic dish shaped mirrors to concentrate solar energy onto a receiver located at the common focal point of the mirrors. Heat transfer fluid contained in the receiver is then heated up to the desirable working temperature in order to generate electricity in a small engine attached to the receiver or is sent to the storage system. They track the sun on two axes.
3) **Linear Fresnel Reflectors:** LFR consists of long flat mirrors mounted on one or two-axis tracking devices. A receiver is mounted on the focus to collect the heat. It is an array of linear mirror strips which concentrate light on to a fixed receiver mounted on a linear tower.
4) **Heliostat field collectors:** The Heliostat Field Collector, also called the Central Receiver Collector, consists of a large array of flat mirrors/heliostats to reflect incident solar radiations onto the central receiving unit (solar tower). The orientation of every individual heliostat is controlled by an automatic control system powered by alt-azimuth tracking technology.

1.2 Advantages of concentrating collectors:

- ➢ Simple in design and reflecting surfaces require less material, thus declining the cost per unit area of the solar collecting surface.
- ➢ Due to the moderately small area of the receiver, heat losses are less, thus increasing the thermal efficiency.
- ➢ Higher thermodynamic efficiency can be attained as heat transfer fluid can reach to higher temperature in a concentrating surface as compared to flat plate collector.
- ➢ Since higher temperature can be attained with concentrating solar collector, the quantity of heat which can be stored per unit volume is larger; consequently the cost of heat storage is less as compared to non-concentrated collectors.
- ➢ Careful surface treatment and vacuum insulation are done to reduce the heat losses, thus increasing the collector efficiency.

1.3 Nanofluid and its applications

Nanofluids are the mixture of nanoparticles and base fluid, which is a new challenge in the field of thermal engineering provided by the nanotechnology. Nanofluids have the distinctive characteristics altered from conservative solid-liquid mixtures in which they are in millimeter or micrometers sized particles of metals and non-metals are scattered onto it. Due to their excellent characteristic nanofluids had discovered extensive applications in enhancing heat transfer. The knowledge behind the improvement of nanofluids is using the thermo fluids in heat exchangers for the enrichment of heat transfer coefficient. And also to minimizes the dimension of heat transfer equipment's. Nanofluids assist for saving of heat energy and material required for the heat exchanger. The essential parameters which have been influencing the heat transfer with its characteristics of nanofluids are the properties which consist of viscosity, density, thermal conductivity and specific heat. The thermo substantial properties of nanofluids is mainly depend on the working temperature of nanofluids.

Application of nanofluids are described as follows:-

- ➢ A broad diversity of industrial processes involves the transmission of heat energy from one medium to other. Throughout processes, the heat should be there to add, removed, or moved from one route stream to other route stream and it have turn out to be a major trade for industrial necessitate. These procedures had been set to give a source for energy for the improvement and development fluid for cooling or heating.
- ➢ The growth of heating as well as cooling inside an industrial process might generate for saving the energy, which reduces the process time, increase in thermal appraisal and acquire longer the life of the working apparatus.
- ➢ Conveniently, there are numerous methods to improve the efficiency of heat transport. Few methods are as follows the relevance of trembling to the heat transfer surfaces, uses

of extended surfaces, and managing of micro channels. With the increase in thermal conductivity there will be enhancement in the heat transport efficiency.

- Heat transfer fluids usually used oil, water, and ethylene glycol which have comparatively less thermal conductivities, as soon as they are been compare to the thermal conductivity of solids. The solids are having elevated thermal conductivity and be capable of increase in the thermal conductivity of a fluid by adding up little amount of solid particles to that fluid.
- Though, there are certain other applications be fond of microprocessors, in laptops for the electronic cooling, engines being cooled in automobiles, cooling in space applications, cooling in electronics power which have been used in the military devices, miniature type heat transport systems has been required. These applications include a fundamental connection among the dimension of a mechanical system and cost which is being associated with the operation along with manufacturing cost and various other factors.

2. Literature Review

Tyagi et al. (2009) presents theoretical investigation of non-concentrating direct absorption solar collector and compare the performance with flat plate collector. Aluminum nanoparticle with water based nanofluid is used as an absorbing medium. They observed that presence of nanoparticle increases the absorption of incident radiation by nine times than that of pure water. Results show that efficiency of direct absorption solar collector found to be 10% higher than that of flat plate solar collector.

Giorgio Cau et al. (2014) described medium sized concentrating solar power (CSP) plants comparison based on parabolic and linear collectors. It was concluded that the performance assessment of concentrating solar power plants based on linear Fresnel collector lead to higher values of electrical energy production per unit area of land. It was observed that the highest specific energy production was 55-60 kWh/y per m^2 square land occupied with solar multiples in range of 1.74-2.5 in 4-12 hours. . It was also observed that increase in solar multiple enhance the thermal energy output of solar field with required collecting and land area as well.

P.K.Nagarajan et al. (2014) described Nano fluid application in solar collectors. He investigated his report on parabolic trough solar collectors. It was revealed that Nano fluids used in the solar collectors enhance the effectiveness of the solar system. It was studied that use of Nano fluids in the solar collectors encountered limitations such as particle agglomeration, erosion, stability, corrosion of heat transfer equipment's. It was also observed that the volume concentration and particle size play vital role in the effectiveness determination.

R.Dharmalingam et al. (2014) described Nano fluids as an innovative technology for heat transfer enhancement. It summarized the heat transfer in Nano fluids. It was revealed that these particles improved the thermal conductivity and convective heat transmission of liquids assorted with base fluids. It was examined that there was a disturbance in path and pressure drop in fluid with respect to the sedimentation, excessive wear and clogging by Nano particles. It was observed that with increase in temperature the dynamic viscosity decreases. Due to this thermal conductivity of Nano fluids found to be higher. Here due to solar energy unsteady state flow was studied which was found to be dependent on angle of inclination of porous wedge. The temperature absorption was found more with high density of Nano fluid in comparison with water. It was revealed that with decrease in fluid flow velocity with increase of unsteady parameter.

Mosavian et al. (2010) described about the heat transport enhancement by means of nano-powder. Altered nanofluids including Al_2O_3 (20 nm), CuO (50 nm), and Cu (25 nm) nanoparticles in water was considered in their work and has been conducted in the course of laminar flow with heat transfer development through the circular tube. They specified their results to identify the enhancement of heat transfer with the increase in concentration of nanoparticle. They had taken the optimum concentration value of Cu nanoparticles to be 2% of volume fraction and the other nanoparticles Al_2O_3 and CuO as 2.5% of volume fraction. The results came out from their experimental work shows that the metallic nanoparticles has improved enhancement with the heat transport coefficient as compare to that of the oxide particles. The nanofluids have better convective heat transfer coefficient not because of the increment in the increase of thermal conductivity other rheological properties such as viscosity has been increased with the concentration of particle.

Khullar and Tyagi (2010) carried out theoretical & numerical investigation regarding the use of nanofluids as operational fluids in parabolic trough collector devices of concentrating type. In this paper mathematical modelling of heat transfer and flow aspects of the linear parabolic solar collectors had been done. Al nanoparticles were suspended in water and utilized as an operational nanofluid and to solve several equations numerically FDM (finite difference method) technique has been used. Evaluation and comparison of the two dimensional temperature field, optical and thermal efficiencies, and mean-outlet temperatures had been done for both conventional parabolic collectors utilizing water as a working fluid and nanofluid based collectors utilizing nanofluid as an operational fluid. In order to achieve the desired output temperature, the effect of various operating parameters such as receiver length, concentration ratio, fluid velocity, volume fraction of nanoparticles taken into consideration. The results indicated that in terms of thermal and optical efficiencies and higher outlet temperatures under same working conditions the collector using nanofluid as a working fluid has a better performance as compare to the conventional collector. The results also showed that the addition of aluminium nanoparticles into the base fluid (water) significantly improves its absorption characteristics.

Wisut Chamsa-ard et al. (2014) described thermal performance testing of heat pipe evacuated tube with compound parabolic concentrating (CPC) collector. Its purpose was to design, fabricate, test thermal efficiency of heat pipe evacuated tube. It major advantage was that it can work without changing direction of CPC to track the sun. A mathematical model was developed for determining energy production base on radiation and ambient temperature data. It was experienced that the monthly average energy of CPC produced throughout the year was 286.16kWh or 3433.87kWh/year. The basic aim after this research was to improve the thermal performance of heat pipe evacuated tube solar collector. The experiment was conducted with three different evacuated tube solar hot water systems. It was concluded that evacuated tube solar hot water systems with 7.76cm height of CPC had best energy production which rise up water temperature from 30 to 51.9 degrees. The thermal efficiency of heat loss coefficients of CPC were measured 78%, 3.55 and 0.0600 W/m^2-^{0}C.

R.D.Jilte et al. (2014) investigated on convective heat losses from solar cavities under wind conditions. The different shapes used were conical, cylindrical, cone-cylindrical, dome-cylindrical and hetero-conical. The study was taken under three isothermal temperature conditions of 523, 723 and 923K and five inclinations of 0, 30, 45, 60, 90degree. Three wind directions such as face-to-face, side-on, back-on was deliberated. It was concluded that convective losses occurring under wind and no wind conditions provide minimum value of 0 degree and convective heat loss under wind condition was higher than no-wind condition. It was resulted that lowest convective losses all shapes were in conical shapes and convective losses went on decreasing with mouth blockage. The generalized Nusselt number was proposed on the basis of convective heat losses data from different profiles and proportions with or without obstruction under face-to-face wind circumstances.

Alhassan Salami Tijani et al. (2014) described the simulation analysis of solar thermal losses of parabolic solar trough collectors in Malaysia using computational fluid dynamics (CFD). This paper simulated heat losses which were associated with heat collection element of solar parabolic trough collector, effect of different wind speeds and mass flow rate of heat transfer fluid. Some assumptions were made to ease the simulation like solar radiation profile was assumed to be unvarying and emission flux was treated as heat flux wall boundary condition for absorber conduit. Surface to surface model was taken for radiation exchange in enclosure of grey diffused surfaces. It provided low temperature of glass envelope in comparison to absorber temperature. The convection and radiation heat losses were examined using resulting temperature of glass envelope from the model.

Rosnani Affandi et al. (2015) described the effect of solar irradiation, collector and the receiver to the receiver losses in parabolic dish system. It was revealed that the parabolic dish with 31.25% conversion efficiency has highest efficiency and is more reliable. It was observed that variation on irradiation at the particular location, reflective material and intercept factors effect heat transfer rate and solar power. Reflective surfaces used were of aluminium and silver material. The data used for observation was taken from Meteonorm 7 Software. It was observed from the imitation outcomes that by diminishing the divert factor, the fraction of solar power incoming the receiver will be diminished. This was resulted in reduction in the solar irradiation transmitted from concentrator to receiver.

Wang et al. (2007) presented the review related to the description of heat transfer in Nano fluid. The convective heat transfer can be progress inertly by the alteration in the thermal conductivity, change in the shape and boundary conditions. They mainly focus on the preparation of Nano fluids because it is the initial step for any experimental study. There must be some important requirement in preparation of Nano fluids are negligible agglomeration, stability, no compound alteration in fluids, durability of suspensions. They had summarizes different method used by the different researchers in their experimental work. The parameters associated with the heat transfer generally thermal conductivity, viscosity, convective heat transfer, boiling heat transfer of the Nano fluid with their measurement had been discussed in their work. Different analytical models and numerical investigation done by the researcher has been summarized by him. They plotted graph which compares the theoretical model versus the experimental data been generated for the thermal conductivity of Al_2O_3 with water as Nano fluids. Their research investigations were mainly resolute on the current conductivity reasonably than on the heat relocation feature.

Murshed et al. (2008) study the viscosity and thermal conductivity of nanofluids. They had investigated both theoretical and experimental studies on the nanofluids about their properties of thermal conductivity and viscosity. For the measurement of thermal conductivity of nanofluids transient hot wire method is used by them with the temperature ranging from 20^0c to 60^0C. The volume fraction is taken from ranging 1% to 5%. Titanium oxide and aluminium oxide nanoparticles with ethylene glycol and deionized water as base fluids are used by them. For the dispersion and stability of nanoparticles with base fluids acetyl trimethyl ammonium bromide surfactant is used. Results were compared with the existing model given by the different researchers and found that increase in the thermal conductivity with the particle volume concentrations. Different graphs demonstrated the results and a linear increase in the effective thermal conductivity with the temperatures. Measurement error was to be within 2% by the calibration due to transient hot wire method used.

Yaghoubi et al. (2013) describes the analysis of heat losses occur in the absorber tube of parabolic trough collector in Shiraz (Iran) solar power plant. Both numerical modeling and experimentation were made for the heat collecting tubes. They observe that heat loss in lost vacuum tube is 40% higher than that of vacuum jacket tube which reduces the collector performance and numerically the performance of broken glass tube reduces by 12-16 %.

Rongrong et al. (2013) analyzed the solar parabolic trough system using thermal oil as the working fluid. They had made the dynamic model and validate the result with real operating conditions in summer and spring days through the references. Analyzes was done through alterations characteristics including different solar radiation, flow rate, collector area and inlet temperature. Results demonstrate to forecast the performance of parabolic trough solar collector in unique working conditions.

S. Chougule, S. K. Sahu (2014) described the thermal performance of nanofluid multi walled carbon nanotubes with water on the charged heat pipe using phase change material as an energy storage material for the purpose of electronics cooling. They had uses water and paraffin (is used PCM) as an Energy storage material. They evaluate their performance on the flat heated pipe with the different concentration of weight carbon nanotubes of 1%, 2% and 3% weight. The operating power supplied was 10W, 20W and 30W with the fan voltage of 3.15 volt and 5.8 volt. The nanofluids with charged heat pipe increases the thermal performance as compared to the water heat charged pipe cooling unit. With the increase in the CNT nanoparticles fraction with water there is increase in the thermal performance of the heat pipe. They demonstrated the heat pipe with paraffin reduces the power consumption by the 66% as compared to the heat pipe using water. The 2% weight fraction shows highest thermal performance in the heat pipe with the paraffin and nanofluids as an energy storage material. The transfer of heat rate mainly depends on the factors mass of the PCM, heater temperature provided and voltage of fan across it.

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Tayade et al. (2015) concerned their work on the manufacturing and design of parabolic trough solar collector with the use of aluminium sheet as a reflector in parabolic shape and aluminium tube as a receiver with glass cover mounted on it. Storage tank of 40 liter capacity with GI sheet material and foam is stick outside the storage tank which act as an insulator has been placed above the level of collector so that the natural flow of fluid takes place. The fluid used in their work is water. The performance of the system has been done during winter in November and December at Chandrapur. It had been found that PTSC is better option for the winter seasons due to the minimum maintenance cost, no running cost, labor cost is minimum and it's economical for all.

T. Coumaressin, K. Palaniradja (2014) uses the nano fluid for analysis of the Refrigeration system. The equipment used for refrigeration process are compressor, condenser, expansion valve, evaporator, capillary tube, and refrigerant R-134a and solenoid valve. The observation has been made by the refrigeration test rig with the pressure drop, temperature and mass of water through the solenoid valve and capillary tube. COP has also calculated across it and to improve the heat transfer coefficient across the evaporator they use CuO nanoparticles. The properties of nanofluids are viscosity, thermal conductivity, density and the specific heat has been calculated by the use of FLUENT software. The results came out in the form of graph between the concentration and the evaporator heat transfer coefficient with the different values of heat flux vary from 10KW to 40KW.

3. Research Methodology

3.1 Working principle of PTSC: - It is having a reflector of parabolic shape to replicate the direct solar radiation and focused them on top of the focal line of the parabola. A receiver tube is employed on this focal axis, to absorb the focused solar radiation flux. It is prepared with stainless steel, iron or copper and coated with a careful coating on the outside surface. The coating is having a high absorption power for entering radiations but low emitting power for the infrared radiations in the solar energy spectrum to decrease the thermal radiation losses. Inside the receiver tube, heat transfer fluid (HTF) flows which is nanofluid here in this study, takes up the focused radiation which drops on the tube and changes the solar radiation into thermal energy. Receiver tube is surrounded by a Pyrex glass cover to decrease the thermal losses to the surroundings. The space between the glass cover and the tube is evacuated to sustain the vacuum which is having low thermal conductivity and high viscosity as heat transfer takes place through radiation in this region. Titanium oxide + water nanofluid was used as the working fluid in different concentrations with the different mass flow rates. The experiment comprises of circulating nanofluid from the storage tank through the collector inlet to the receiver tube, where it catches the heat and then streams back to the storage tank. A pump is used for circulation of the working fluid in the system. Two digital thermometers are used on the inlet and outlet separately to measure the increase in the temperature. By the use of solar power meter and anemometer, solar intensity and wind speed repetitively measured during the experiment. The PTSC is slanted in south-east direction to track the sun. The experiment is performed by taking altered mass flow rates and changing concentrations of nanofluids.

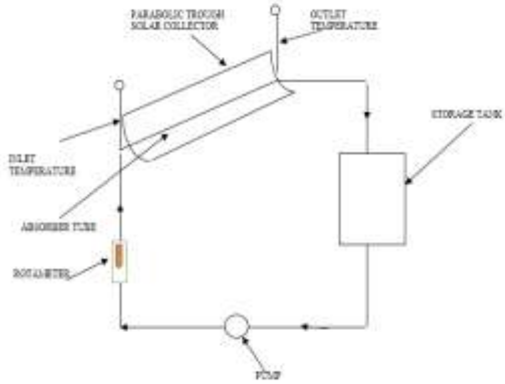

Fig. 3.1 Flow Diagram of a Parabolic Trough Solar Collector

3.2 Various measuring instruments and devices used: -

There are some instruments and devices which are utilized to measure the temperature of the working fluid and the extent of solar intensity. These instruments and devices are as follows:

1) **Solar power meter:** this is a device which is utilized to measure the solar intensity of rays coming from the sun. It consists of a sensing knob to sense the solar radiation. It is having a digital display which displays the solar intensity in W/M^2. The calibration of the device is done by using the linear algebraic equation:-

$$Y= 0.745X + 1.839$$

2) **Temperature measuring devices:** Mainly, digital thermometers are used as the temperature measuring devices. These devices measure the temperature in the ^{0}C. Two individual thermometers are required to measure the temperature at inlet and outlet of the absorber tube. These are used

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to measure temperature in range of -50 to $+200^0$C.

3) **Anemometer:** Anemometer is utilized to measure the wind speed. It is having a minor fan and a sensor. The fan revolves on setting it in the way of wind flow; the sensor senses it and shows the value on the screen. In our experiment, wind speed was taken from the online weather information.

4) **Rotameter:** It is used to measure mass flow rate. In the experimental setup used here the glass tube rotameter which is having a range of 25-250LPH mass flow rate was used.

Fig. 3.2 Fabricated parabolic trough solar collector

3.3 Nanofluid Preparation: -

1) **Weighing:** The amount of nanoparticle to be used in the nanofluid depends upon the concentration of nanofluid. This can be easily calculated by using the following expression:

Percent (%) By mass= mass of solute ×100/mass of solution

Where,

Mass of solution= density of nanoparticle× volume of base fluid

After calculating the amount of nanoparticle required, it is measured with weighing machine.

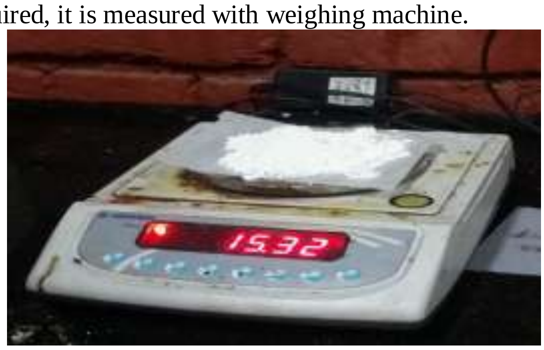

Fig. 3.3: Weighing Machine

2) **Stirring:** The measured nanoparticle is now mixed with the base fluid. This mixing is accomplished with the stirring machine. Stirring is required to be done to disperse the nanoparticles in the base fluid. Stirring is done for approximated 30 minutes.

Fig. 3.4: Magnetic Stirrer

3) **Sonication:** Lastly, sonication of the nanofluid is done to stabilize the nanoparticles for approximated 2 to 3 hours.

Fig. 3.5: Ultra bath Sonicator

3.4 Calculation of Thermo Physical Properties of Nanofluids: -

1) **Thermal conductivity:**
M. Chandrasekar et al. (2010) expressed thermal conductivity as follows:

$$K_{nf}/K_{dw} = (C_{P\,nf}/C_{P\,dw})^{-0.023}(\varrho_{nf}/\varrho_{dw})^{1.358}(\mu_{dw}/\mu_{nf})^{0.126}$$

2) **Viscosity :**
Viscosity of nanofluid is calculated by involving the following equation (Khalil Khanafer et al. (2011)):

$$\mu_{eff} = \mu_f / (1-\varphi_p)^{2.5}$$

3) **Density:** It is also calculated by relating the following equation (Khalil Khanafer et al. (2011)):

$$\rho_{eff} = (1-\varphi_p)\, \rho_f + \varphi_p\, \rho_p$$

4) **Specific heat:** Specific heat also calculated by relating the following equation (Khalil Khanafer et al. (2011)):

$$C_{eff} = \{(1-\varphi_p)\, \rho_f C_f\}/ \rho_{eff}$$

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3.5 Performance Evaluation Parameters of Solar Collector: -

To study the performance of nanofluid using parabolic trough solar collector, following formulae are used:

1. Useful heat gain

It is calculated under steady state condition from the following relation:

$$Q_u = \dot{m}_{eff}\, C_{eff}\,(T_0 - T_i)$$

2. Thermal efficiency: -The efficiency of the PTSC under steady state conditions can be obtained from following equation:

$$\eta_{th} = m_{eff} C_{eff} (T_0 - T_i) / A_{aper}\, GT$$

3. Overall thermal efficiency

The overall thermal efficiency under the steady state conditions is calculated as:

$$\eta = m_{eff} C_{eff} (T_{max} - T_{min}) / Aa_{per} G_{avt}$$

4. Instantaneous efficiency

$$\eta_i = Q_u / G_T R_b WL$$

5. Absorbed Flux

$$S = G T R_b \rho\gamma(\alpha\tau)$$

$$R_b = \cos\theta / \cos\theta_z$$

Where,

$$\cos\theta = \sin^2\theta + \cos^2\theta.\ \cos W$$

$$\cos\theta_z = \sin\emptyset.\ \sin\boldsymbol{\delta} + \cos\emptyset.\cos\boldsymbol{\delta}.\ \cos W$$

7. Concentration ratio

Concentration ratio is the ratio of aperture area to the absorber area. It is denoted as CR.

$$C_R = (W - d_{co})\, L / \Pi L D_O = (W - d_{co}) / \Pi D_O$$

8. Convective heat transfer coefficient

$$h_f = N_u * k / D_i$$

Where,

$$N_u = 0.023 * Re^{0.8} * P_r^{0.4}$$ (Dittus-Boelter correlation)

$$P_r = C_p v \rho / K$$

$$Re = V D_i / v$$

$$V = 4\dot{m} / \Pi D^2$$

The Nusselt number relation used here was only for the heating applications as described by Dittus-Boelter correlation.

9. Overall heat transfer coefficient of tube

$$U_L = Q_{thermal\_loss} / A_{glass} (T_{abs} - T_a)$$

Where,

U_L = Overall heat transfer coefficient

$$Q_{thermal\_loss\ \sigma\sigma} = Q_{convcetion} + Q_{radiation}$$

$$Q_{convcetion} = h_c (T_g - T_a) A_{glass}$$

$$h_c = 4 d^{-0.42} V_w^{0.5}$$ (Mullick & Nanda correlation)

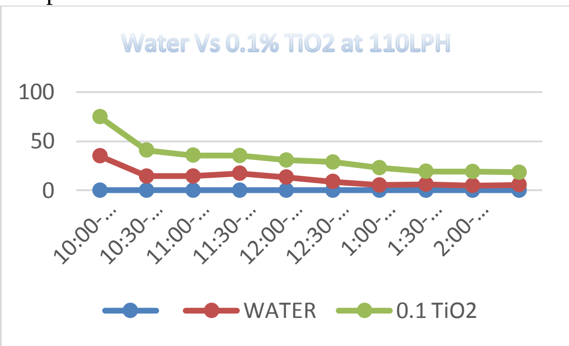
$$Q_{radiation} = \sigma\, \epsilon_g (T^4_g - T^4_{sky}) A_{glass}$$

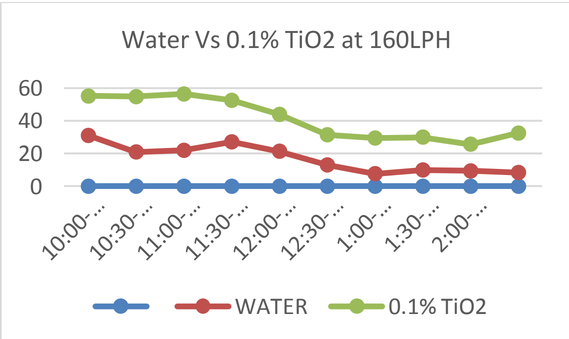
$$T_{sky} = 0.0552 T_a^{1.5}$$ (Swinbank's formula)

The losses are mainly calculated on the basis of the wind speed variation in accordance to Mullick & Nanda correlation.

4. Results and Discussion

The parabolic trough solar collector was investigated over two different mass flow rates (110LPH and 160LPH). The experiment was performed on different days of the month to evaluate the performance of the parabolic trough solar concentrating collector. Thermal efficiency of the collector was calculated at different mass flow rates and at different time intervals. The working fluid used was the water and nanofluid made by nanoparticle and water mixture at 0.1% concentration of TiO_2. The mass flow rate was increased from 110LPH to 160LPH. An increase in thermal efficiency was observed with increase in mass flow rate. After the performance evaluation with the nanoparticle (TiO_2), the parabolic trough solar collector performance was also evaluated by using water as the working fluid. Afterwards the efficiencies by using different working fluids were compared.





5. Conclusions

The effects of using Water and TiO_2 based nanofluid as the absorbing medium on the parabolic trough solar collector efficiency were calculated experimentally. The impact of the mass flow rate on the parabolic trough solar collector efficiency was also investigated. The working fluid mass flow rate was taken as 110LPH and 160LPH. The concentration of nanoparticle was taken as 0.1% concentration of the nanoparticle. The results revealed that using TiO_2 based nanofluid increases the solar collector efficiency in comparison with that of water. The experimental outcomes demonstrate that the maximum heat absorption by the collector occurs at different mass flow rates for water and nanofluid. The favorable mass flow rate is influenced by the working fluid thermo physical characteristics. In future, we can vary the mass flow rate to visualize the performance of PTSC by using different nanofluids at different concentration according to optimum concentration of nanoparticle, because after a certain optimum concentration the nanoparticle will start to settle earlier which will require more sonication and stirring of nanofluid.

Acknowledgments

This paper provides a useful way to enhance the effectiveness of the parabolic trough solar collectors with the help of nanofluid. It is concluded that all the experimental work is successfully conducted at the various mass flow rates of water and nanofluid on different days of a month in various time intervals.

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