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Performance Improvement of Energy Efficiency in Heat Pipe Solar Collector with Nano Composite

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Abstract

The objective of this research is to investigate the performance increase of evacuated solar collector with nano fluid. Solar collector includes absorber unit to transfer the heat energy to a working fluid. In this research it was intended to evaluate performance considering with nano fluid. Improving the heat collection efficiency, efficient extraction of the heat from the solar collector, controlling the operating temperature, long maintenance free life of the device are some of the major challenges in collecting and extracting heat from the evacuated solar collectors. Using nano fluids as working fluids are interesting and challenging. Improvement in the performance of the evacuated heat pipe was obtained using heat transporting nano fluid consisting of aqueous dispersion (3 weight %) of Copper Oxide (CuO) nanoparticles; in comparison with the device without utilizing the nano fluid. From the past research, authors have analysed the performance with numerous trials. The result shows that evacuated tube heat pipe collector with nano fluid give the better result than heat pipe collector without nano fluid.

Keywords: *Copper Tube, Glass Tube Solar Collector, Nano Fluid, Solar Energy*

1.0 Introduction

It is important to utilize the energy with low cost and more efficiency. India is running large renewable capacity expansion program in the world. The power generation in India depends on coal and oil mainly and that increases carbon dioxide emission to the environment. Solar energy has a capacity to save heat. The problem came in the engineering design of equipment for solar energy use is the low flux density that requires more area to collect solar energy for more utilization. In India 31% population lives in urban area and they have more demand than rural area. Evacuated tube collector equipment to transfers the thermal energy of the sun to heat water. In chemical process heat energy transfers from one process to another process. Exchange of thermal energy in an industrial process may saves the time and increase the performance of equipment. The improvement of thermal performance in an industrial process may save thermal energy, reduce time, raise thermal heating, and increase the overall life of equipment. Some processes are even affected by the action of more heat transfer.

The thermal efficiency of solar system is today a key topic in the utilization of solar energy. The basic concept of solar heat collection is that when solar radiation come upon object, a part of it is absorbed, and increases the temperature of the system. Water heaters of solar system are available in various systems. Heat pipes are used to transfer thermal energy in automobiles and computer applications as for laptops with improvement of technological equipment it is necessary to find effective ways to manage heat energy transfer in heat pipe technology. Nano materials have been utilized as a working fluid for cooling purposes include engine oil,

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water, andethylene glycol. These nano materials have lower thermal conductivity than metals and ionic components such as silicon carbide and copper oxide materials. Heat pipe works on the principle of two-phase thermal energy transfer in which the fluid flow of working fluids within a device changes its phase continuously. When one end of the heat pipe called the evaporator that is heated, the working material evaporate and increase the pressure of vapor, which goes through the adiabatic section and reaches another end called the condenser. Vapor gets cooled in the condenser and returns with small structure by capillary force. Thermal energy is transferred through latent heat in vapor and sensible heat transfer by liquid slurry. Thermal properties of the nano fluids are more effective of their performance.

2.0 Literature Review

Baque A Thulfaquir *et al.*[1] carried out the research work for improvement of the thermal efficiency of the evacuated tubes solar water by using a reflector. He used three diverse types of reflective materials such as aluminium foil, mirror, and white painting. Each system was compared with a reference one which was set without reflector. Based on thermal efficiency calculations, the result showed that the mirror at a distance of 0.17 m was the best. Naik B K *et al.*[2] investigated the performance assessment of evacuated u tube solar collector with FEM software based three-dimensional thermal model for evaluating the performance of evacuated U tube solar collector. He concluded that copper is the best material compared to brass and aluminum and water is better than air as working fluid. Using the developed model, it is suitable to design and analyze the performance of an evacuated tube solar collector. Mevada D *et al.*[3] studied the applications of evacuated tubes collector to control the solar energy and concluded that the problem of lower output and efficiency of solar still can be determined using the evacuated tube. Evacuated tubes require less area for installation than the flat plate collector, but cost of installation remains higher. The force mode heat transfer in the evacuated tube gives more output than the natural mode system. Use of nano fluids with evacuated tube gives higher efficiency and increases the output. Adel A. Ghoneim *et al.*[4] carried out research work on performance optimization of evacuated tube collector for solar cooling of a house in hot climate and he has recorded thermal performance for one year period in hot climate concluded that evacuated tube collector provides 80% efficiency of air Sakthivel M. Reddy *et al.*[5] Have developed analytical model of solar water heating using heat pipe with evacuated tubes using creo parametric software and analyzed in ANSYS software at specific mass flow rate and at one temperature. CFD analysis is executed to determine the velocity, drop of pressure, flow rate of mass, rate of heat transfer for evacuated tube solar collector and concluded that by increasing these parameters heat transfer rate increases by increasing the inlet flow rates. Harender *et al.*[6] examined the CFD analysis of active and passive evacuated tube solar collector and studied that parameter in natural and forced circulation. Thermal efficiency of active evacuated tube solar collector at minimum mass flow rate is compared with efficiency of passive evacuated tube solar collector. With CFD analysis he concluded that passive system is most suitable than active system. Farjallah R *et al.*[7] have carried out research work on thermal performance of the U tube solar collector using CFD simulation and developed three-dimensional model of tubular solar collector with a U tube and concluded that with the increase of the working fluid flow rate. The efficiency of the solar collector is improved up to 40%. Olcha A S *et al.*[8] has done study of thermal performance of an evacuated tube heat pipe solar collector in polish climate conditions. The solar collector and solar hot water test system located in Lublin (Poland) used for experimentation. He concluded that an increase in the temperature difference between the mixture of water and propylene glycol at the solar collector inlet and ambient temperature shows increase in the exergy efficiency and decrease in the thermal efficiency. The exergy efficiency and energy efficiency increase with increase in wind velocity. Eros M A *et al.*[9] has studied different working fluid on the performance for energy for evacuated tube with thermo heat pipe. The different evacuated tube solar collectors with thermo syphon heat pipe with the same dimensions and properties are used for the air heating and tested under outdoor climate conditions. He used acetone, hexane, petroleum ether, methanol, ethanol, chloroform as working fluids. Out of these liquid, chloroform and acetone show the superior performance in terms of energy and exergy. He suggested further study for thermo syphon heat pipe by using

nano fluids to improve the thermal efficiency. Kumar S S *et al.*[10] has carried out design work of evacuated tube solar collector with heat pipe. He has selected heat pipe evacuated tube solar collector made up of borosilicate glass with length with suitable length and diameter. He concluded that the performance of heat pipe collectors was found more suitable to external conditions such as solar radiation, ambient temperature. The important parameter for the design is length of evaporator. Hlaing S *et al.*[11] has done research work on design calculation and heat transfer analysis of heat pipe evacuated tube solar collector for water heating, and he concluded that the collector efficiency is obtained 72% vary to daily heat required. Hot water outlet temperature depends on the number of heat pipe evacuated tube collector, amount of solar radiation and environment conditions. Mishra D *et al.*[12] has done research work on solar energy conversion on evacuated tube solar collector for water heating and discussed analysis of thermal efficiency and payback period. He compared efficiency difference between circular pipe fin in evacuated tube solar collector and water in glass evacuated tube solar collector and concluded that copper fin evacuated tube solar collector gives efficiency with 75%. The temperature achieved up to 95^0C with full sunlight.

3.0 Methodology And Objective

It is important to utilize energy at low cost and more efficiency. India is running large renewable capacity expansion program in the world. The power generation in India depends on coal and oil mainly and that increases carbon di oxide emission to the environment. Solar energy has a capacity to save heat. The problem that came in the development of equipment for solar energy use is the low flux density that requires more area to collect solar energy for more utilization. The challenge in the production of future generation evacuated tube collector technology is the control and management of operating temperature and heat generation. Difficulties in the filling ratio and concentration level of nano fluids to increase the stability. Copper oxide nano fluid found suitable for filling ratio and stability.

Table 1. Copper Oxide Nanoparticles

CuO	Description
Purity	99.9%
Average Particle Size	30-70 nm
SSA	60-80 m^2/g
Bulk Density	0.66 g/cm^3

Difficulties in filling ratio and concentration level of nano fluids to increase the stability. Copper oxide nanoparticles are used in this study with purity 99.9% and average particle size of 50 nm. The copper oxide nanoparticle dispersion ratio used is 0.1%, 0.2%, 0.5%, 1%, 2%, 3%.

The experimental system consists of a heat pipe with copper oxide mixed with DI water to absorb solar energy and that solar energy transferred to recirculating water and converts in thermal energy and completes the cycle. The mass flow rate at the inlet of the header is controlled by rota meter. Inlet and outlet temperature measured by thermocouples.

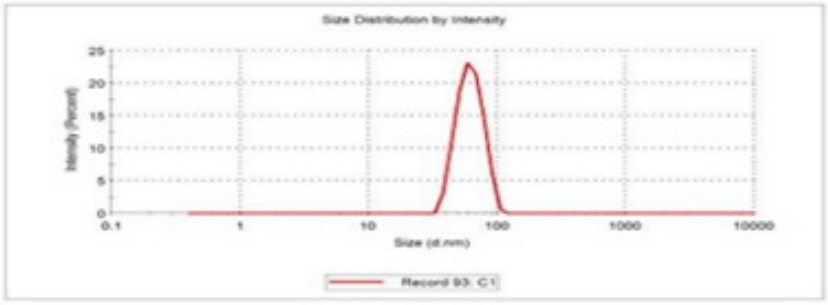


Figure 1. Copper oxide nanoparticle size distribution as a function of scattered light intensity.

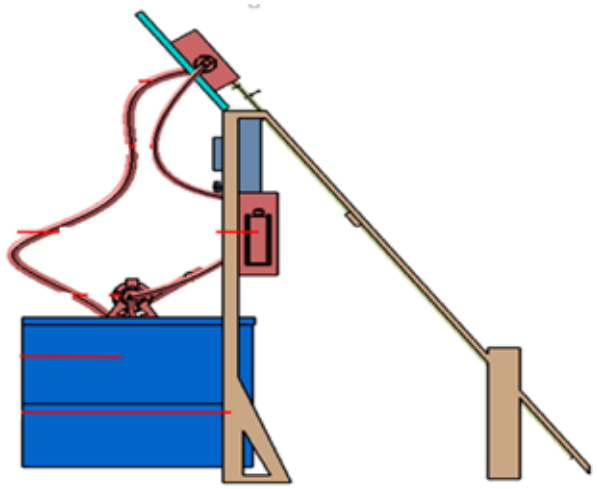


Figure 2. Side view of line diagram of experimental setup.

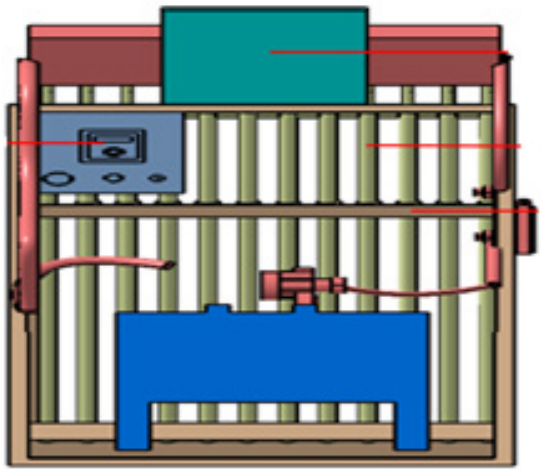


Figure 3. Front view of line diagram of experimental setup.

Table 2. Equipment's details

SN.	Equipment Details	
	Particular	Qty
1	Evacuated Tubes	4
2	Copper Heat Pipe	4
3	Header for Heat Pipe	1
4	Inlet Outlet Pipe	1
5	Water Recirculating Pump	1

The solar system consists of evacuated tubes, copper pipes, and tank with circulation pipe, and a suitable frame for mounting. The equipment details of evacuated tube heat pipe collector are shown in Table (2). There are four copper tubes installed with some inclination as shown in Figure (4). These copper tubes are surrounded by borosilicate glass tubes. Inlet pipe connected to header and tubes are press fitted in header. Another thermocouple was placed inside the storage tank. Water was circulated through the header. The heat pipe removes heat from the glass tubes with the highest efficiency. Copper tube solar collector controls operating temperature and prevent overheating which is common problem in solar system. During the experimentation, each of the copper tubes and evacuated tubes will be arranged in tilted position and tested in outdoor conditions but we are waiting for full sunshine hours for solar radiation.



Figure 4. Photograph of Experimental setup..

4.0 Observations

Table 3. Factor information for taking readings

Variable	Parameter	L1	L2	L3
V1	Angle in Degree	20	40	60
V2	CuO in Percentage	1	3	5
V3	Input Temperature	24	27	30

5.0 Result and Discussion

Table 4. SN Ratio

Parameter	**L1**	**L2**	**L3**
Angle in Degree	43.89	**56.22**	53.56
CuO in Percentage	44.00	52.33	**57.33**
Input Temperature	46.67	51.44	**55.56**

Table 5. Analysis of variance for outlet temperature

Source	**DF**	**SS**	**MS**	**F**	**P**
Angle in Degree	2	758.0	379.000	46.28	0.000
CuO in Percentage	2	816.7	408.333	49.86	0.000
Input Temperature	2	356.2	178.111	21.75	0.000
Error	20	163.8	8.189		
Total	26	2094.7			

Table 6. R Square values

S	R-sq	R-sq(adj)
2.86162	92.18%	89.84%

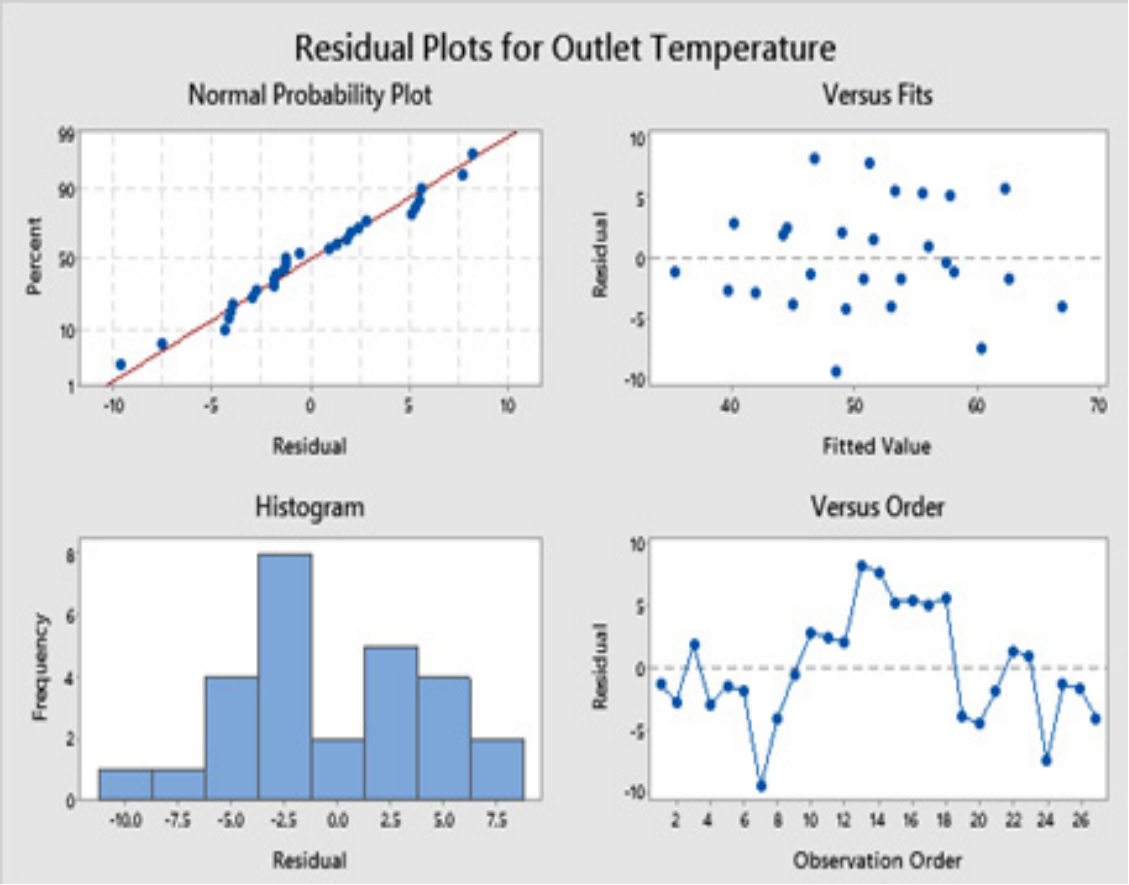


Figure 4. Residual plots for outlet temperature.

6.0 Outcome of the Research Work

Nano fluids are proposed and developed over the past decade for heat transfer applications. Thermo physical properties of the nano fluids are quite essential to predict their heat transferbehaviour. It is necessary to control for the industrial and energy saving in chemical processes. There is great industrial interest in nano fluids. Nano particles have more potential to increase the thermal transport properties compared to conventional particles fluids of small size particles. In the last decade, nano fluids have gained significant attention due to its enhanced thermal properties

7.0 Conclusion

Experiments were conducted to calculate the overall performance of evacuated tube solar collector. The results are good. The temperature variation is observed with variation of input parameters like angle of inclination, nano fluid copper oxide percentage and inlet water temperature. The outlet temperature also depends upon the solar radiation and number of tubes. The statistical regression analysis is performed in the minitab software. For the experimental data set ANOVA analysis is conducted for prediction of the quality of the data. From the observations it has been observed that P measure value for all input parameter viz, angle of tilt, copper oxide percentage, input temperature are less than 0.05. Hence all these input parameters are identified as significant factors. From the analysis it also observed that R square value as 92.18 % and R square adjusted value as 89.84 %. Hence the result is satisfactory. Regression analysis is conducted to find the relationship between input parameters and output response. In this research work the outlet temperature comes 68 ^{0}C with significant 40^0 angle of inclination, 5 % nano fluid copper oxide dispersed in

distilled water and 30 ^{0} inlet water temperature. Curve fitting was done in minitab software for experimental and theoretical results and the best fit smoothing model.

8.0 References

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