Performance Enhancement and Improvement of Energy Efficiency In Evacuated Tube Heat Pipe Solar Collector with Nano composite –Review

Prof. Shamkant Desale[1], Dr. Premendra Bansod[2]

Department of Mechanical Engineering

[1,2]G H Raisoni College of Engineering and Management

Domkhel Road,Wagholi,Pune-412 207.

Shamdesale27@gmail.com

Abstract - The objective of this research is to investigate the performance analysis of evacuated heat pipe collector with Nano composite. Solar collector includes absorber unit in order to transfer the heat energy to a working fluid. In this research it was intended to evaluate performance considering with Nano composite. The Challenge in the production of future generation evacuated tube solar collector (ETSC) technology is the control and management of operating temperature and heat generation. An essential aspect of EVTC design and application is the heat produced by the evacuated tube solar collector. Losses are present in design of solar system but must be reduced into a heat recovery system. From the past research, Authors have analysed the performance with numerous trials. The result shows that evacuated tube heat pipe collector with Nano composites give the better result than heat pipe collector without Nano composites. The heat transfer coefficient increases with higher mass flow rate hence use of Nano fluid give more efficiency.

Keywords - heat pipe, Evacuated tube solar collector, base fluid, Nano fluid

INTRODUCTION

A wide variety of industrial processes involve the transfer of heat energy. Throughout any industrial facility, heat must be added, removed, or moved from one process stream to another and it has become a major task for industrial necessity. These processes provide a source for energy recovery and process fluid heating/cooling. The enhancement of heating or cooling in an industrial process may create a saving in energy, reduce process time, raise thermal rating and lengthen the working life of equipment.

Some processes are even affected qualitatively by the action of enhanced heat transfer. The development of high performance thermal systems for heat transfer enhancement has become popular nowadays. A number of works has been performed to gain an understanding of the heat transfer performance for their practical application to heat transfer enhancement. Thus the advent of high heat flow processes has created significant demand for new technologies to enhance heat transfer. There are several methods to improve the heat transfer efficiency. Some methods are utilization of extended surfaces, application of vibration to the heat transfer surfaces, and usage of micro channels. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid. Commonly used heat transfer fluids such as water, ethylene glycol, and engine oil have relatively low thermal conductivities, when compared to the thermal conductivity of solids. High thermal conductivity of solids can be used to increase the thermal conductivity of a fluid by adding small solid particles to that fluid.

The energy efficiency of solar system is today a key topic in the Solar Energy utilization. The basic principle of solar thermal collection is that when solar radiation strikes a surface, a part of it is absorbed, thereby increasing the temperature of the surface. Solar water heaters are available in two different Technologies. Flat Plate Collector Technology and Evacuated Tube Collector Technology. The Evacuated tube collector is an improvement on the flat plate design.

The evacuated tube collector operates at a higher efficiency because a vacuum with the glass tubes eliminates conductive heat losses and the cylindrical tubes are always at the most advantageous perpendicular angle to the sun.

Heat pipes are used to transfer heat in vehicles and hardware applications as for instance laptops. With continuous development of technological equipment it is necessary to find effective ways to manage heat transfer in heat pipes. Fluids have been utilized as a working fluid for cooling purposes include engine oil, water and ethylene glycol. These fluids have lower thermal conductivity than metals and ionic components such as: copper, silver, silicon carbide and copper oxide. Heat pipe works on the principle of two-phase heat transfer in which the circulatory flow of working fluids within a device changes its phase continuously. When one end of the heat pipe called the evaporator section is heated, the working fluids evaporate and increase the vapor pressure, which travels through the adiabatic section and reaches another end called the condenser section. Vapor gets condensed in the condenser section and returns with wick structure by capillary force. Heat is transferred through latent heat in vapor and sensible heat transfer by liquid slug. The heat pipe as a two-phase heat transfer device, with high effective thermal conductivity in comparison with common thermal conductors such as metal rods and fins, plays a vital role in many industrial applications, including cooling of electronic devices, power generation, aerospace, cooling of high wattage LED lights and chemical processes. Traditional heat transfer fluids like water and alcohols have been extensively used in heat pipes; their low thermal properties become a primary obstacle limiting the thermal performance of heat pipe-heat exchangers. As a new class of heat transfer fluids. 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 transfer behavior. It is extremely important in the control for the industrial and energy saving perspectives. There is great industrial interest in Nano fluids. Nanoparticles have great potential to improve the thermal transport properties compared to conventional particles fluids suspension, millimeter and micrometer sized particles. In the last decade, Nano fluids have gained significant attention due to its enhanced thermal properties

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 di oxide 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. It is partly true an economically feasible, eco-friendly energy source and can be used in a variety of heat applications like heating of air or water, removal of moisture of crops, heating of food, cooling and many more. In India 31 % population lives in urban area and they have more demand than rural area. Evacuated tube collector is a heat exchanger, transfers the heat energy of the sunrays to heat to a heat transfer fluid. In chemical process heat energy transfers from one process to another process. These processes provide a source for energy recovery and process fluid heating/cooling. The improvement of heating or cooling in an industrial process may saves energy, reduce process time, raise thermal rating and increase the working life of equipment. Some processes are even affected qualitatively by the action of enhanced heat transfer. The development of high performance thermal systems for heat transfer enhancement has become popular nowadays. Thus the advent of high heat flow processes has created significant demand for new technologies to enhance heat transfer. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid

Table 1: Thermal conductivity of different solids and liquids

Solid/Liquid	Material	Thermal Conductivity (W/m K)
Metallic solid	Silver	429
	Copper	401
	Aluminum	237
Non-metallic solids	Diamond	3300
	Carbon nanotubes	3000
	Silicon	1458
	Aluminum oxide (Al_2O_3)	40
Metallic liquids	Sodium @ 644K	72,3
Non-metallic liquids	Water	0,613
	Ethylene glycol	0,253
	Engine oil	0,145

MATERIALS AND METHODS

The Challenge in the production of future generation EVTC technology is the control and management of operating temperature and heat generation. An essential aspect of EVTC design and application is the heat produced by the evacuated tube solar collector. 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%.

Table 2
Equipment's details

SN.	Equipment's	
	Particular	Qty
1	Evacuated Tubes	30
2	Copper Tubes	4
3	Heat Pipe	4
4	Header for Heat Pipe	1
5	Inlet Outlet Pipe	1
6	Water Recirculating Pump	1

Table 3 **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

Table 4 **Copper Oxide Nanoparticles Dispersions**

ITEM-CODE	PRODUCTS OF DISPERSIONS		
AD-CCHC	Copper Oxide Nanoparticles Dispersions in Water	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCAcC	Copper Oxide Nanoparticles Dispersions in Acetone	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCIC	Copper Oxide Nanoparticles Dispersions in IPA	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCDC	Copper Oxide Nanoparticles Dispersions in DMF	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCDAC	Copper Oxide Nanoparticles Dispersions in DMA	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCXC	Copper Oxide Nanoparticles Dispersions in Xylene	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCEC	Copper Oxide Nanoparticles Dispersions in Epoxy	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCPC	Copper Oxide Nanoparticles Dispersions in PU	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCAC	Copper Oxide Nanoparticles Dispersions in Acrylic	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter
AD-CCCC	Copper Oxide Nanoparticles Dispersions Customized	0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 5%, Customize	1/5/25/50/200 Liter

There are two methods of Nano fluid preparation namely single-step method and two-step method]. The single-step method is also known as bottom-up process since the nanoparticles are created from the atomic or molecular components that grow up in size becoming nanometer-sized particles. In this process, base fluids are prepared simultaneously with the nanoparticles preparation. This kind of method is typically applied in laboratory scale. In the two-step method, nanoparticles are made from a bulk material that is disintegrated into smaller parts (top-down process). At the second step, the resulted nanoparticles are suspended in their base fluid. The typical method used in practical applications is the two-step method due to the easiness factor.

The inclusion of nanoparticles aims to increase the thermal conductivity of nanofluid since the added nanoparticles have higher thermal conductivity than base fluids. water and other conventional HTF have much lower thermal conductivity than common metallic and non- metallic solid.

EXPERIMENTAL SETUP

Experimental system consists of 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 inlet of Header is controlled by Rota meter. Inlet and outlet Temperature measured by Thermocouples.

Figures 01 Experimental Setup

Figures 02 PT 100 Sensors used with multipoint temp indicator

The collector consists of glass tubes, copper tubes, storage tank, connecting pipes, reflectors, insulation and a suitable stand for mounting. The dimensions of evacuated tube heat pipe selected as shown in Table 1. There are four copper tubes with black coating at the outer surface which absorbs heat energy from the sun heats the inside flowing water as shown in Fig 01. These absorber tubes are surrounded by glass tubes with vacuum in between the two tubes to reduce the heat loss. The end of each glass tubes were sealed with a non-porous sealing material. After connecting the tubes with each other, they were mounted on a structure which when put under the sun make an angle of 15^0 while facing south. The headers were connected to the storage tank. Thermometers were placed at inlet and outlet of the storage tank. Another thermocouple was placed inside the storage tank. Water was circulated through the tubes by thermo-siphon principle. The evacuated tube removes heat from the absorbing surface with the highest efficiency. Heat pipe solar collector controls operating temperature and prevent overheating which is common problem in solar applications. During the analysis, each of the solar collectors will be arranged in tilted position and tested in outdoor conditions with reference to Table 5.

Table 5: Monthly solar radiation at location of pune,India for experimentation (Longitude 74.15^0 , Latitude 18.6^0).

Month	**Sunshine hour**	**Day length**
Jan	8.7	11.15
Feb	8.9	11.53
March	9.0	12.02
April	9.7	12.55
May	9.6	12.99
June	5.0	13.21
July	2.6	13.11
August	2.9	12.74
Sept	5.7	11.24

Oct	7.8	11.72
Nov	8.3	11.27
Dec	8.4	11.03

RESULT AND DISCUSSION

The Ansys Fluent software is used to calculate the outlet temperature.

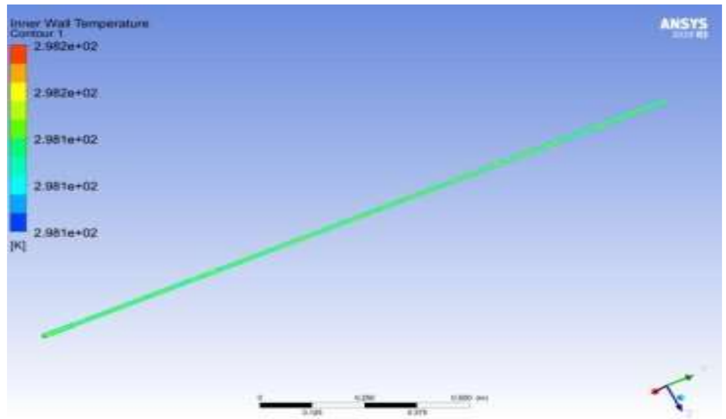

Figure. 3 Inner wall Temperature contour (Copper Tube)

The design of high performance thermal systems for heat transfer improvement has become popular in present days. A number of works has been performed to gain an understanding of the heat transfer performance for their practical application to heat transfer enhancement. Thus the improvement of high heat flow processes has created more demand for new technologies to increase heat transfer. There are many methods to improve the heat transfer efficiency. Some methods are utilization of extended surfaces, application of vibration to the heat transfer surfaces, and usage of micro channels. The efficiency can also be improved by increasing the thermal conductivity of the working materials.

CONCLUSION

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 transfer behavior. It is necessary to control for the industrial and energy saving in chemical processes. There is great industrial interest in Nano fluids. Nanoparticles 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

ACKNOWLEDGMENT

My sincere thanks go to my supervisor Dr. P.J. Bansod who provided me valuable guidance and constant support for this research work.

REFERENCES

[1] Baquer A. Alhabeeb, Thualfaquir J. Kadhim, Hasan T. Hashim, `Enhancement of the Thermal Efficiency of the Evacuated Tubes solar Water Heater by Adding a Reflector`, International Energy Journal 20(2020)57-66.

[2] B kiran naik, P Muthukumar, `Performance assessment of evacuated U-tube solar collector-a numerical study`, Indian Academy of Sciences, (2019) 44-23

[3] Dineh Mevada, Hitesh Panchal, Hagar Alm , `Application of evacuated tubes collector to harness the solar energy`, International Journal of Ambient Energy, (2019) ISSN 0143- 0750

[4] Adel A. Ghoneim ` Performance optimization of evacuated tube collector for solar cooling of a house in hot climate`, International Journal of Sustainable Energy, (2016) ISSN 1478-6451

[5] Sakthivel M, Rajanikanth Reddy` Analytical Investigation of solar eater heating using heat pipe with evacuated tubes`, International Journal of innovative and exploring engineering-2278-3075,Vool-8 Issue-8,june2019.

[6]] Harender, Dhruv mittal, Deepak Deo, S Aditya, Arvind kumar, `Computational Analysis of Active and passive evacuated tube solar collector, (2019) springer Nature Singapore P Ltd,doi /10.1007/978-981

[7] Rim Farjallah, Monia Chaabane , Hatem Mhiri, Philippe Bournot, Haten Dhauadi` Thermal Performance of U tube solar collector using computational fluid dynamics simulation`, Journal of solar Energy Engineering,ASME, Dec 2016/Vol 138/061008-1

[8] Alicja Siuta Olcha, Tomasz Cholewa, Kingo Dopieralska Howoruszko` Experimental studies of thermal performance of an evacuated tube heat pipe solar collector in polish climate conditions`, Environment Science and pollution Research, Springer Ltd, doi.org/10.1007/s11356-020-07920-3/ 12 feb 2020.

[9] Mustafa Ali Ersoz,`Effect of different working fluid on the energy and exergy performance for evacuated tube solar collector with thermo syphon heat pipe`, Elsevier Ltd, Renewable Energy 96(2016)244-256.

[10] S S Kumar, K Mohan Kumar, S R Snjeev Kumar ,` Design of Evacuated tube solar collector with heat pipe `, Elsevier Ltd, Materials Today-4(2017)12641-12646.