Nanofluid : A Tool to Increase the Efficiency of Solar Collector

Barot Vishalkumar G
Department of Mechanical Engineering (ME Energy engineering)
Government Engineering College, Valsad, Gujarat, India

K.D Panchal
Assistant Prof- (ME CAD/CAM)
Department of Mechanical Engineering
Government Engineering College, Valsad, Gujarat, India

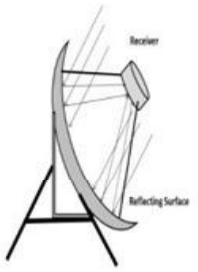
Abstract- Performance and efficiency of solar collectors depends upon various factors like collector & receiver material, solar radiation intensity, nature of working fluid etc. In This factor the properties of working fluid which flows through the collectors, greatly affects its performance. In this research work an effort has been made to enhance the efficiency and improve the performance of solar collector by using Nano fluids instead of conventional fluid like water as working fluid. Nano fluids are the fluids that exhibit thermal properties superior than that of the conventional fluid. The Reason behind using of Nano fluids is to achieve the highest possible thermal properties at the smallest possible concentrations .Nano fluids contains metallic or non-metallic nanoparticles like aluminum, aluminum oxide, copper oxide etc. Nano-fluid based solar collector are commonly used in areas such as industries, heating and cooling for domestic purpose, thermal power plants, solar cooker, automobiles, etc. This paper contains information and methodology to Enhance and improve the heat transfer and performance of solar collectors using Nano fluid.

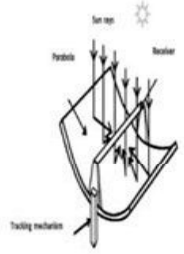
Keywords - Nano fluid, Heat transfer, solar collector, Alumina-copper

I.INTRODUCTION

Nanofluid is the fluid with Nano sized solid particles. The metallic or nonmetallic nanoparticles change the transport properties and heat transfer characteristics of the base fluid. Nano fluids are the new generation heat transfer fluids for various industrial and automotive applications because of their excellent thermal performance. Solar energy is widely used in applications such as electricity generation, chemical processing, and thermal heating due to its renewable and nonpolluting nature. Most solar water heating systems have two main parts: a solar collector and a storage tank. The most common collector is called a flat-plate collector but these suffer from relatively low efficiency. There are so many methods introduced to increase the efficiency of the solar water heater. But the novel approach is to introduce the Nano fluids in solar collector instead of conventional heat transferfluid(likewater).

A.SOLAR THERMAL COLLECTOR: Solar thermal collectors can also be considered legendary based on the type of heat transfer liquid and their construction used (water, non-freezing liquid, air, or heat transfer fluid) and whether they are covered or uncovered. Most popular types of solar collectors are parabolic Dish, Parabolic Trough and Power Tower system and solar flat plate. Solar flat plate collectors are used for water heating applications and the efficiency of these systems are around 70% which is very high as compared to solar direct energy conversion systems having efficiency around 17% [1].These collectors are useful for domestic applications, space heating and industrial low temperature applications. Currently a large number of solar collectors are available on the market based on concentrating solar power (CSP) systems which use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam.





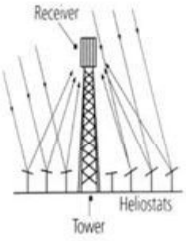


Fig-1(a) Parabolic Dish Collector Fig-1(b) Trough Collector Fig-1(c) Tower system

B. B.SOLAR PHOTOVOLATIC EFFECT – French physicist Edmond Becquerel discovered how to produce electric current in a solid material with the help of sunlight as early as 1839. The photovoltaic effect cause certain materials to convert light energy into electrical energy at the atomic level, which was first studied in 1876 by Adam and Day, who made solar cell from selenium that had an efficiency of 1-2%. The photovoltaic effect was explained by Albert Einstein in 1904 via his photon theory [3]. A noteworthy breakthrough related to modern electronics was the invention of a process to produce pure crystalline silicon by Polish scientist Jan Czochralski in 1916 [4]. The efficiency of first generation silicon cells was about 6% [5], which is substantially lower than that of current solar cells (about 14-20%). Early efforts were made to make the photovoltaic cells viable for generating electricity for worldly applications were unsuccessful due to the high device costs. The lower prices of these photovoltaic cells and need for green technology gained interest in employing this technology.

C.NANOFLUID

(i) WHAT IS NANOFLUID-- Nano fluids demote to a solid-liquid mixture or suspensions produced by dispersing tiny metallic or nonmetallic Solid Nano particles in liquids. Nano fluids are a new class of fluids engineered by dispersing nanometer sized materials (Nano-particles, Nano-fibers, Nano-tubes, Nano-wires and Nano-rods) in base fluids. The size of nanoparticles (usually less than 100nm) in liquids mixture gives them the ability to interact with liquids at the molecular level and so conduct heat better than today's heat transfer fluids depending on nano particles. Nano fluids can display enhanced heat transfer because of the combination of convection & conduction and also an additional energy transfer through γ-particles dynamics and collisions. Metallic Nano fluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water. In current years, Nano fluids established greater potential in many fields like solar collector and solar thermal storage. Even though some review articles involving the progress of Nano fluids investigations were published in the past several years , most of the reviews are concerned with the experimental and theoretical studies of the thermo physical properties or the Convective heat transfer of Nano fluids.

(ii) PREPARATION OF NANOFLUID- In order to carry out experimental studies with Nano fluids, their preparation is the first main step. Nano fluids are prepared by dispersing Nano sized solid particles like alumina (Al), silicon oxide (SiO), copper oxide (CuO) into base liquids such as water, ethylene glycol therminol-VP-1 etc. There are mainly two techniques used to produce Nano fluids: the single-step and the two-step method. In the present experimental work two-step method is used as this method is widely used for the preparation of Nano fluids. In this method, first the nanoparticles are obtained by different Methods and then are dispersed in an appropriate base fluid like water, oil, ethylene glycol, therminol-VP 1.

(iii) *CLASSIFICATION OF NANOFLUID*-- Nano fluids can be normally classified into two categories metallic Nano fluids and non-metallic Nano fluids. The result of study about the atomic and micro scale-level characteristic behavior of Nano fluids shows that the enhancement of thermal conductivity, temperature dependent effects and significant raise in critical heat flux. Metallic Nano fluids often refer to those containing metallic nanoparticles such as (Cu, Al, Zn, Ni, Si, Fe, Ti, Au and Ag), while Nano fluids containing non-metallic nanoparticles such as aluminum oxide (Al2O3), copper oxide (CuO) and silicon carbide (SiC, ZnO, TiO are often considered as non-metallic Nano fluids, semiconductors (TiO), Carbon Nanotubes (SWCNT, DWCNT and MWCNT) and composites

materials such as nanoparticles core polymer shell composites. In addition, new materials and structure are attractive for use in Nano fluids where the particle liquid interface is doped with various molecules.

(iv) *REASON BEHIND USE OF NANOFLUID-* The rise in effective thermal conductivity is important in improving the heat transfer behavior of fluids. The number of other variables also plays key role, For example, for forced convection the heat transfer coefficient for tubes depends on many physical quantities related to the fluid and the geometry of the system through which the fluid is flowing. These quantities include properties of the fluid such as, its , density, viscosity, thermal conductivity, and specific heat along with extrinsic system parameters such as tube diameter and length and average fluid velocity. Therefore, it is essential to measure the heat transfer performance of Nano fluids directly under flow conditions. Researchers have shown that Nano fluids have not only better heat conductivity but also greater convective heat transfer capability than that of base fluids. The effective utilization and more usages of Nano fluids in heat exchangers as a heat transfer fluids. And there are many other advantages of Nano fluid in enhancement of heat transfer are,

•Higher thermal conductivity of Nano particles will increase the heat transfer rate.

• Successful employment of Nano fluid will lead to lighter and smaller heat exchanger.

• Heat transfer rate increases due to large surface area of the Nano particles in the base fluid.

• Nano fluids are most suitable for rapid heating and cooling systems

(v) *THERMAL PROPERTIES OF NANOFLUID-* Metallic Nano fluids clearly exhibit improved thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity, convective heat transfer coefficient, emissivity and optical absorption. The property change of Nano fluids depends on the volumetric fraction of nanoparticles, shape and size of the nanomaterial [6]. Increased thermal conductivity of Nano fluid in comparison to base fluid by suspending particles is shown in Table 1.

Table 1, Thermal conductivity of various solids and liquids.

Material	Specification	Thermal Conductivity (W/m-K)
Metallic Solids	Copper	401
	Aluminum	237
	Silver	429
Nonmetallic Solids	Silicon	148
	Alumina	40
	CNT	2000
Nonmetallic liquids	Water	0.613
	Ethylene Glycol	0.253

(vi) HEAT TRANSFER USING NANOFLUID- Now a days use of Nano fluid technology instead of conventional fluids is seen as potential area where performance of solar collectors can be improved. The selection of Nano fluid is most important for using in solar collectors, Nano fluids have some limitations i.e. corrosion and erosion of components, pumping power problem, pressure drop, high cost, etc. Pressure drop enhances by employing CuO-oil based Nano fluid under laminar regime, Pressure drop enhances by enhancing volumetric concentration of TiO2water based Nano fluid under turbulent regime. So, the proper selection of Nano fluids is most important for improving the performance of solar

collectors. For the high volumetric concentration of Nano fluids, viscosity is needs to be higher. The Nano fluids can be used in parabolic trough systems, photovoltaic or thermal systems, solar ponds, solar thermoelectric cells, solar cooling systems, solar absorption refrigeration systems and the combination of various different solar devices. There are many experiments was done by many different authors on solar collectors by using water and Nano fluid as working fluid, the results shows the heat transfer rate increases using Nano fluid in solar collectors.

II. EXPERIMENT AND RESULT

A. EXPERIMENTAL SETUP-

Fig-2 Parabolic trough collector system

The experimental setup carried out for testing the performance of collector consists of the parabolic shaped collector, parabolic reflectoreceiver tube, glass cover tube, 10 liter storage tank, supporting structure, tracking mechanism, piping system and ball valve as throttling valve. The storage tank is located below the receiver's pip level to allow the heating fluid to flow in a forced manner with pumping system. The storage tank is filled with water/Nano fluid .The flow takes place in a closed system. The complete set-up of Parabolic Trough Solar Collector is shown figure 2.

The Parabolic trough collector system consists of following parts:

A Stainless steel sheet having dimensions (1.21 m × 0.90 m) forms the parabolic shape. Parabolic shaped mirrors are used as reflectors with a reflectivity of 95%. The receiver tube is composed an outer glass cover tube, a vacuum type enclosure or annular space & an inner black painted tube made of copper material. In receiver tube the flowing heat transfer fluid such as water or Nano fluid gains heat from the solar radiation coming from the reflector part. A black painted copper tube which has higher thermal conductivity is used as a receiver tube and is covered by a glass cover tube. A receiver tube has 3.5ft length with inside and outside diameter of 28 mm & 29 mm. glass cover tube has 3ft - length with inside and outside diameter of 63 mm & 65 mm. The support structure for the parabolic solar collector is made of cast iron. The selection of cast iron material for the support structure is because of its greater rigidity, hardness and more flexibility. Mainly two types of tracking systems are used namely, manual tracking system and automatic tracking system. In this experiment manual tracking is used because it is inexpensive as compared to automatic tracking as, automatic tracking requires a motor and a gear mechanism. "SUPERLON" insulation is used for entire piping system. Pump is used for the circulation of water or Nano fluid from the storage tank to the inlet of the receiver tube at some appreciable height. In this experiment submersible pump is used with a maximum height of 6ft., 11010/hr output and 19 W Power.

B. EXPERIMENTAL RESULT- Following Fig. shows the comparison of instantaneous efficiency w.r.t. time for water & water based alumina and CuO Nano fluid with 0.01% volume concentration at 20 l/hr mass flow rate. From the graph it is observed that the copper oxide Nano fluid shows higher efficiency from 9:30-11:30 AM & from 12:003:00 PM in comparison with alumina Nano fluid & water.

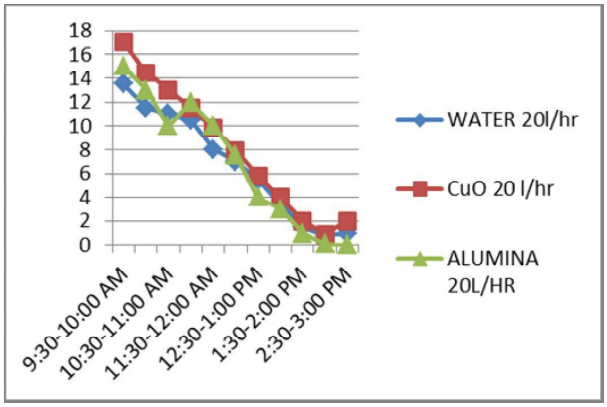


Fig-3(a) Comparison of Instantaneous Efficiency w.r.t. Time for Water & Water Based Alumina and CuO Nano fluid With (0.01%) at 20 l/hr Mass Flow Rate.

If we talk about alumina Nano fluid, it shows higher efficiency than water from 9:30 to 10:30 AM & from 11:00 AM to 12:30 PM because of higher temperature difference & lower intensity of radiations. But there is sudden drop also observes in the thermal efficiency of alumina at 10:30-11:00 AM than water because of the higher specific heat of water, as instantaneous efficiency directly depends upon specific heat. If specific heat increases efficiency increases. From 12:30-3:00 PM water has higher efficiency because of the higher specific heat & faster variation in temperature difference as compare to alumina Nano fluid.

Fig. 3(b) shows the comparison of instantaneous efficiency w.r.t. time for water & water based alumina and CuO Nano fluid with 0.01% volume concentration at 40 l/hr mass flow rate. From the graph it is observed that the copper oxide Nano fluid shows the higher efficiency at the time interval from 9:30 AM to 3:00 PM in comparison with water & alumina Nano fluid.

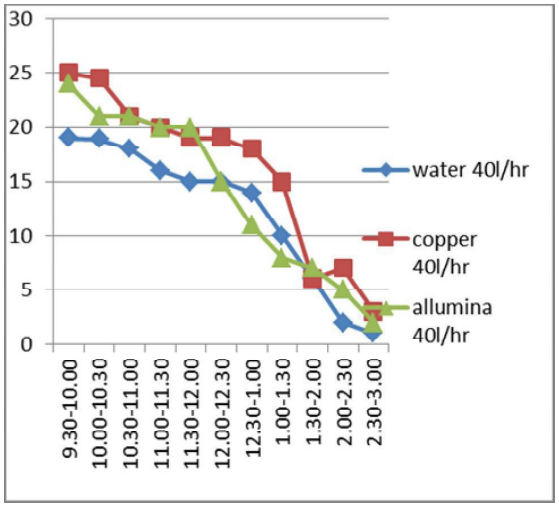


Fig. 3(b): Comparison of Instantaneous Efficiency w.r.t. Time for Water & Water Based Alumina and CuO (0.01%) Nano fluid at 40 l/hr Mass Flow Rate

On the other hand, alumina Nano fluid shows higher efficiency from 9:30 to 12:30 PM & at 2:00 to 3:00 PM in comparison with water because of higher temperature difference & lower Intensity of radiations. Water shows

higher efficiency as compare to alumina Nano fluid from 12:30 to 2:00 PM because of its higher specific heat value. The overall maximum value of instantaneous efficiency for CuO is 25.17%, for alumina is 22.35% & for water is 18.91% at 9:30-10:00 AM.

III. CONCLUSION

The purpose of this experimental work is to check the performance of parabolic concentrating solar collector by using water, water based aluminum oxide (Al2O3) & copper oxide (CuO) Nano fluid as the working fluids. Following are the conclusions drawn.

1. with copper oxide (CuO):
By using copper oxide Nano fluid as a working fluid with 0.01% concentration, collector's instantaneous efficiency has been found to be improved from 0.88 to 2.88%, 1.24 to 6.28%, for 20, 40 l/hr mass flow rates. Whereas, Collector's thermal efficiency is improved from 0.95 to 3.05%, 0.65 to 3.46%, for 20, 40 l/hr mass flow rates.

With copper oxide (CuO) Nano fluid as a working fluid with 0.01% concentration, collector's instantaneous efficiency is improved from 0.03 to 4.87%, 0.46 to 7.81%, for 20 and 40 l/hr mass flow rates. Collector's thermal efficiency is improved from 0.6 to 5.18%, 0.22 to 4.25%, for 20 and 40 l/hr mass flow rates.
2. with alumina (Al2O3)
By using alumina Nano fluid as a working fluid with 0.01% concentration, collector's instantaneous efficiency is enhanced from 0.93 to 3.38%, 0.1 to 3.45%, for 20 and 40 l/hr mass flow rates. Collector's thermal efficiency is enhanced from 1 to 2.85%, 0.05 to 1.88 for 20 and 40 & l/hr mass flow rates.

IV. REMARKS AND FUTURE SCOPE

There is a lot of scope in the field of solar energy harvesting using Nano fluid-based concentrating parabolic solar collector (NCPSC) system. In the present experimental work fixed dimensions & same material of receiver tube, glass cover tube, and parabolic collector & only one size of nanoparticles is taken. In addition, thermo physical properties (density, specific heat, viscosity & thermal conductivity) are taken at standard temperature. In the following investigations will be carried out to check out the performance of parabolic collectors:-

1. By varying the dimensions (length, diameter) of the receiver tube and glass cover tube.
2. By varying the dimensions (length, height) of parabolic collector.
3. By changing the material of receiver tube & glass cover tube such as quartz or Pyrex glass,
4. By changing the material of reflector such as stainless steel Sheet, aluminum sheet or aluminum sheet.
5. By changing the size of nanoparticle and try with different Concentrations with different base fluids other than water like with ethanol or therminol-VP1.
6. Calculating thermo physical properties (density, specific heat, Viscosity & thermal conductivity of Nano fluid at varying temperatures).
7. By using air as a working medium instead of using Nano fluids with the help of blower.

REFERENCES

[1] Jaisankar S, Ananth J, Thulasi S, Jayasuthakar ST, Sheeba KN. A comprehensive review on solar water heaters. Renewable and Sustainable Energy Reviews.2011; 15 -6: 3045-3050.
[2] Nano fluids for solar collector applications: A Review P.K.Nagarajan ,J.Subraman, S.Suyambazhahan,Ravishankar Sathyamurthy
[3] Luque A, Hegedus S. Handbook of photovoltaic science and engineering . England: Wiley; 2003.
[4] Chow TT. A review on photovoltaic /thermal hybrid solar technology. Applied Energy .2010; 87(2): 365 -79.
[5] Maxwell JC. Treatise on electricity and magnetism .Oxford: Clarendon Press US; 1973.
[6] Hong TK, Yang HS, Choi CJ. Study of the enhanced thermal conductivity of Fe Nano fluids. Journal of Applied Physics.2005; 97: 06431