THE EFFECT OF NANO FLUID ON THE HEAT TRANSFER IN SOLAR WATER HEATER WITH USING NANO MATERIAL ON CFD

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Abstract
Renewable energy is an alternative source of energy. Among all renewable energy sources, we have solar energy in abundance and solar collectors are commonly used to harvest the energy. The conventional fluids which are used as the heat transfer medium in solar collectors suffer from poor thermal and heat absorption properties. This study was performed in an open environment in bright sunlight. The solar water heater was used for the study of the effect of sunlight on the Nano-fluids. The solar water heater was directly facing the sun.. Four different Nano Particles are used named ZnO, CuO, PbO and SiO2. A Nano-fluid was prepared by using Nano-particles of different materials with water. The mass flow rate of the water at the inlet was 1lpm (0.017kg/s). The Nano-fluids were made to flow through the solar heater from the inlet at a temperature of about 320k. The outlet temperature of the Nano-fluid was observed in order to find the Nano-fluid with the highest temperature. The results shows to increase the efficiency and performance of solar heat pipe collector using SiO2 Nano fluids at 0.5% fraction.
Keywords: plate solar collector, SiO2/water Nano fluids, flow rate, the outlet-inlet temperatures difference

INTRODUCTION

Sun is the main source of energy in system. It offers us the energy of great potential in terms of activity the world's need. As the primary energy resources are depleting constantly, solar energy draws attention of investigators all through the world. Solar energy is one among the alternative energies that have large potential. It's estimated that the earth receives close to 1000W/m2 quantity of solar irradiation during a day. The radiation incident on the Earth's surface is comprised of two kinds of radiation – beam and diffuse, go inside the wavelengths from the ultraviolet to the infrared (300 to 200 nm), that's characterized by a mean solar surface temperature of approximately 6000°K. The number of this solar power that is intercepted is 5000 times larger than the sum of all totally different inputs – terrestrial nuclear, energy and gravitated energies, and lunar gravitational energy. to place this into perspective, if the energy created by 25 acres of the surface of the sun were harvested, there would be enough energy to provide this energy demand of the world (Bouska, 2004)[1].

SOLAR ENERGY COLLECTOR

The conversion of solar Thermal Energy into a lot of usable type (e.g. Heat or Electricity) is completed by solar energy collectors. A solar collector may be a device that transmissions the collected solar energy to a fluid passing in dealings with it, accordingly it's always a problem of analysis to know that however with efficiency solar collectors are changing solar energy into thermal energy.

The Classification of solar collectors is:

(i) Non-Concentrating or flat plate type solar collector

(ii) Concentrating type solar collector

Non-Concentrating solar collector:

As the solar collectors are of two type, concentrating and non-concentrating. A cross sectional view of non-concentrating solar collector is shown in figure 1

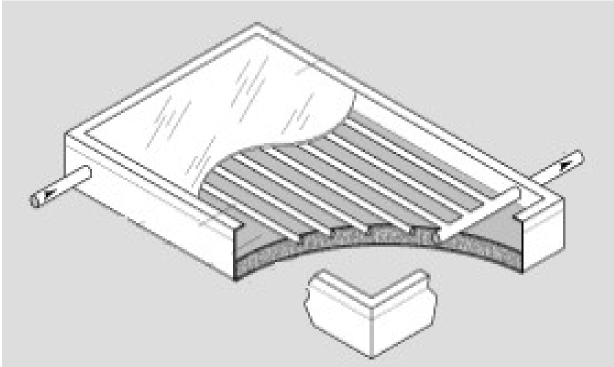

Fig. 1: Cross-sectional view of Flat plate collector

Concentrating Type solar collector:

Another type of solar collector is concentrating type of solar collector, which is also classified as parabolic trough and dish type collector. Both are shown in figure 2a and ab.

a) (Parabolic trough) b) (Dish type collector)

Fig. 2: Concentrating solar collector

NANOFLUIDS

The term Nano fluids is coined by Choi (1995). The suspension of Nano - particles into the fluids are referred to as Nano fluids. Nanomaterials have unique mechanical, Optical, Electrical, Magnetic and Thermal properties with a mean sizes below 100nm. A really small amount of nanoparticles once distributed in any host fluids (e.g. Water, Oil, and Ethylene Glycol) will improve the thermal properties of fluids dramatically. Nano fluids are established to enhance the performance and heat transfer characteristics for solar collector's application. However, there are still some issue with Nano fluid together with the raised of viscosity of the fluid which will lead to increase in pumping power load and also the major issue of Nano fluids for long run engineering applications is the stability.

NANOFLUIDS IN SOLAR ENERGY APPLICATIONS

Some analysis showed on thermal conductivity and optical properties of Nano fluids also are in short-term studied, as a result of these parameters will validate the probable of Nano fluids to improve the performance of solar systems.

Collectors and Solar Water Heaters

A Nano-fluid poses the subsequent benefits as compared to standard fluids that build them appropriate to be used in solar collectors: Absorption of solar energy is maximized with modification of the size, shape, material and volume fraction of the nanoparticles. The suspended nanoparticles increase the area and therefore the heat capacity of the fluid because of the very little particle size. The suspended nanoparticles enhance the thermal conductivity which ends in improvement in efficiency of heat transfer systems. Properties of the fluid are often modified by varying concentration of nanoparticles. Very little size of nanoparticles ideally permits them to pass through pumps. The elemental difference between the standard and Nano fluids, based collector lies within the mode of heating of the working fluid. Within the former case the sunlight is absorbed by a surface, wherever as within the later the daylight is directly absorbed by the working fluid (through radiative transfer). On reaching the receiver the solar radiations transfer energy to the Nano fluids via scattering and absorption. The Nano fluid based solar water heater and collector are shown in Fig.3.

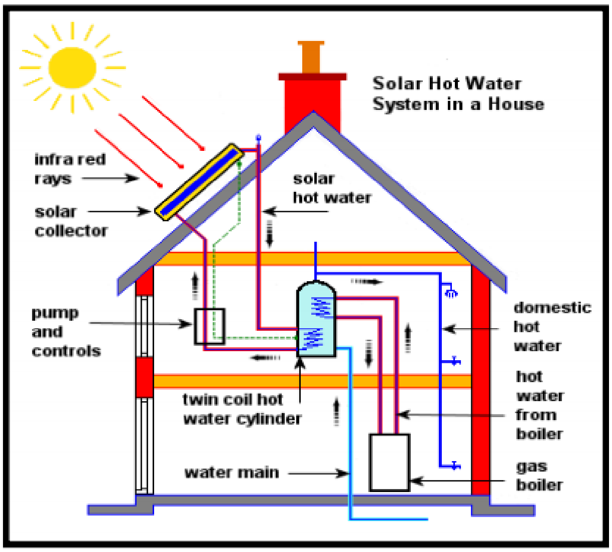

Fig. 3: The Nano-fluid based solar water heater and collector

LITERATURE REVIEW

(Khudhayer et al., 2018)[2]concentrated on improving the heat transfer performance of FPSC with a curved tube planning by replacement the base fluid (water) with CuO/water and TiO2/water nanofluids. The results of the fluid kind on the inlet-outlet temperature difference furthermore as a result of the thermal efficiency of FPSC were investigated. The outcomes displayed that the CuO/water nanofluid as an operational fluid between the FPSC presented higher heat transfer performance matched to TiO2/water nano-fluid furthermore as a result of the base fluid (water) due to the higher thermal conduction of CuO nanoparticles. The inlet-outlet temperature distinction at 1.5 lit/min rate of flow for water, CuO/water and TiO2/water nanofluids were 6.6 °C, 7.1 °C, and 7.9 °C, in turn. Additionally, the maximum efficiency was in line with be 55% for the CuO/water nanofluid compared to 54 and 500th for 0.1 % by vol. TiO2/water and water, severally. To end supported the raw investigational data; the empirical relationships for the base fluid (water), CuO/water nanofluid, and TiO2/water nanofluid were obtained utilizing statistical software system.

(Basim, Abdel-Mohsen and Shareef, 2017)[3]concluded that for (0.5 vol. %) (ZnO/water) nano-fluid used as working fluids, the outlet- inlet temperature variations were increased with the decreasing mass rate of flow and maximum outlet-inlet temperature difference are obtained at low rate of flow (1 L/min) was 150C at whereas the minimum temperature difference are obtained at highest rate of flow (3L/min) was 13.10C for nano-fluid. The results demonstrate that by using ZnO/water nano-fluid as absorbing medium the outlet-inlet temperature variations were increased compared with water. The outlet-inlet temperature variations increased with nano-fluid than pure water for all flow rates. There was a good convention between the experimental and CFD results for outlet temperatures wherever the maximum error was (8.4%).

(Sahi Shareef, Hassan Abbod and Qahtan Kadhim, 2015)[4]concluded that for water and (0.1 vol. %) Al2O3nanofluid used as working fluids, the outlet-inlet temperature variations were decreased with the mass rate of flow increase and maximum outlet-inlet temperature difference were achieved at low rate of flow the whereas the minimum temperature difference was achieved at highest rate of flow. While (0.5 vol. %) nanofluid on the contrary of that wherever the temperature variations increase with the rate of flow rise and maximum outlet-inlet temperature difference was achieved at highest rate of flow. important improvement in solar radiation absorption and collector temperatures difference makes nanofluids as an applicable heat transfer fluid for solar collectors and may be make a significant develop within the solar renewable energy applications.

(Sahi Shareef, Hassan Abbod and Qahtan

Kadhim, 2015)[4]The impact of using Al2O3-water nanofluid on the flat plate solar collector has been studied experimentally. The volume fraction of nanoparticles has been selected as 0. 5%. The collector outlet inlet temperatures alteration improved with nanofluid than pure water for one lpm flow rates. Each the utmost and average temperatures difference determined to be increase once Al2O3-water nanofluid has been tested. The solar radiation intensity has been recorded to observe its impact on the solar collector. Significant enhancement in solar radiation absorption and collector temperatures variance makes nanofluids as an proper heat transfer fluid for solar collectors and might be make a big develop within the solar renewable energy applications.

(MOHD FAIZAL FAUZAN, 2015)[4]focuses on the advantages of using totally different nanofluids during a flat plate solar collector. the effects of volume rate of flow, nanoparticles volume fraction, mass rate of flow, density and heat energy on energy and energy efficiency of the solar collector are studied. Investigative outcomes expose that via CuOnanofluid can growth energy and energy efficiency of a flat plate solar collector in equivalence with water as motivating fluid by 38.46% and 15.52%, respectively. Analytical study in addition remarks that the increment of volume fraction, mass rate and density can enhance every energy and energy efficiency. For equal volume rate of flow, mass rate may be enlarged by injecting nanoparticles in base fluid only and represents higher efficiency.

(Mahian et al., 2014)[5]An investigative analysis was useful to analysis the significances of tube roughness, nanoparticle size, and wholly totally different thermos-physical models on the heat transfer and entropy generation throughout a flat plate solar collector using Al2O3/water nanofluid with volume fraction by four-dimensional and for constant mass flow rates. The findings of the paper are going to be summarized as follows:

- Nusselt range decreases with increasing the degree fraction whereas a rise among the dimensions of nanoparticles can increase the Nusselt range.
- The trend of changes in outlet temperature and Nusselt range is exactly opposite, therefore the volume fraction and nanoparticle size among that the outlet temperature is maximized are going to be determined by minimization of the Nusselt range whereas not doing long calculations.
- Heat transfer constant has an opposite trend compared to the Nusselt point varied volume fractions and particle sizes.
- There is an optimum volume fraction among that the heat transfer constant is maximized.

(Moghadam et al., 2014)[6]The effects of using Cu–O nanofluid as a result of the absorbing medium on the flat-plate solar collector efficiency are studied through an experiment. The experiments are administered in Mashhad, Iran (latitude 36.19°N and longitude 59.37°E). The influence of the mass rate of flow on the solar collector efficiency has in addition been investigated. The operating fluid mass rate of flow has been chosen inside the vary of 1–3 kg/min. the degree fraction of nanoparticles is prepared to 0.4%; the particle dimension is forty nm. The results demonstrate that using CuO–H2O nanofluid can increase the solar collector efficiency compared with that of water by 16.7% (especially inside the optimum mass flow rate). The experimental results in addition prove that the best heat absorption by the collector happens at entirely totally different mass flow rates for water and nanofluid. The optimum mass rate of flow depends on the operating fluid thermal characteristics.

(Ekramian, Etemad and Haghshenasfard, 2014)[7]The heat transfer performance of various nanofluids within a flat plate solar collector was investigated numerically. MWCNT/water, Al2O3/water, and CuO/water nanofluids with mass percent of 1, 2, and 3 WTC are used as working fluids. Effects of working fluid, mass flow rate, nanoparticle mass percent, and inlet temperature on the heat transfer coefficients and thermal efficiency were examined. The numerical predictions were validated using the experimental information within the literature with a similar conditions and good agreement was obtained.

(Nasrin, Parvin and Alim, 2014)[8]forced convective flow and heat transfer by fully totally different nanofluids through a flat plate solar collector is analyzed numerically by this text. The solar collector has the flat plate cover and curved wavy absorber. Four fully different nanofluids like water silver nanofluid, water based copper nanofluid, water Al2O3nanofluid and water CuOnanofluid are used as a result of the operational fluids at intervals the solar collector. The governing partial differential equations with correct boundary conditions are resolved by FEM using Galerkin'sweighted residual scheme. The behaviour of varied nanofluids associated with performance like temperature and rate distributions, radiative and convective heat transfers, mean temperature and rate of the nanofluid is investigated systematically. This performance includes the solid volume fraction with regard to higher than mentioned nanofluids.

(Faizal, Saidur and Mekhilef, 2013)[9]The efficiency of using the Al2O3nanofluid as absorbing medium in flat-plate reflector is analyzed supported totally different mass rate, nanoparticles mass fraction and presence of wetting agent. The thermal efficiency of using zero.4 World Trade Center Al2O3nanofluids while not surfactant is lower than 0.2 WTC however increased with the presence of surfactant. For increasing mass rate of flow, the thermal efficiency increased whereas the output temperature decreased. once applying a similar output temperature of nanofluid like water, it are often observed that the collector's size are often reduced up to 24-% of its original size and so creating value and energy savings to manufacture flat- plate solar collector possible.

FLAT PLATE SOLAR COLLECTOR

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar area heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorbent plate. These collectors heat liquid or air at temperatures but 80°C.

For design proposed model some specifications are shown in table 4.

Table 1 The specifications of solar collector

Component	Dimensions	Remarks
Absorber Plate	(0.95x0.526x0.003)m	Material: stainless steel
Glass cover	Thick (4 mm)	Window glass
Collector area	(1.04x0.64x0.12)m	
header pipes	Inner diameter (16) mm, outer diameter (20) mm Length (60) cm	Copper
Riser pipe	Inner diameter (8) mm, outer diameter (10) mm, Length (80) cm, centre to centre distance (7.5 cm)	copper Number of tubes: six

MATERIAL PROPERTY

***Table 2:** Material property of nanoparticles*

Material	Density (kg/m3)	Heat Capacity (J/kg.K)
ZnO	5606	376.8
CuO	6500	535.6
PbO	9530	205.2
SiO_2	2220	745

Table 3: Properties of water

Heat capacity (J/Kg.K)	4185.5
Viscosity (Kg/m.s)	0.001054
Thermal conductivity (w/mK)	0.6
Mass flow rate (kg/s)	0.017 (1 lpm)

Calculations for density and specific heat capacity of Nano fluids

The volume fraction of the nanoparticle with water is 0.5%.

The following expression has been used for calculating the density of the nanofluid.

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_{bf}$$

For calculating Specific Heat Coefficient of the nanofluid, following expression will be used,

$$C_{pnf} = \frac{\varphi\rho_p C_{pp} + (1-\varphi)\rho_{bf} C_{pbf}}{\rho_{nf}}$$

And for calculating thermal conductivity of Nano Fluid, following expression is used,

$$K_{nf} = \left[\frac{K_{np} + 2K_{bf} + 2f_v\left(K_{np} - K_{bf}\right)}{K_{np} + 2K_{bf} - f_v\left(K_{np} - K_{bf}\right)}\right] K_{bf},$$

Where, Cp_{nf} = heat capacity of nanofluid

C_{pp} = heat capacity of nanoparticle

Φ = volume fraction

Cp_{bf} = heat capacity of base fluid

ρ_p = Density of particle

ρ_{bf} = density base fluid

ρ_{nf} = density nano fluid

k_{np} = thermal conductivity of nano particle

k_{bf} = thermal conductivity of base fluid

Properties of Nano fluid

Table 4: *Material property of nanoparticles*

Material	Density (Kg/m3)	Heat Capacity(J/kg.k)
ZnO+Water	1023.03	2281.15
CuO+Water	1027.5	2360.55
PbO+Water	1042.65	2152.75
SiO_2+Water	1003.115	4146.9

Model of solar pipe

Table 5: *Pipe dimensions*

Component	Dimension	Material
Header pipe	Length – 60 cm, Outer diameter – 20 mm, Inner diameter – 16 mm	Copper
Riser pipe	Inner diameter -8 mm, Outer diameter -10 mm, Length -80 cm	Copper

BOUNDARY CONDITIONS AND ASSUMPTIONS

In this analysis rate of flow (1, 2 and 3) with numerous inlet temperatures was introduced and also the pressure outlet condition is carried at the exit. The thermo- physical properties of the operating fluid (water and ZnO/water, CuO/water, PbO/water and SiO_2/water) assumed constant at mean bulk temperature. Impermeable boundary and no-slip wall conditions was performed on the channel walls.

Assumptions:

a) Water and ZnO/water, CuO/water, PbO/water and SiO_2/waternanofluids was used as operating fluid, it's incompressible fluid.

b) The flow regime was thought-about to be laminar.

c) The thermal-physical properties of water and absorbent material tube are independent of temperature.

d) The face of the absorbent material plate and also the bottom a part of the absorbent material tube was supposed to be adiabatic.

RESULT

The study was carried out using ANSYS FLUENT tool

CASE 1

Using the Nano-fluid – ZnO

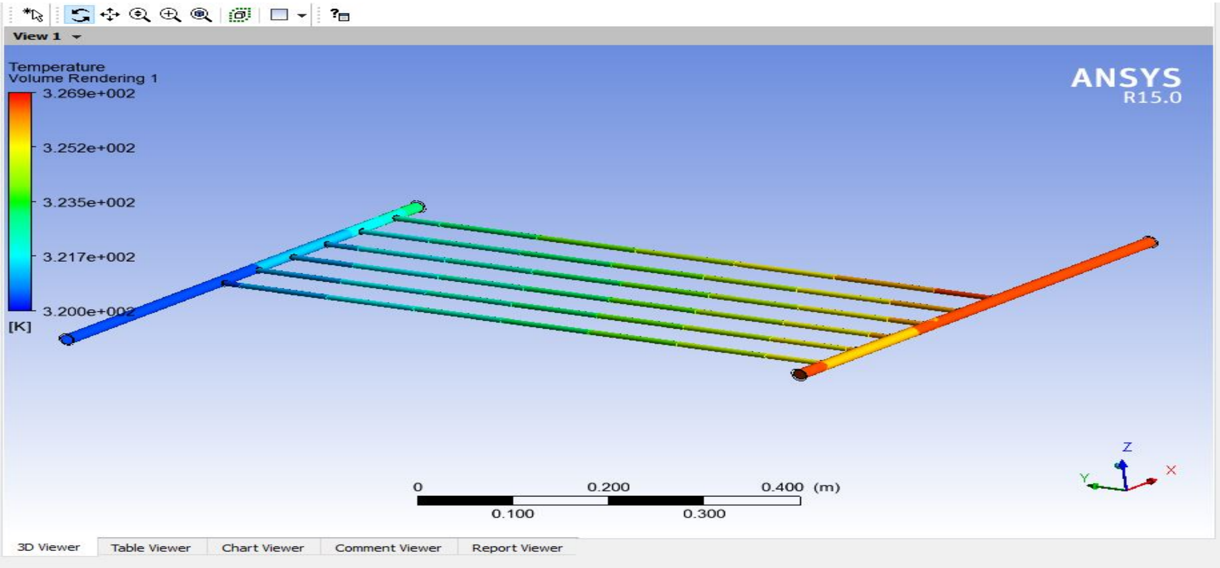

Fig. 4. Temperature for using ZnOnanofluid

CASE 2

Using the Nano-fluid – CuO

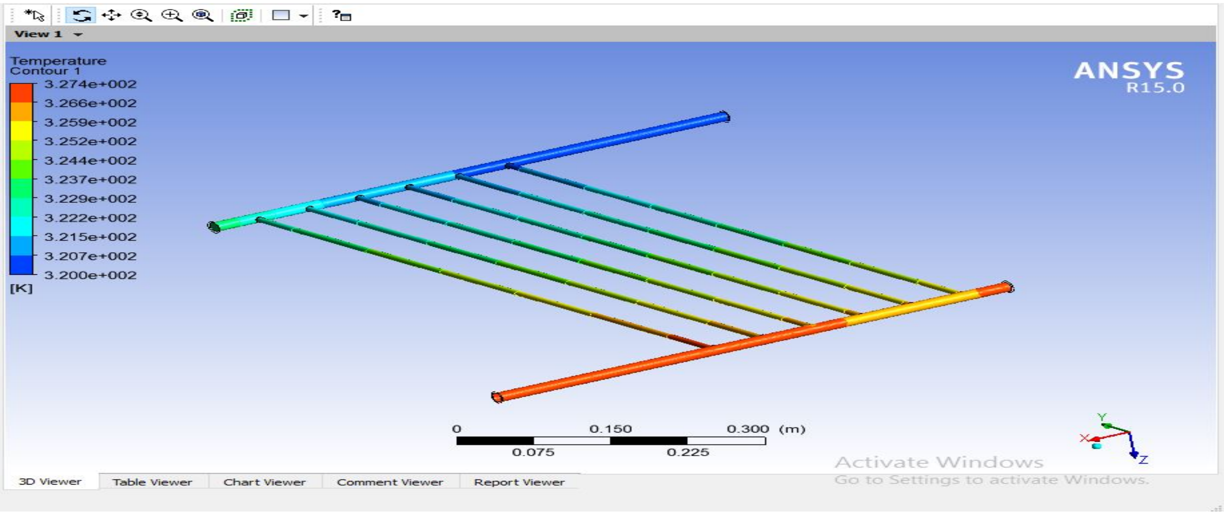

Fig. 5. Temperature for using CuOnanofluid

CASE 3

Using the Nano-fluid – PbO

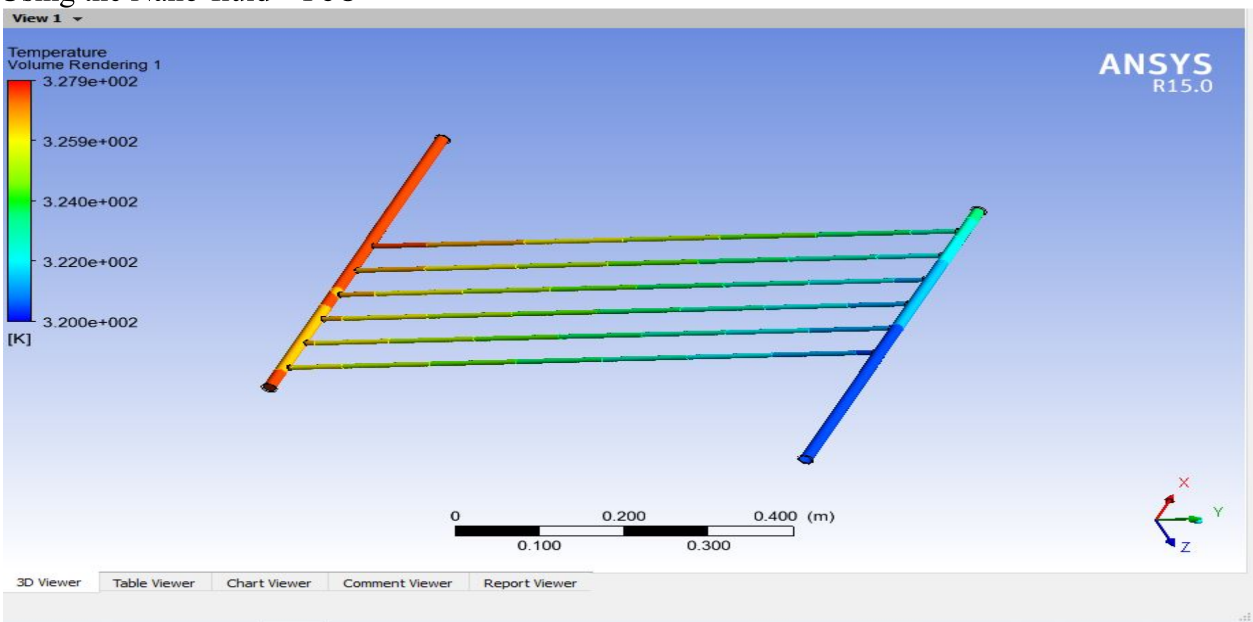

Fig. 6. Temperature for using PbOnanofluid

CASE 4

Using Nanofluid - Silica

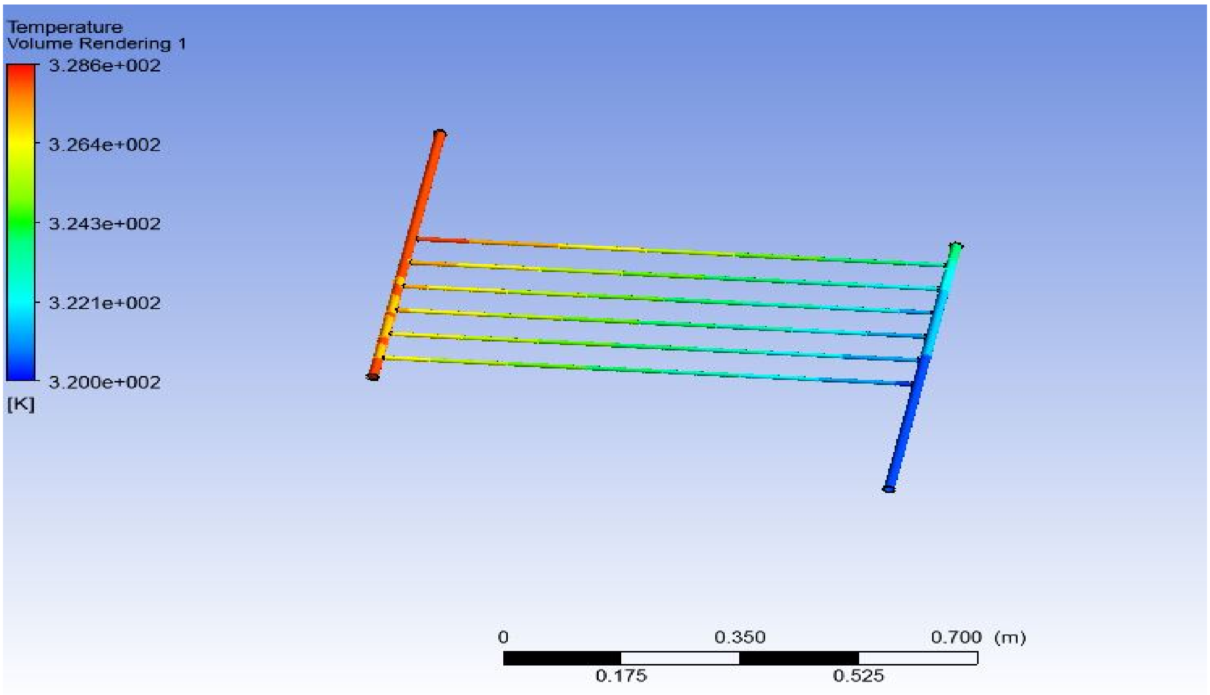

Fig. 7.*Temperature Using Silica + Water Nanofluid*

COMPARISON TABLE

Comparison of the outlet temperature of the nanofluids is shown in below table.

Table 6. *All case comparison table.*

Case	Inlet temp (K)	Outlet temp (K)
1 ZnO	320	326.9
2 CuO	320	327.4
3 PbO	320	327.9
4 SiO_2	320	328.6

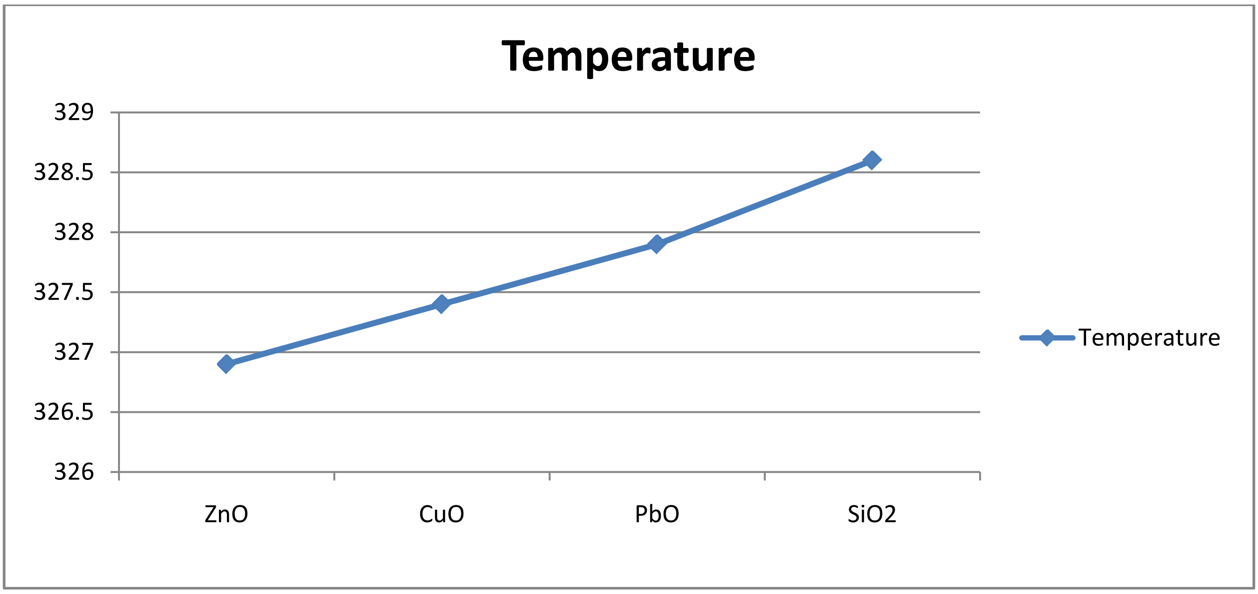

Fig. 8: *Comparison graph of achieved temperature*

CONCLUSION

The purpose of this research work is to perform simplified analysis of how to increase the efficiency of solar heat pipe collector. The concluded points of this work are as follows:

- In this work studied four simulation of the flat plate solar heater. There are fournanofluidsZnO, CuO, PbO, and SiO_2 are used at 0. 5%.
- To increase the performance of solar heat pipe collector, we are using the SiO_2nanofluids with water.
- In this observed that the Nano-fluid containing SiO_2+water reach the highest temperature at the outlet of the solar water heater. Thus, using the nanofluid of SiO_2 is most suitable for absorbing heat energy.
- SiO_2nanofluids with 0.5% volume fraction of efficiency is increase.
- One of the main causes of receiving higher efficiency is the very small particle size, which improves the absorption capacity of nanofluids so; improvement in efficiency could be obtained by using various particle size distributions.
- Comparison of four cases at outlet temperature of the nanofluids.

REFERENCES

[1] C. K. Bouska, "Dissertation on Biosynthesis," no. 97, pp. 1–69, 2004.

[2] W. J. Khudhayer, H. Ghanbarpourasi, H. T. Jalel, and H. R. Al-dayyeni, "Enhanced Heat Transfer Performance of a Flat Plate Solar Collector using CuO / water and TiO 2 / water Nanofluids," vol. 13, no. 6, pp. 3673–3682, 2018.

[3] Z. Basim, Abdel-Mohsen, and A. S. Shareef, "Experimental and numerical investigation the effect of mass flow rate on the heat transfer flat plate solar collector with using nano fluid," ARPN J. Eng. Appl. Sci., vol. 12, no. 11, pp. 3518–3525, 2017.

[4] A. Sahi Shareef, M. Hassan Abbod, and S. Qahtan Kadhim, "INTERNATIONAL JOURNAL OF ENERGY AND ENVIRONMENT Experimental investigation on a flat plate solar collector using Al 2 O 3 Nanofluid as a heat transfer agent," vol. 6, no. 4, pp. 317–330, 2015.

[5] O. Mahian, A. Kianifar, A. Z. Sahin, and S. Wongwises, "Entropy generation during Al2O3/water nanofluid flow in a solar collector: Effects of tube roughness, nanoparticle size, and different thermophysical models," Int. J. Heat Mass Transf., vol. 78, pp. 64–75, 2014.

[6] A. J. Moghadam, M. Farzane-Gord, M. Sajadi, and M. Hoseyn-Zadeh, "Effects of CuO/water nanofluid on the efficiency of a flat-plate solar collector," Exp. Therm. Fluid Sci., vol. 58, pp. 9–14, 2014.

[7] E. Ekramian, S. G. Etemad, and M. Haghshenasfard, "Numerical Analysis of Heat Transfer Performance of Flat Plate Solar Collectors," J. Fluid Flow, Heat Mass Transf., vol. 2, 2014.

[8] R. Nasrin, S. Parvin, and M. A. Alim, "Heat transfer by nanofluids through a flat plate solar collector," Procedia Eng., vol. 90, pp. 364–370, 2014.

[9] M. Faizal, R. Saidur, and S. Mekhilef, "Potential of size reduction of flat-plate solar collectors when applying MWCNT nanofluid," IOP Conf. Ser. Earth Environ. Sci., vol. 16, no. 1, pp. 3–8, 2013.