Experimental Investigation of the Thermal Behavior of Nano-fluid (Al_2O_3-H_2O) on Parabolic Solar Collector

Dissertation-II

Submitted in partial fulfillment of the requirement for the award of degree

Of

Master of Technology

IN

THERMAL ENGINEERING

By

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PUNJAB
2017-2018

CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled **"Experimental Investigation of the Thermal Behavior of Nano-fluid (Al_2O_3-H_2O) on Parabolic Solar Collector"** in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **Mr**. **Ashish Kumar Patel**, **Assistant Professor** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Acknowledgement

With deep sense of gratitude I express my sincere thanks to my esteemed and worthy supervisor, **Mr.Ashish Kumar Patel**, Assistant Professor, Department of Mechanical Engineering, of Lovely Professional University, Phagwara for his valuable guidance in carrying out work under his effective supervision, encouragement, enlightenment and cooperation. His feedback and editorial comments were also invaluable for writing of this dissertation.

I shall be failing in my duties if I do not express my deep sense of gratitude towards **Dr. Manohar Singh Saini** (HoS) and **Mr. Sudhanshu Dogra** (HoD) of Mechanical Engineering, Lovely Professional University, Phagwara.

I would like to thankful towards my university Lovely Professional University, Phagwara, Punjab for giving a change to prove myself in this challenging world.

I am greatly indebted to friends who constantly encouraged me and also would like to also thankful to the authors whose work have been consulted and quoted in this work.

At last but not the least my gratitude towards my parents, who always supported me in doing the things my way and whose everlasting desires, selfless sacrifice, encouragement, affectionate blessings and help made it possible for me to complete my degree. I would also like to render my gratitude to the Almighty God who bestowed self-confidence, ability and strength in time to complete this task and for not letting me down at the time of crisis and showing me the silver lining in the dark clouds.

Place**: LPU, Phagwara** **Rahul Shrikrishna Choudhari**

Date**:** **(11612536)**

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Abstract

Sun is the foundation of solar energy source on the earth which is freely available. Efficiency of solar collector is majorly depend upon intensity of solar energy, working fluid, design and material of solar collector and reflector. This naturally gifted energy would be use in concentrating solar collector. In this report, the parabolic solar collector is taken into consideration to study the thermal behavior of the system. In this report attempt will be made to enhance the performance of solar collector by using nanofluid. In our experiment water (H_2O) will use as base fluid and Aluminum oxide (α-Al_2O_3) as nanoparticles. In different volumetric concentration ratios and different mass flow rates we will calculate thermal conductivity, heat transfer rate, temperature rise, thermal efficiency, overall efficiency in the parabolic solar collector. The experimental work will be simulated on the computational. The experiment work and simulation work will be compared.

Keyword: Copper pipe, Flow control valve, Glass tube, Magnetic stirrer, Nanoparticles, Rotameter, Sonic heater, Temperature sensor.

1 Introduction

Since some decades, due to growing inhabitants featuring in the world, energy demand goes higher every year. The world is using fossil fuel to fulfill the demand. The fossil fuel is the exhaustible source of energy which is used once and release heat, by this we can generate energy by using mechanical and electrical components. The main element of fossil fuel is carbon, the time period that take to formed the carbon is approximately 300 to 400 millions of year this formation is known as carboniferous. The fossil fuels are Coal, Natural gas, Petroleum. Due to this formation of energy by exhaustible source the issue of global warming is has been enhanced. To solve this major issue now it's end of the age of oil and move towards the inexhaustible source of energy.

In the inexhaustible energy it formed natural which are renewable or regenerative, there are several methods for this energy source that can be adopted to form the energy they are as follows,

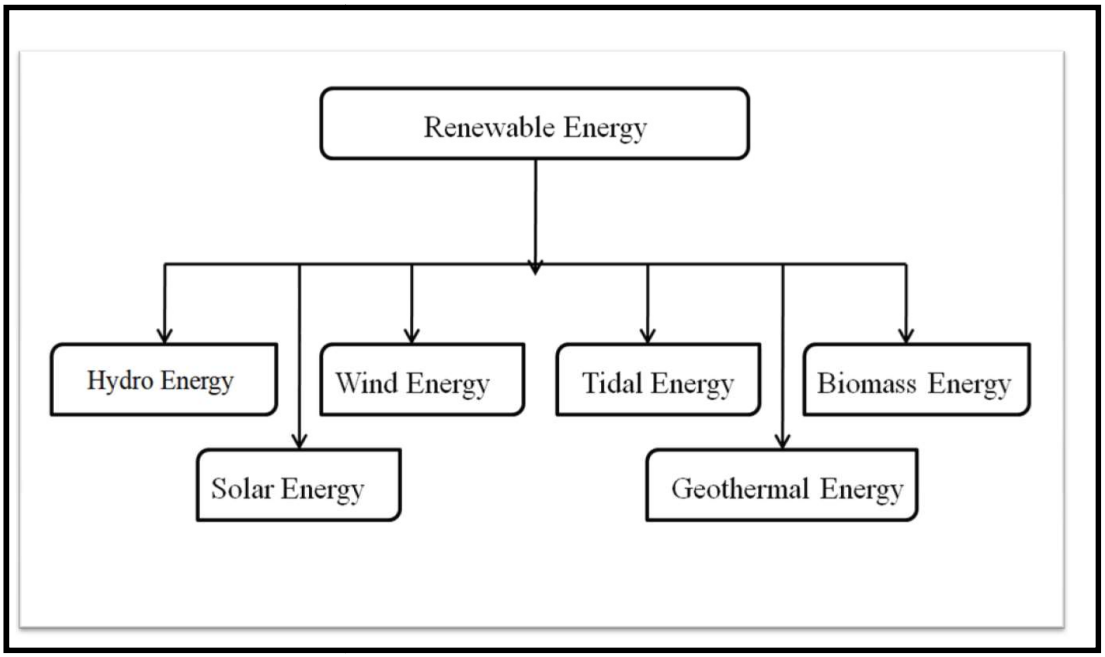


Figure 1.Types of renewable energy

1.1 Solar Energy

In solar energy the sun play the important role in renewable source of energy. It is abundant source of energy it's known as electromagnetic radiation. To balance the nature on the earth sun is the important source. Energy from sun emits in form of light and heat energy from this some amount of energy is used balmy the earth and for the different densities of water , air between two regions hot and cold .To continuation the water cycle form ocean to cloud and cloud to rain it also formed due to absorbed of heat by ocean from sun which emits heat and some part of light is scattered and absorbed by the different gases such as dust,H_2O,O_2,O_3,CO_2 etc. while some is reflected back to space as shown in fig 2.

1.1.1 Solar Radiation

Radiation- The radiation can be defined as the energy transmission in form of waves.

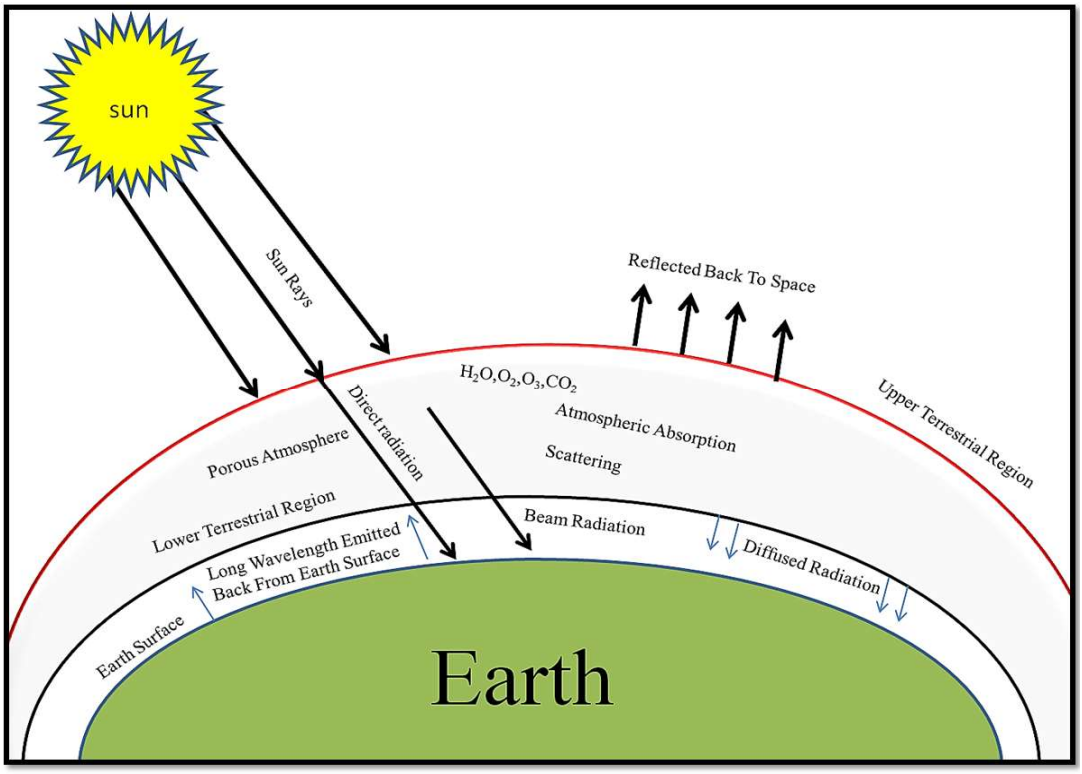


Figure 2. Solar radiation

Direct radiation-On earth surface the solar radiation received without any change in direction called as direct or beam radiation.

Diffused Radiation-On terrestrial region or surface the solar radiation received by scattered form in the dome.

Total Radiation-The sum of direct and diffused radiation is known as total radiation.

Global Radiation-Direct and diffused radiation measured in horizontal surface of earth.

Irradiance-The rate of sun incident energy per unit area on earth surface called irradiance.

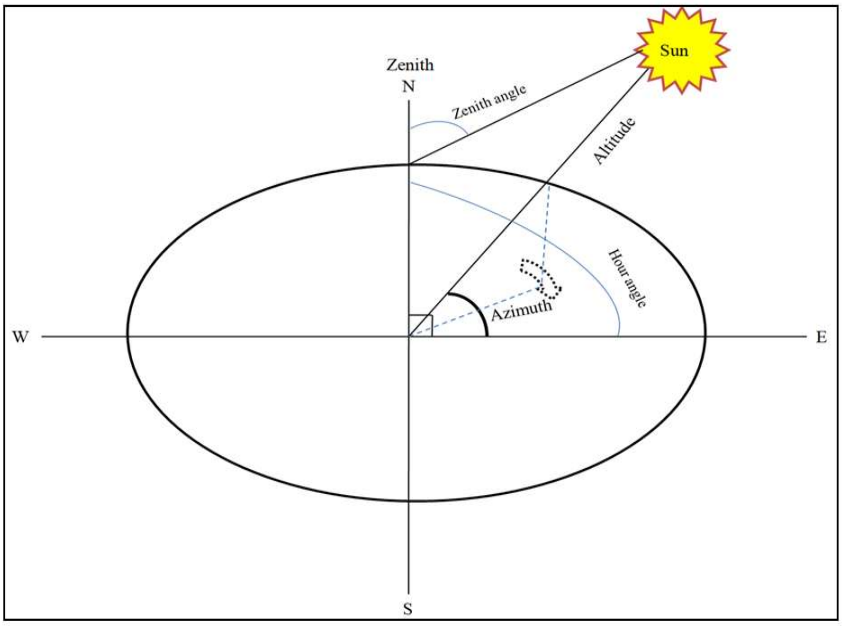


Figure 3. Altitude, Azimuth, Zenith angles of sun on earth

Altitude Angle-The Inclined projection line of sun ray's between the horizontal surface of earth and zenith.

Azimuth Angle- The angle measured horizontally to a plane in clockwise direction at a fixed reference point.

Zenith -The position of the sun on overhead or 90^0.

Zenith Angle-The line perpendicular to horizontal plane (y-axis) to theangle between sun rays & zenith.

Hour Angle-The rotation of earth to bring the meridian point under the sun, the angle is measured from the zenith .The angular measurement of hour angle (360/24) is 15^0.

Declination-Sun projection on earth on equator line and center of earth are joining together termed declination. The declination is denoted by δ.

During winter the sun is near to earth than in summer, but we received more radiation during summer due to favorable angle as show in figure 4 below.

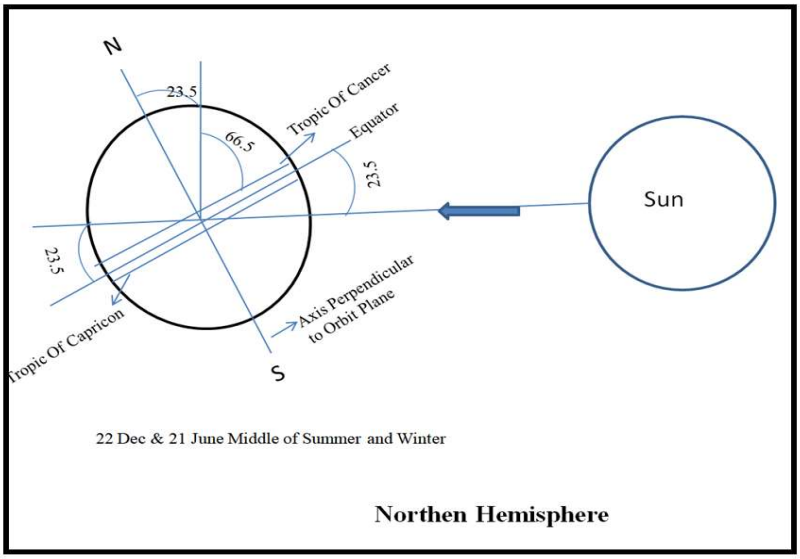


Figure 4.22 Dec & 21June of Northern hemisphere

1.1.2 Instruments for solar radiation measurement

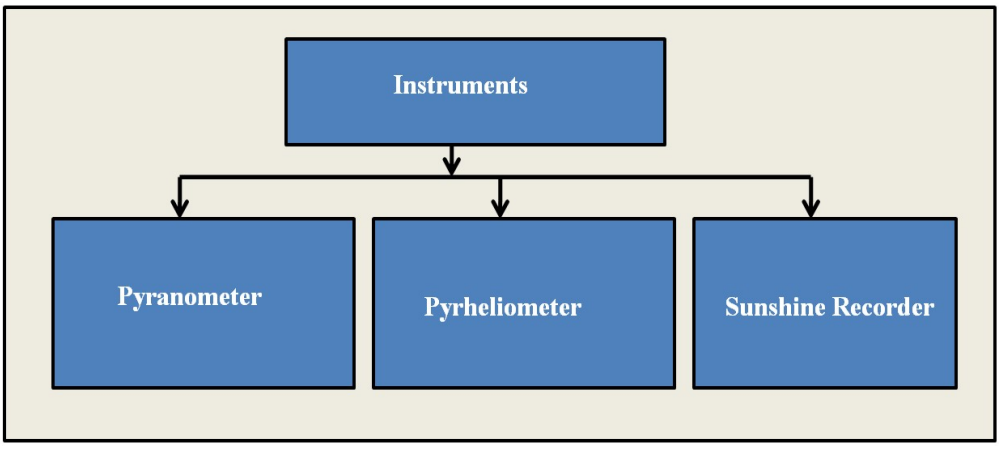


Figure 5.Types of measuring instruments

Pyranometer: It designed to measure global or diffused radiation on horizontal and inclined surface.

Pyrheliometer: It designs to measure direct or beam radiation usually used long narrow tube to collect the direct radiation from sun at normal incident.

Sunshine Recorder: When the sun present it gives burn mark on the paper which received solar radiation on which chemically treated.

1.2 Solar Collector

Solar collector is work as heat exchanger device that convert solar radiation into heat or thermal energy. The function of solar collector is to absorbed the energy from sun of radiation in form of diffused or direct radiation and convert it to thermal energy or heat energy that heat is further transfer to working fluid such as air, water etc.

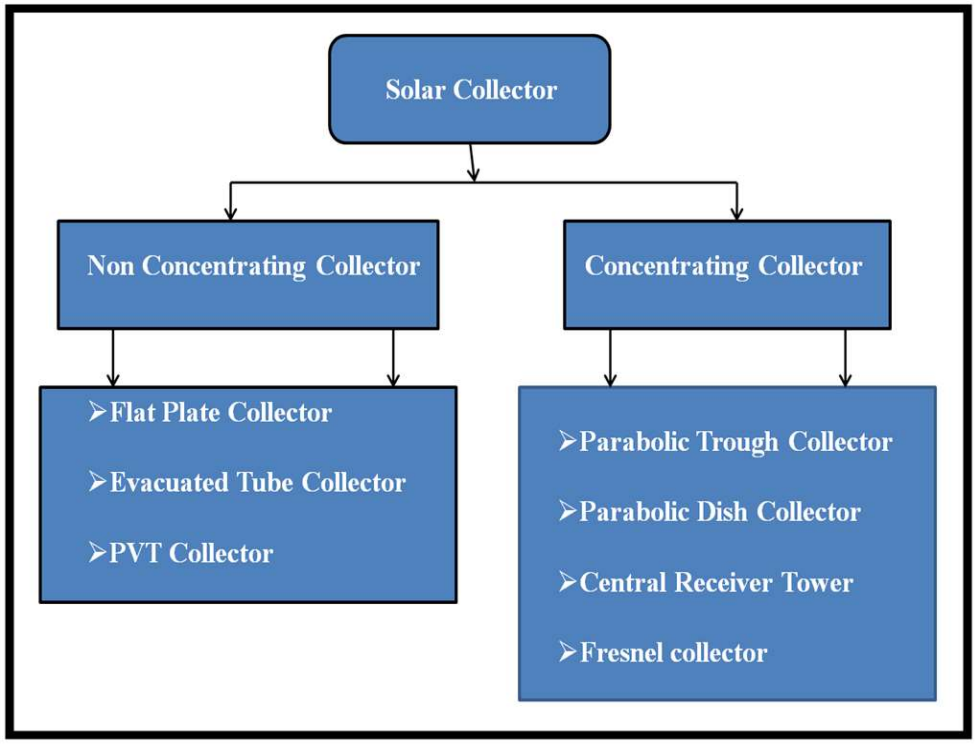


Figure 6. Types of solar collector

1.2.1 Non Concentrating collector

This type of solar collector has a small area to expropriate the global and beam radiation so they are compact for low temperature generation. These types are mostly used in heating up swimming pool, wax melter, distillation, space heater etc.

a) Flat Plate Collector

As the solar radiation passes through transparent glass it influences the increase in temperature of absorber plate. The heat is transfer to a tubes array from the absorber plate. In tubes the working fluid is passes out from one side and exist from other side thus we can utilized that thermal energy as shown in below figure 7.

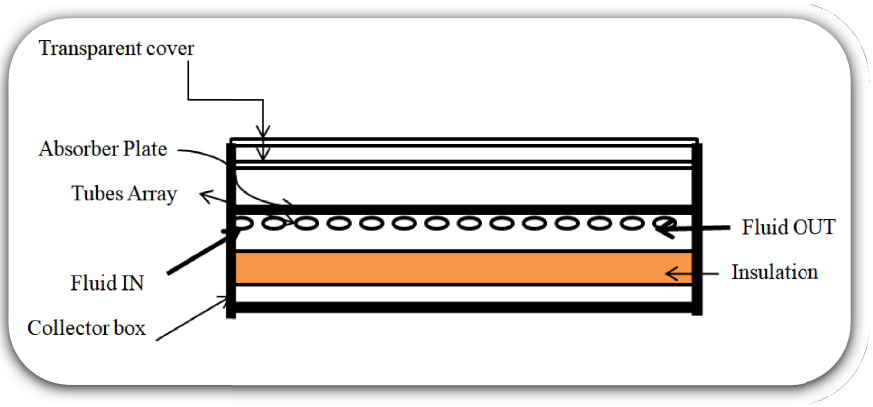


Figure 7.Flat Plate Collector

b) Evacuated Tube Collector

Evacuated tubes are used to reduce conduction and convection heat losses; by this we can achieved higher efficiency than flat plate collector. The evacuated tubes are made single and double layer glass tube, one layer of glass is blend to heat pipe and other end encompass heat pipe and absorber in vacuum one.

c) PVT Hybrid Collector

In photovoltaic hybrid collector (PVTHC) this system consist of solar cells which convert light into electricity. The energy is generated by photovoltaic hybrid collector and excess energy is dissipated by PVT module (package of solar cell).The efficiency of PVTHC is very low.

1.2.2 Concentrating collector

This types of solar collector are used to concentrated a large amount of radiation by concentrating on one point .To concentrated a large area in small area the reflector are place to transmit the solar rays in form of diffused and direct radiation. By this heat is produced in large scale, the efficiency of the concentrating collector is high than the non concentrating collector .The increase in the temperature due to increase in the heat flux radiation.

a) ParabolicDish Collector

In this collector complete heat turnoveris 1200°C. The focal point is at one point due to the shape of the reflector is dish type. The tracking of solar radiation into two axes. The

fluid is passed through the receiver tubeand passes this fluid into an engine togenerate energy.

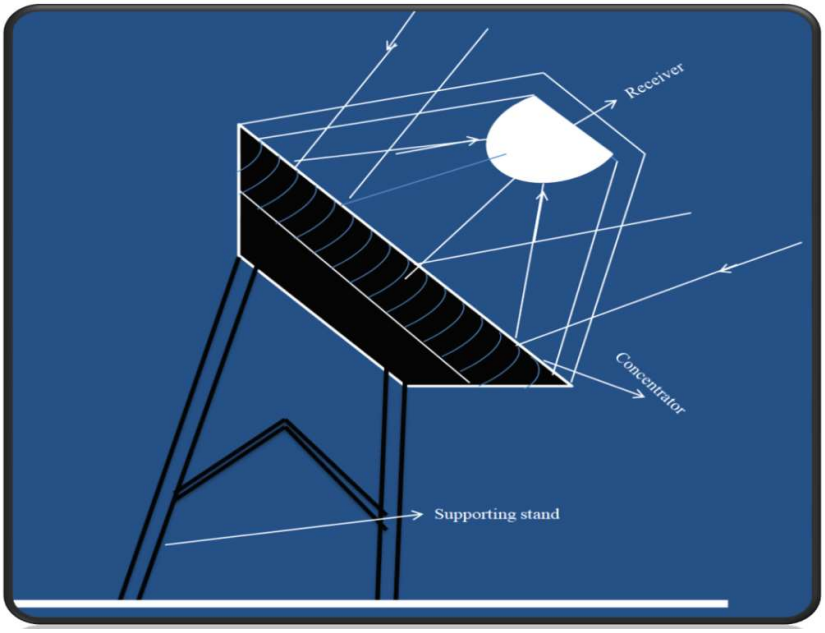


Figure 8. Parabolic Dish Collector

b) Fresnel Collector

The fresnel can also be known as linear fresnel reflector. It consist of magnifying mirror type in focus, it is placed I such a manner that it concentrated on one point.

c) Center Receiver tower Solar

In center receiver solar the sun radiation falls on the mirrors or reflectors which are place beside the tower in circular manner. The radiation reflected the radiation on the receiver which is place on the top side of the tower. These types are used in power generation as shown in figure below.

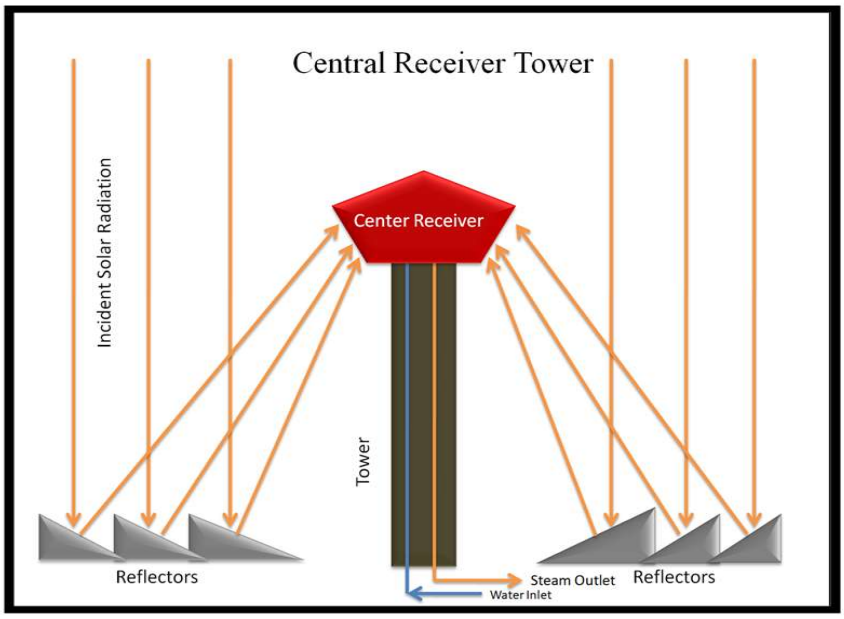


Figure 9. Central Receiver Tower

d) Parabolic Through Collector

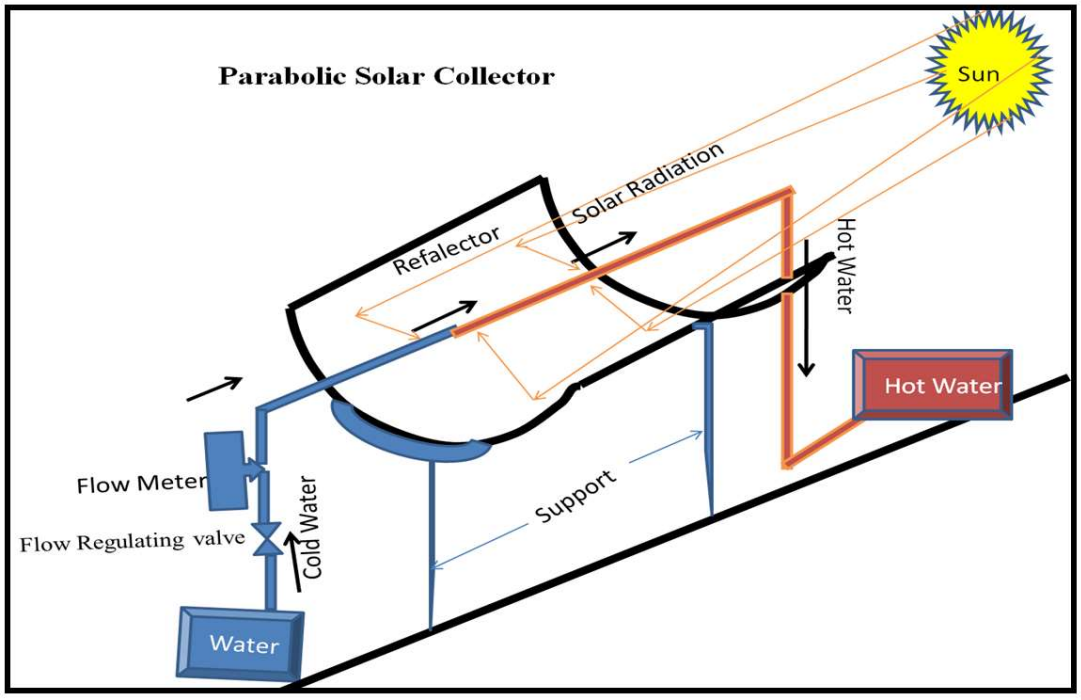


Figure 10. Parabolic Through Collector

In the experiment parabolic solar collector is carried out for study, the sun radiation is used to heat the working fluid. The reflector is used in parabolic shape, it generally it made by shinny metals like mirror, aluminum sheet. The experiment is carried with the

help of nanofluid Al_2O_3 and base fluid H_2O at the different concentration ratio the thermal behavior of fluid will be tested at different mass flow rate. This concentrating collector has a capacity to generate more than about 300^0c temperature.

1.3 Nanofluid

As we study the base fluid has low thermal conductivity, to increase thermal conductivity of fluid we added nanoparticles into it .Nanoparticles has good thermal conductivity it absorb heat directly .By adding nanoparticles into base fluid the absorb heat in fluid by nanoparticles is transfer it in fluid thus we can achieve better thermal conductivity of system by this we can improve efficiency of system by nanofluid.

Nanoparticles has some types such as metal, carbon, oxide the nanoparticles are very fine in size near about 1-100 nm.The nanoparticles have capacity to increase the thermo physical properties such as viscosity, density, thermal conductivity. The enhancement in thermal conductivity of fluid we can improve the efficiency of the system.

2 Scope of study

Indoor swift period of modernization, the rapidly increasing the pollution has a major issue in present time. The energy demand is higher by which the world reserved fuel is depleting day by day. Now to fulfill the demand and seeing global warming the renewable energy is been in demand. The using of concentrating collector, the efficiency of a boiler can be widely reduced. By heating the fluid with the help of solar radiation parabolic solar concentrating collector is used.

To study the thermal behavior of fluid with nanoparticles mixed with a different concentrating ratio. The efficiency of the fluid has the capability to rise in temperature Al_2O_3 are highly flammable.

3 Objective of study

- The main goal of this project is to investigate the thermal behavior of parabolic solar collector by using Al_2O_3 as a nanoparticle and H_2O asbase fluid with different volumetric concentration ratio.
- To compare the effectiveness of PSC by using nanofluid and convectional fluid.
- To compare temperature rise with different concentration ratio of nanofluid.
- Toexperimental result and computational result.

4 LiteratureReview

Salgado conrado et al.[1], The research reveals the parabolic solar collector by combining the different models, it observed that it has large range to improve the thermal modeling and by combining the different thermal models it find difficult to solve the simulation because it is complex model.

Sayed amen murtuza et al.[2],It was observed that the experiment was conducted of 5 m PSC the receiver is made of stainless steel and base fluid is used H^2O.The experimental work is carried to obtain the result of surface temperature, outlet temperature, thermal efficiency at different mass flow rate 1.2 l/m, 0.8 l/m, 0.4 l/m, in overall year, the maximum temperature is obtained 80^0c to 103^0c in month of february, march, april, may.

Ali et al.[3], The author reviewed the thermal conductivity of various Nanofluid at various concentration it was observed from the paper that. The thermal conductivity of nanofluid majorly depends upon the volume concentration and temperature. At temperature increased of nanofluid the thermal conductivity of the nanofluid decreases. The volumetric concentration increases the thermal conductivity of the nanofluid increases but only the critical volumetric concentration of the nanoparticles.

Chrishophersansom et al.[4], This paper, compares the two glass black and silver mirror gage repeatability and reproducibility, abengeo condor. By comparing both it found that the condor mirror contain more reflective because of six wavelength spectrums.

Bhat et al.[5], Experimentally invested the effect of Cu based nanoparticles with water on flow behavior and heat transfer characteristics on corrugated pipe of a double pipe test heat exchange .The result reveled that convective heat transfer increases which enhance heat transfer when 0.05% CuO-H_2O Nanofluid flows inside the inner pipe of heat exchanger. The addition of nanoparticles increases inertia force due to increase in reynolds number. The pressure drop increase which enhance pumping power of system.

V.K.Jebasingh et al.[6], The paper reviews that the efficiency of the system parabolic solar collector .working fluid, collector length, diameter of receiver tube should be efficient to environment condition. The thermal efficiency can be improved by affecting parameter like coating, working fluid, material.

Hongbo et al.[7], In this paper author compare the 1-D and 3-D models to calculate the heat transfer in parabolic solar collector; it was observed that in 1-D model is carried by

meshing the heating element (110 m) in n segments. By simulating the efficiency is 0.75% and outlet temperature is 25^0c where as in 3-D module outlet temperature is 0.65^0c to simulate the 1-D and 3-D, 1-D is easier.

Aggrey mwesigge et al.[8], The Al_2O_3nano particle and base fluid synthetic oil is used as nanofluid at different volume fraction it increases from 0% to 4%, 6%, 8% of heat transfer up to 35^0c, 54^0c, 76^0c. The mass flow rate is 25 m^3/h, thermal efficiency increased by 7.6%.

C.Tzivanidis et al.[9], The calculation of convection heat coefficient inside the absorber tube is calculate and compare with the theoretical results and efficiency of angle is been carried out to obtained maximum thermal, optical efficiency into desired. By simulation result 75% is higher the temperature efficiency, the efficiency has very low heat losses coefficient about 0.6 to 1.3 w/m^2k totally depend upon inlet temperature.

Victor C. Pigozzo Filho et al.[10], The thermal losses in small parabolic solar collector of 3×4 m width and length is selected to experiment work. By simulating the result the degradation vacuum in annual region receiver tube the efficiency is obtained 0.3 % to 0.55% varies.

Qianjun mao et al.[11], The author say that, by heat flux the efficiency is affected, this is carried by simulation using MCRT. Parameter he used for irradiation solar100 to 1100 w/m^2, aspect ratio of absorber is 0.5 to 1.5. The simulation carried up to 200 conditions. It observed that as radiation flux minimum at 80 mm and maximum at 130 mm.

Jaifar Albads et al.[12], In this paper at different concentration with base fluid Al_2O_3 nanoparticles of size 30 nm in diameter and flow through heat exchanger with inlet and mass rate are same. The result is found that particle volumetric concentration increases the friction factor increases. Dispersing the nanoparticles in the base fluid, increment in thermal conductivity.

SoteriesA.Kalogirou.[14],In this paper it was observed that ,the modes of heat transfer to the receiver pipe, glass cover to receiver pipe , annulus to the glass cover, glass to ambient temperature, radiation from glass to the receiver are all taken into consideration. The radiation on glass cover to receiver are resulted the efficiency is 58% at a temperature 200^0c,solar radiation at 900 w/m^2, wind speed 0.45 m/s, flow rate of fluid is 8.8 kg/s and ambient temperature is 25^0c.

Cheng et al.[15], In this paper it was observed that, the 3-D simulation of heat transfer is analyzed, by using two methods fluent and Monte Carlo ray trace .By using sylthem 800 oil and collector as LS2 of SEGSI type, as result the radiation decreases by 53 to 70 w/m-^{2} and increase in efficiency the losses of radiation must be reduce.

5 Equipment, Materials, and Experimental Setup

5.1 Parameters and specification

Sr.No.	Parameters	Specification
1	Base Fluid	H_2O
2	Nano Particles	Al_2O_3
3	Fluid Circulating Pump	18w
4	Collector Length	1.8288 m
5	Collector width	0.9144 m
6	Collector plate thickness	0.00053 m
7	Receiver inner diameter	0.0127 m
8	Receiver outer diameter	0.01778 m
9	Glass cover tube diameter	0.0254 m
10	Water storage Tank	20 L

Table 1. Specification of the parabolic solar collector

5.2 Materials

a) Absorber Tube

Absorber tube is of copper and it coated with black from outside of the pipe to absorber the maximum solar radiation from sun. In the tube the working fluid is made to flow and exist in the storage tank. The absorber tube is also known as receiver tube.

b) Support Structure

The support structure is provided to a parabolic solar collector with a material of cast-iron. Cast iron provides a greater strength to the frame of parabolic solar collector. The cast iron frame is painted with black paint to avoid corrosion, rust.

c) **Reflector**

The reflector is the main element in solar collector; they are made by various materials such as mirror, aluminum, and lance. We used the aluminum sheet which is shinny from

one side which can concentrate the solar radiation on absorber tube which is place on focal point of parabolic curve.

d) Control Valve

Control Valve is provided to control the flow of the fluid as the required mass flow rate.

e) Pump

The pump is submersible it is deep into the fluid, it has a capacity of 1100 l/hr. Which circulate the working fluid to absorber tube.

f) Digital Thermometer

Digital thermometer can measure the temperature from -50^0c to 100^0c.They are provided from both the side of absorber tube inlet and outlet sides. By this we can measure the initial temperature of working fluid and ambient temperature after it passes from absorber tube.

g) Flow Meter

Flow meter is measured the flow rate of working fluid .It can measured from 20 to 200 l/mim.

h) Pipe

The pipe is provided to parabolic solar collector to circulate the working fluid from one container to another container. It is made of plastic material.

i) Container

Container is provided to store the working fluid;it is made up of an aluminum tin having capacity to store 20 liters.

5.3 Nanofluid (Al_2O_3) Properties, Preparation

5.3.1 Properties of Al_2O_3

Color	White
Name	Aluminum oxide
Shape	Spherical
Crystal Form	Alpha
Purity	99%
Thermal Conductivity	40 w/m k
Specific heat	765 J/kg k

Table 2. Properties of Al_2O_3

5.3.2 Preparation of Al_2O_3

There are two methods for preparing the nanofluid they are as follows,

A- The nonomaterial such as aluminum, copper, etc, are used. The processes like drying, transport, store, dispersion of the particles are avoided.

B- Nanoparticles are made by various different methods then they are mixed with the base fluid then they called as nanofluid.

5.3.3 Base fluid H_2O

Density	1000 kg/m^3
Thermal Conductivity	0.766 w/mk
Specific Heat	4187 j/kg k
Viscosity	$4.06 \times 10^{-4} m^2/s$

Table 3. Properties of water

6 Research Methodology

6.1 Experimental Setup

In parabolic solar collector the equipments such as absorber tube, glass cover, reflector, Control valve, flow meter, thermometer, pump, piping arrangement, supporting structure, and container to store the working fluid. The reflector is made up of aluminum sheet is shinny will be make parabolic shape with cast iron support and the focal point will be calculate of parabolic curve on focal point the absorber tub will be places and over that the glass cover will placed due to this re-radiation loss can reduce. The fluid will circulate with the help of pump and control valve will be provided to control the flow of fluid in a pipe. The flow meter and thermometer will give the reading of flow of fluid and temperature at inlet and outlet. By different concentration of nanoparticles will mix with base fluid and their properties will be tested.

6.2 Nanoparticles Identification

There are some types of nanoparticles such as metallic particle, oxide and carbon out of this Al_2O_3 is selected in nanoparticles oxide type it has good thermal conductivity.

6.3 Identification of Base Fluid

In the base fluid contain ethylene glycol, water, engine oil. Water as a base fluid has been carried out for this work.

6.4 Nanofluid Preparation

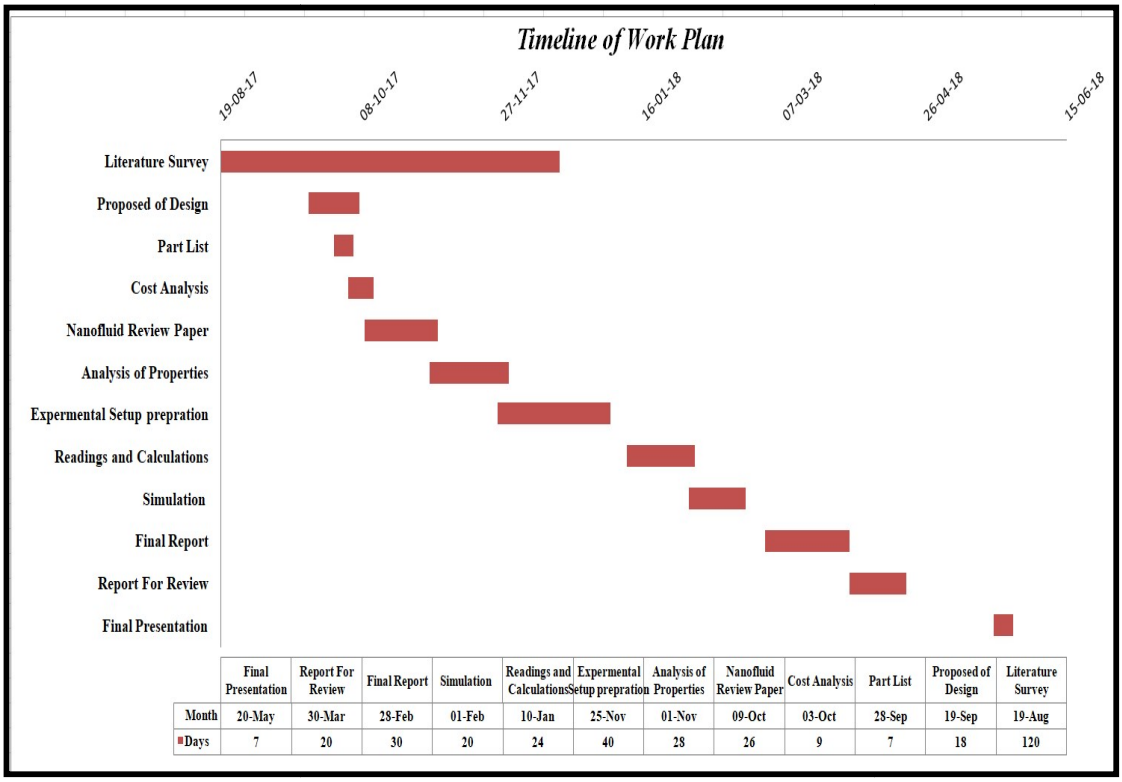
By combining the nanoparticles with base fluid the thermo physical property increases in the nanofluid.

6.5 Experimentally Measurements

In the outdoor month February, March the experiment will be conducted and reading will carried out .The simulation work will be carried out and then we will get the temperature effects by different concentration and mass flow rate.

7 Proposed Work Plan with Timelines

The work is started in August 2017 until the date the half of the work has been completed under the guidance of a guide.



	Final Presentation	Report For Review	Final Report	Simulation	Readings and Calculations	Expermental Setup prepration	Analysis of Properties	Nanofluid Review Paper	Cost Analysis	Part List	Proposed of Design	Literature Survey
Month	20-May	30-Mar	28-Feb	01-Feb	10-Jan	25-Nov	01-Nov	09-Oct	03-Oct	28-Sep	19-Sep	19-Aug
Days	7	20	30	20	24	40	28	26	9	7	18	120

Figure 11. Work plan with timeline

8 Expected Outcome

- Improvement in both instantaneous efficiency and thermal efficiency will be observed by experiment.
- Temperature rise will be seen with respect to increasing flow rate of nanofluid.
- Thermal conductivity of the nanofluid will increase with respect to increasing in concentration ratio of nanofluid.

9 Summary and Conclusion

In this experiment study of the parabolic solar collector the study of thermal behavior of nanofluid using the different concentrating ratio the effect on the temperature rise can obtained due to the different flow rate. The thermal conductivity is increase due to increase in concentration ratio. We will compare the nanofluid with the conventional fluid and Al_2O_3 and convectional fluid will improve the thermal efficiency of parabolic solar collector.

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