Comparative Investigation on Performance of Flat-Plate Solar Collector Using Different Nanofluid

Dissertation-II

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by

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2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.00
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.50
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5	Social Applicability: Project work intends to solve a practical problem.	7.50
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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**Comparative Investigation on performance of Flat Plate Solar Collector Using Different Nanofluid**" 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 (Gaurav Vyas, 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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ABSTRACT

Flat plate solar collector (FPSC) is one of the most popular equipment among solar energy systems which can be utilized for heating of domestic or public buildings. The performance flat plate solar collector depends on working fluid. Researchers are trying to find out best nanofluid which can give high efficiency or more heat transfer rate. In this work, performance of flat-plate solar collector is investigating using different nanofluid. It is a comparative study of nanofluid which will give us high heat transfer rate. This report includes review of research paper from 2012 to present. This report also includes experimental set up, research methodology, expected outcome.

Table of Contents

List of figures

1 Introduction

Solar energy is most common energy. It can to give large amount of power. Solar energy comes from sun to earth and 10^{16} watts is energy which strike on earth surface and sun gives us 1000 time more power than we need**.**

Solar radiation and its measurement-Energy come from sun as electromagnetic wave. Wave length lies in between 0.2 to 0.4 micrometers. Radiation is coming from sun at 5762-degree Kelvin. Solar constant- it's represent by (I). Solar radiation can divide one is direct radiation and other is diffuse radiation

1.1 Solar radiation measurements-these are basic instrumental for solar radiation measurement

1.1.1 Pyrheliometer- beam radiation or direct radiation can calculate by this equipment. This instrument doesn't calculate diffuse radiation. In base of a tube disc is placed.

1.1.2 Pyranometer-diffuse radiation can calculate by this apparatus. This instrument doesn't calculate direct radiation. Hot junction and second is cold junction is component of this instrument.

1.1.3 Sunshine recorder- time period of bright sunshine can calculate by this equipment.

1.2 Solar energy collector- work of this collector to is collect heat energy. Then in step two that energy transfer to other system. Focusing (concentrating) and flat plate solar collector are the type of this energy collector.

1.2.1 Focusing (concentrating) solar collector –this is connected with absorber and absorber is the important component. Heat or electricity energy is obtained by focusing collector. The area of collector and the area of absorber both are same in case of flat plate collector. In other type, the area of focusing is not same as area of absorber. Other type collectors have better efficiency than the non-concentrating. Focusing (concentrating) collector collects solar energy with high intensity. This kind of system use optical system as reflector. Temperature range is around 500 degrees for focusing. There is only one major difference between focusing collector and non-concentrating collector is that non-concentrating collector doesn't have reflecting or refracting surface. Radiation falling on a focused collector is large as compare to a non-concentrating collector.

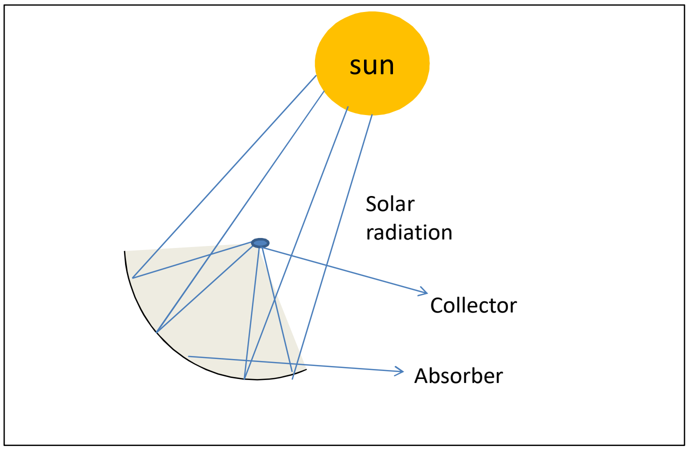

Figure 1Focusing solar collector

1.2.2 Non- concentrating collector-Below 90-degree temperature, non-concentrating is used. For water heating, non- concentrating is used. Both beam and diffuse solar radiation can absorb by non-concentrating

Non-concentrating collector can divide in to liquid heating collector and solar air heater.

Tube-shape of tube is circular which contain heat fluid. Tubes are connected with collector.

Absorber plate- solar radiation is absorbed by absorber. Plate is made a metallic.

Insulation**-** Insulation is important component which can define thermal residence. It helps for reducing heat losses.

Casing-casing can define as container which helps to holds the other component and protects them from the weather.

1.2.2.1 Liquid Collector

Liquid collector comes under tube and plate type collector. Main component of liquid collector are tube, absorber, glass cover and casing. Typically, flat surface is made of copper, steel with thickness of 1mm to 2mm and the diameter of tube varies between 1 to 1.5 cm. Thermal insulation varies from 5-10 cm. Solar radiation come from sun it's absorbed by absorber surface then absorber plate transfer to tube.

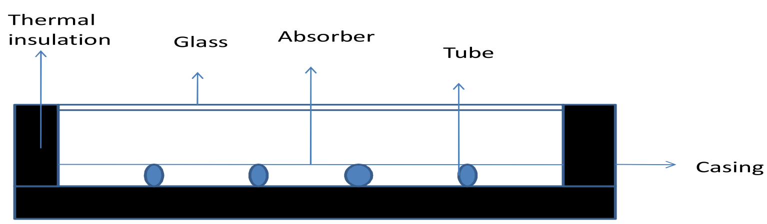

Figure2Liquid Collector

1.2.2.2 Typical air collector

Air is used as working fluid. Air is passes from the back side of the collector. Basic work of solar collector is to transfer heat to air. In this collector air is working as medium and it has also some advantage over water. For reduction of power requirement in the pump the required volume of air through tubes, wider flow channels are used. Freezing and corrosion both problems can eliminate by using air as medium. Air is best heat transfer fluid because air leaks are less then water leaks. The heated air can be directly used for many applications like space heating. For transferring of heat from air to water in a hot water supply system is considered to be inefficient

Basically, heaters are classified in the following two categories:

1.2.2.2.1 Non-porous absorber plate type collectors-A non –porous absorber can easily be cooled by stream flowing over both sides of plates. In common designs air flows behind the absorbing surface. When the air flows over the upper surface increases the losses from cover plate occurs but it is not recommended if the air inlet temperature rise at the collector is large. The absorption and transmission of solar radiation through transparent cover system is identical to that of liquid type flat-plate collector

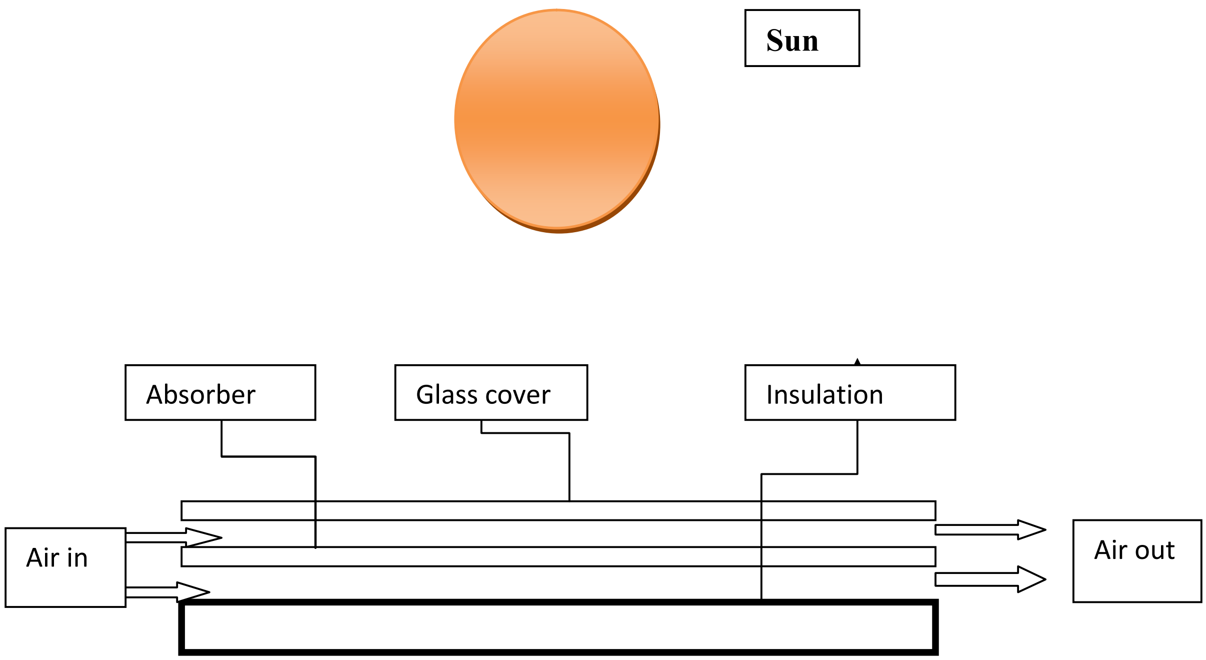

Figure 3 non-porous absorber plate collector

1.2.2.2.2 Collectors with porous absorbers- The principle disadvantage of the non-permeable safeguard plate is the need of engrossing every approaching radiation over the anticipated range from a thin layer over the surface which is in the request of a couple of microns. Particular covering is utilized. The weight drop along the channel shaped between the safeguard plate and the back protection may likewise be precluded particularly on account of added balances to build the warmth exchange surface and turbulence rate. The trouble with turbulences is the weight drop over the gatherer. An excessive number of surfaces and a lot of confinement to wind stream will require a bigger fan and a bigger measure of vitality to drive the air through. The vitality required for this counterbalance sparing from utilizing sun powered vitality, especially if fan is electrical and it the measure of vitality which is scorched at the power plant to deliver the electrical vitality is incorporated.

1.3 Solar Energy applications

1. Heating and cooling of residential building.
2. Solar water heating.
3. Solar drying of agricultural and animal products.
4. Salt production by evaporation of seawater.
5. Solar cookers.
6. Solar engines for water pumping.
7. Solar Refrigeration.
8. Solar electric power generation.
9. Solar photo voltaic cells, which can be used for electricity.

1.4 Nanoparticle–A nanoparticle is basic component of nanostructure. It is very small particle. Nanoparticle varies between 1nm to 100nm.

Different types of nanoparticle

1. Metallic oxide
2. Ceramics
3. Carbide ceramics
4. Metal
5. Semiconductor
6. Alloy

1.5 Nanofluid -Heat transfer is very important factor. Heat transfer needs in either cooling or heating. Heat transfer is mainly depending upon thermal conductivity. nanfluid has two component one is nanoparticle and other is base fluid. The diameter of nanoparticle lies between 1nm to 100nm. Water, oil, ethylene glycol and engine oil are base fluid.

1.5.1 One step method –this is a common method which is use for producing Nanofluid. In this single-step method there is only one step. Drying, storage can avoid by using one step method. The stability of the Nanofluid one step is better than two step method.

1.5.2 Two step methods- name of this method itself suggesting that it has two steps. These steps are production of nanoparticle and dispersion of nanoparticle in a base fluid. The stability of the Nanofluid one step is better than two step methods.

1.6 Stability of Nanofluid: The three common techniques-

1.6.1 Addition of surfactant- surface tension is one of cause for instability and it can reduce by surfactant which is a chemical component. The most of surfactant are SDBS Salt and oleic acid, Gum Arabic.

1.6.2 PH Control-stability of Nanofluid can achieve by pH control. By using pH control, stability of Nanofluid can increase. Some of pH value is given for alumina is 8. And pH value for copper is 9.5

1.6.3 Ultrasonic agitation-ultrasonic agitation is equipment which helps to increase stability of Nanofluid.

1.7 Stability Evaluation Method

1.7.1 U V-Vis spectrophotometer

This method helps for investigating the stability. Light's ray is passing through fluids and when its passes through fluid the intensity of light changes because of absorption and scattering.

1.7.2 Zeta potential test

Zeta potential value is one of the causes of stability. As the value of z potential increases with that value stability will also increase.

1.7.3 Sedimentation photograph capturing

Capturing photos of fluid is theme of sedimentation photograph capturing. Stability of Nanofluid can calculate by sedimentation photograph capturing method. It can also define as one of post preparation method

1.7.4 TEM (Transmission Electron Microscopy) and SEM (Scanning Electron Microscopy)

As shown figure it is capable to capture photos in small sizes and because of that photo this can find suspension situation of nanoparticle inside the Nanofluid fluid

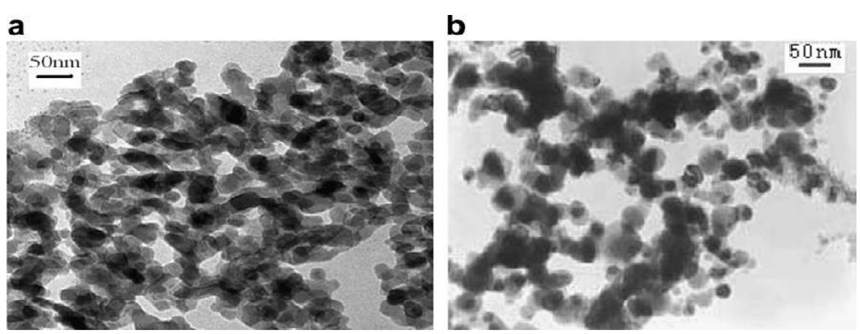

Figure 4 TEM micrograph of nanoparticle (a) Nano-alumina (b) Nano-copper [21]

1.8 Thermo physical properties-Type of thermo physical properties are shown in figure

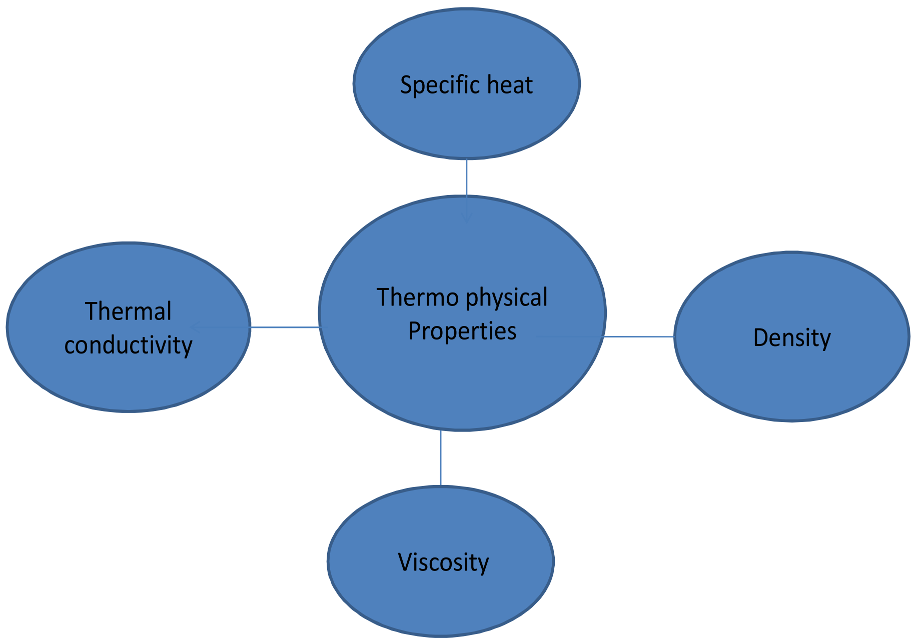

Figure 5 Thermo physical properties

These all thermo physical properties depend on nanoparticle size, shape, concentration

1.9 Thermal conductivity- it denoted by (k). thermal conductivity of material can define as ability to transfer heat energy. As shown in figure7 thermal conductivity of liquid is less as compare to solid. Thermal conductivity of Nanofluid depends on both particle's conductivity and base fluid's conductivity. Thermal conductivity of material is shown in figure

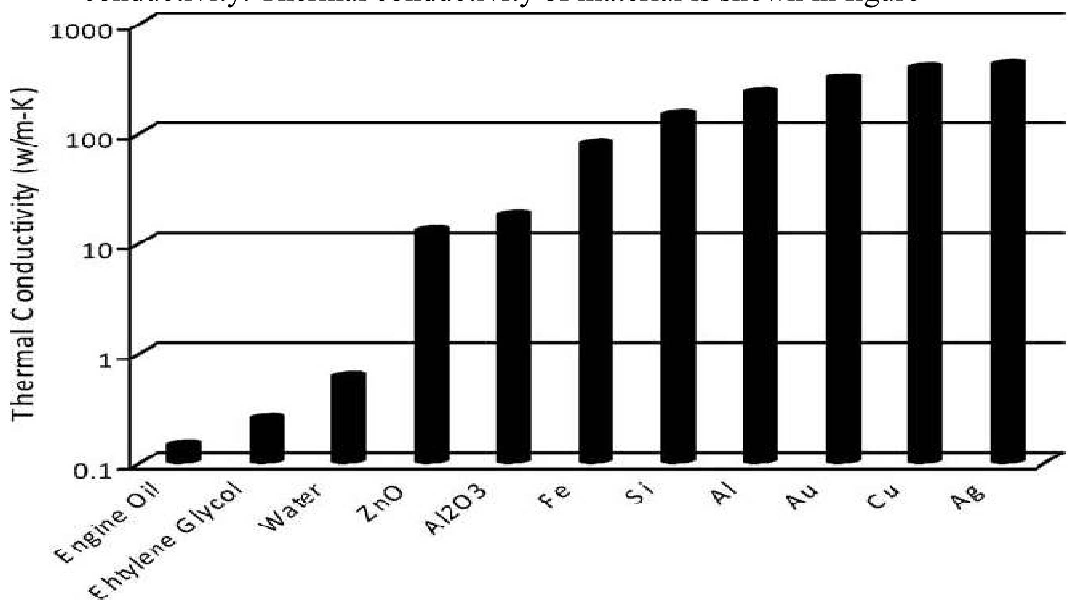

Figure 6Comparison of thermal conductivity of common liquids and solids [20]

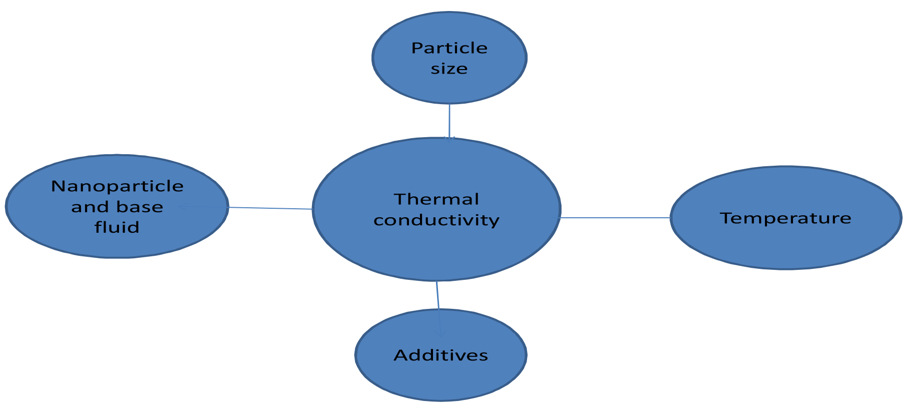

Figure 7various factor that affect thermal conductivity

1.10 Measurement techniques for thermal conductivity

Temperature difference can cause heat transfer through materials which is known as thermal conduction. Fourier's law helps to evaluate the thermal conductivity of any material. Thermal conductivity is different for different material. Mathematical formula is given below.

$$q = k\frac{dT}{dx}$$

Where k- thermal conductivity
q- Heat flux

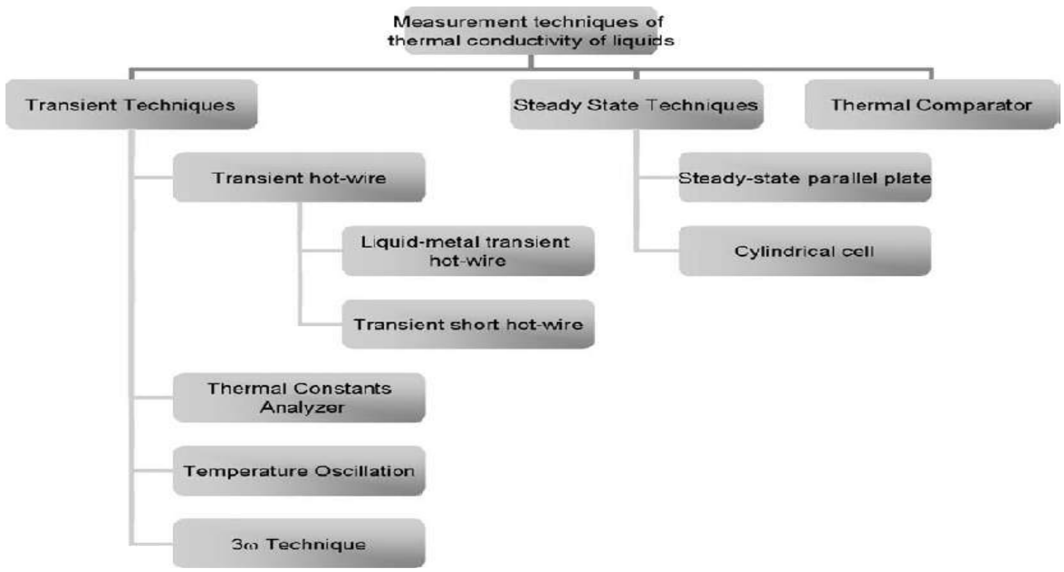

Figure 8Different thermal conductivity measurement techniques for nanofluids. [20]

1.10.1 Transient hot-wire (THW) method

Thermal conductivity can be measured by THW method which is fast and better method then other method. And design of this apparatus is simple as well. Detail diagram is given below.

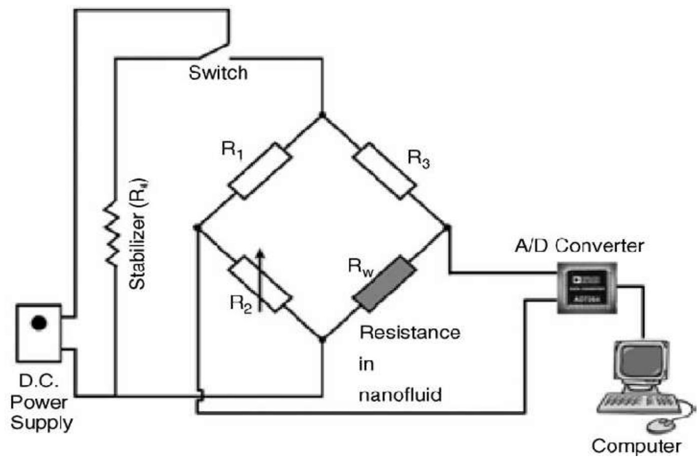

Figure 9Schematic of transient hot- wire experimental setup[20]

1.10.2 Transient Plane Source (TPS) method–Use of probe is only one major difference between TPS and THW. Thermal bath with thermometer, TPS sensor, sample holder, thermal constants analyzer and computer are part of experimental setup which is shown in figure.

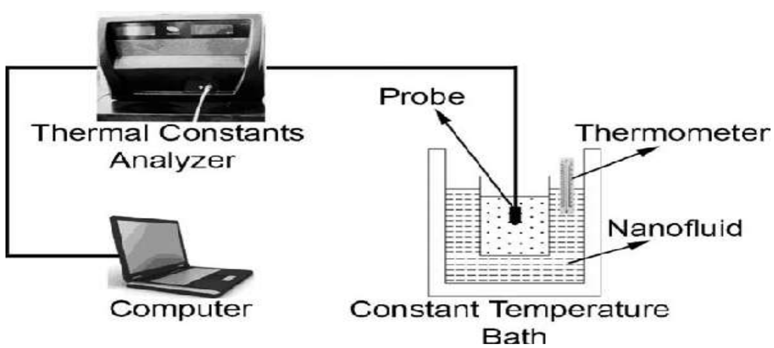

Figure 10Schematic diagram of the experimental setup for transient plane source method [20]

1.10.3 Steady-state parallel plate method- Thermal conductivity of nanofluid is can evaluate by steady-state parallel plate method. Two parallel round pure copper plates are present in equipment. First plate is known as upper plate and other plate is known as lower plate. There are two thermocouples one is on top and other is on bottom for measuring temperature difference of the sample. This method use Fourier's law for calculating thermal conductivity. Detail diagram is given below.

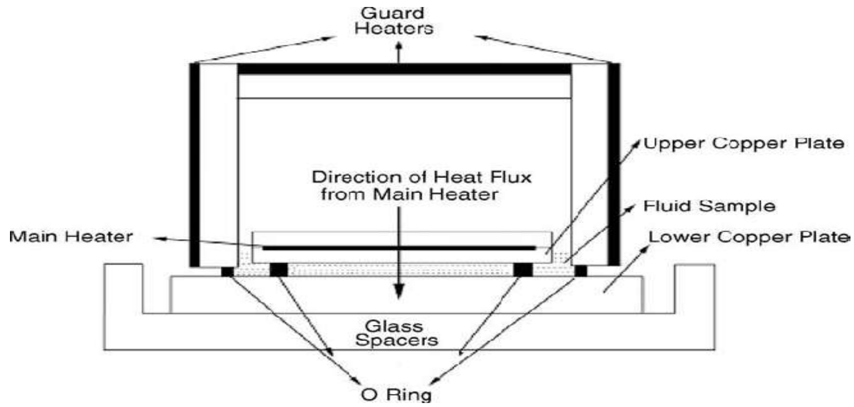

Figure 11Experimental set up for steady-state parallel-plate method [20]

1.10.4 Cylindrical cell method – it consists of two coaxial cylinders one is inner and other is outer cylinders. There is a gap between outer and inner cylinder, fluid sample is kept between that gaps. Temperature difference of outer and inner cylinder is measured.

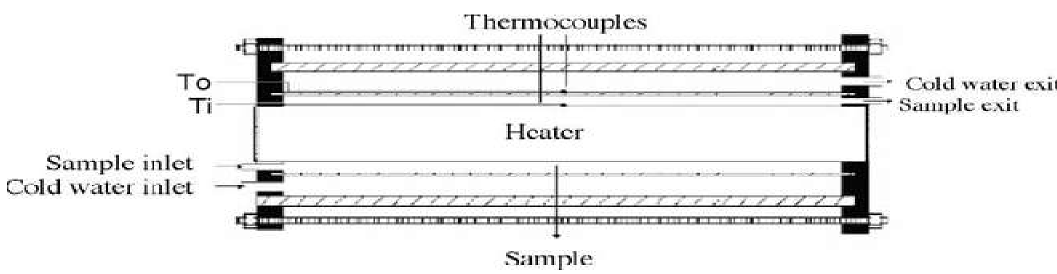

Figure 12Cross-section of the cylindrical cell equipment [20]

1.10.5 3-method- The main difference between THW and 3-method is that in the former time dependent response is used while in the latter temperature oscillation is applied.

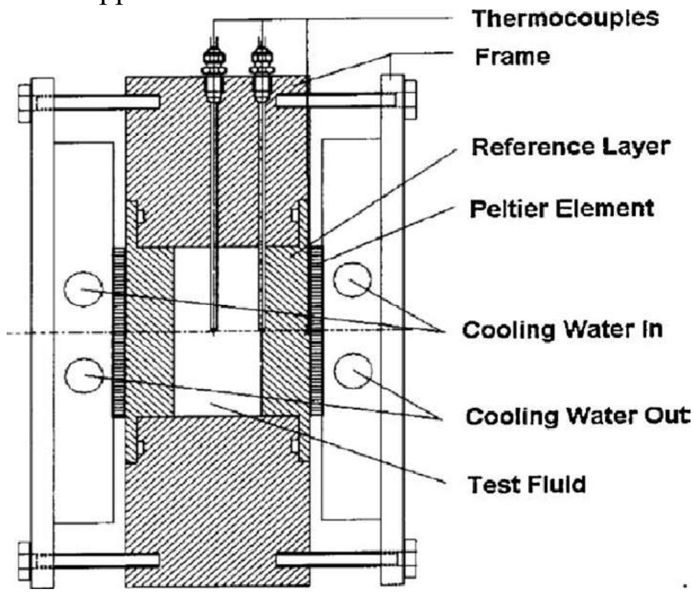

Figure 13 test cell construction [20]

1.10.6 Thermal comparator method-thermal conductivity of materials like aluminum, iron can evaluate by this method

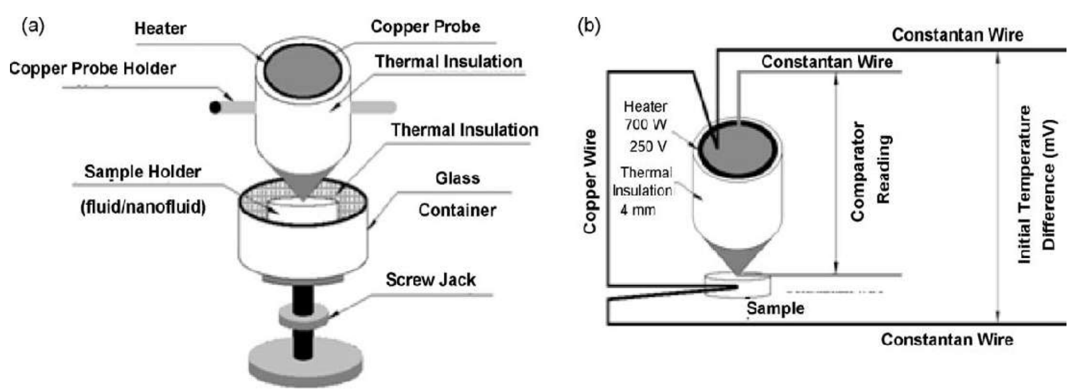

Figure 14Thermal conductivity measurements based on the thermal comparator method (b) the principle for recording differential thermo-emf using (a) [20]

1.11 Viscosity of Nanofluid-Viscosity means internal resistance of a fluid to flow. Pumping power and pressure drop are related to viscosity.

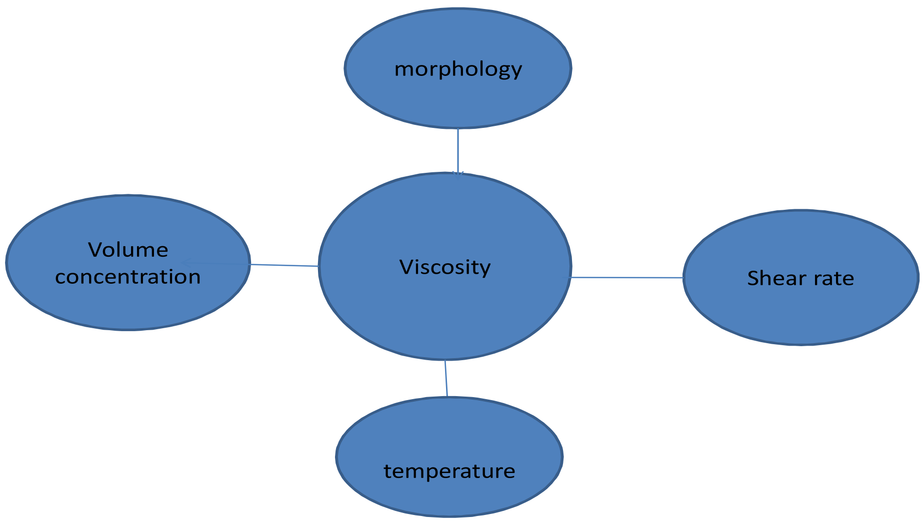

Figure 15viscosity depend various factor

1.12 Specific heat-specific heat can define as amount heat stored by particle for raise the temperature of one gram of Nanofluid by one degree centigrade. Heat transfer rate depends on cp value.

1.13 Application of Nanofluid- Nanofluid is used in various fields

1. Automobile applications
2. Solar applications
3. Mechanical applications
4. Friction reduction
5. Magnetic sealing
6. Biomedical applications
7. Reactor-heat exchanger
8. Optical application

2 Objective of research

Based on literature, it has been observed main objective of this research project is find best possible combination of Nanofluid with flat plate solar collector and get optimum efficiency of flat plate solar collector using Nanofluid. Also get maximum heat transfer rate for flat plate solar collector. We are also going to do the simulation analysis on the desire research problems. This simulation work will help to verify experimental result.

3 REVIEW OF LITERATURE

Chen et al., [2012] at different mass flow rates performance the collectors are calculated. The result came out from efficiency is that; mass flow rate is factor for the efficiencies variation. Theoretical efficiency compares the measured efficiencies.

Khullar et al., [2012] Concentrating sunlight based water warming framework (NCSWHS) is a contrasting option to frameworks in light of petroleum products. From the investigation has been discovered that outflow would reductions be able to and fuel funds can be accomplished if the NCSWHS are utilized. Higher yield temperatures can be accomplished by concentrating sun powered water warming framework (NCSWHS) when contrasted with customary level plate sun based water warming frameworks.

Nasrin et al., [2012] in this a numerical report has been done to explore the regular convection inside a sunlight based gatherer having a level plate cover and a sine-wave safeguard. In this water-alumina nanofluid is utilized as the working liquid inside the sunlight based authority. Recreation work is done to discover the impacts of physical parameters on the normal convection warm exchange. Normal speed field in the authority while, Ra, Pr, and ε are settled at 5%, 104, 6, and.9, separately.

Yousefi et al., [2012] Al2O3-water Nanofluid work as working fluid. Flat-plate solar collector's performance was calculated experimentally. 0.2%, 0.4% is weight fraction for experiment. Particle's diameter is 15 nm. In Experiments they used surfactant. 1 to 3Lit/min is volume flow rate. 28.3%. Is result came out at 0.2 wt%.

Verma et al., [2013] Al2O3-H2O is work in direct absorption solar collector. Direct absorption solar collector's performance is calculated by conducting an experiment. Volume fraction is taken as 0.005% and 0.05%. Result shows collector's performance increases about to 3-4%

Alim et al., [2013] Al2O3, CuO, SiO2, TiO2 nanoparticle are dispersed in water. Variation of entropy, heat transfer and also pressure drop are calculated theoretically. Nanoparticle's volume fraction was varying from 1% to 4% and volume flow rate define as 1 to 4 *L/min*. results show that entropy generation reduced by 4.34%

Moghadam et al., [2014]CuO–water Nanofluid work as working fluid. Experiment is performed for flat-plate solar collector's performance.0.4% is volume fraction of CuO and 40 nm is particle dimension. At 1 kg/m the Efficiency collector increased about 21.8%.

Zamzamian et al., [2014]in this experimental study, Cu nanoparticle is used. And base fluid is water. Flat plate solar collector's performance is calculated. 0.2% and 0.3% is taken weight fractions same as diameter of nanoparticle is taken 10 nm. Mass flow rate is from 0.016 to 0.050 kg/s. Weight fraction is the factor on which efficiency is depends.

He et al., [2015]at different mass flow rate and size, flat plate collector's performance is evaluated by conducting experiment using Cu-H2O Nanofluid. Mass flow rate doesn't change that is taken 140L/h. Conclusion came out from this work was that with nanoparticle size increasing, solar collector's performance decrease.

Salavati et al., [2015]an experiment is conducted for evaluating flat plate collector's performance using SiO2/ethylene glycol (EG)–water Nanofluid at 1%. And mass flow rates vary from 0.018 to 0.045 kg/s. result show that the collector's performance has positive relation with concentration and also efficiencies at 0.75% and 1% are very close

Karami et al., [2015]an experiment is conducted for investigating domestic solar water heater's performance where copper oxide is mixed 70 %water and30% ethylene glycol in mixture. Their thermo-physical and optical properties were presented. The collector's performance has positive relation with volume fraction and flow rates and also collector's performance is increased by 9–17%

Sarsam et al., [2015] this is review paper which reviewed past year research work where an experiment study is conducted for evaluating flat-plate solar collector's performance using Nanofluid.

Said et al., [2016]an experiment is conducted for evaluating flat plate solar collector's performance using (Al2O3)-water Nanofluid at 0.1% volume fraction and particle diameter are 13nm, 20nm.Also include one more factor mass flow rate which is lies between 0.5 to 1.5 kg/min. thermal conductivity at 13 nm Al2O3 nanofluid is higher than at 20 nm.

Noghrehabadi et al., [2016] researcher performed an experiment for evaluating square flat-plate solar collector's efficiency using SiO2-water at 1%.mass fraction. Performance of collector includes various factors on which collector' efficiency is calculated that are solar radiation, mass flow rate, and temperature variation. The results indicate that square flat-plate solar collector's performance is increased.

Kim et al., [2016] researcher performed an experiment for evaluating U-tube solar collector's efficiency using Al2O3 –water at 1.0% and mass flow rate is0.047 kg/s. Experiment include various factor like concentration, size of nanoparticle on which bases performance is calculated. U-tube solar collector's performance is by increased24.1%.

Choudhury et al., [2017] in this work numerical model and MATLAB code were utilized for computing the proficiency of a level plate sun powered authority. In this CuO-water nanofluid is utilized as a working liquid. CuO-water enhances the productivity of level plate sun powered authority up to 5%. The gatherer productivity was relying upon volume fixation and size of the nanoparticle. The outcomes demonstrated expanding in gatherer effectiveness by expanding the volume focus up to 2%

Verma et al., [2017] in this work diverse sort of nanoparticle is utilized for ascertaining productivity of level plate sun based gatherer. Trials demonstrate that for 0.75% molecule volume fixation at a mass stream rate of 0.025 kg/s, exergy effectiveness for Multi walled carbon nanotube/water nanofluid is expanded by 29.32%. For Graphene/water is expanded by 21.46%. For copper Oxide water is expanded by 16.67%. For Aluminum Oxide/water is expanded by 10.86%. For Titanium oxide/water is expanded by 6.97%. Silicon is expanded by 5.94%

4 Experimental setup

1. Pressure gauge 2. Stand3. Insulation4. Casing

5. Tubes 6. Absorber plate 7. Thermocouple

Figure 16Experimental setu

Component of experimental setup-

1. Pressure gauge
2. Stand
3. Insulation
4. Casing
5. Tubes
6. Absorber plate
7. Thermocouple

5 Research methodology

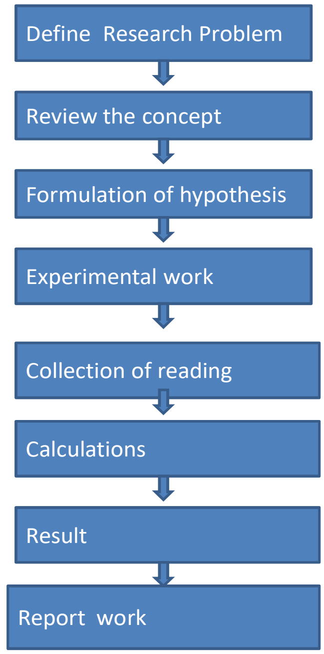

Figure 17step involved in research problem

1. **Define a problem**-it is initial phase of research. In this phase research problem is define based on research gap
2. **Review the concept**-in this step review is done on research problem.
3. **Formulation of hypothesis**-in this set we set a hypothesis which can be positive or negative
4. **Experimental work**-in this experimental setup is prepared. It is very important step of research work because reading of research is majorly depending on experimental setup.
5. **Collection of reading**-after experimental set up ,collection of reading is next step. In this step many experiment is perform on experimental setup for collection of reading.
6. **Calculations**-in this step calculation part of research is done.
7. **Results** –in this step comparison is done
8. **Report work** –this is final step of research methodology .in this step report work is prepared.

6 Work timeline

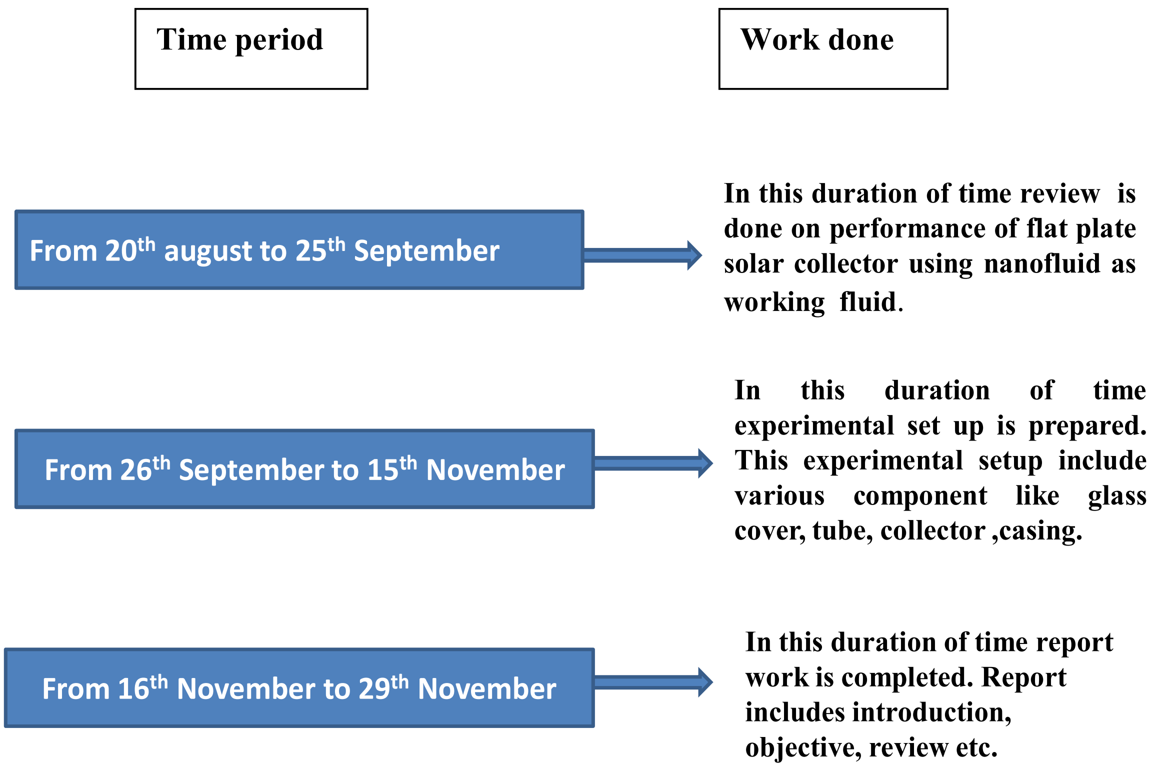

Figure 18 work timeline

7 Expected outcomes

This research work is a comparative study of Nanofluid when it is used in flat plate collector. Efficiency of flat plate major depends on the thermal conductivity of working fluid and heat transfer rate.

- From this experiment the corresponding results which are to obtained will comprise of respective points.
- To find the best Nanoparticle from all Nanoparticles available to use in Nanofluid, this can give best efficiency for flat plate solar collector.
- To get optimize heat transfer rate for flat plate solar collector.

8 Conclusion

In this report, some of work is presented which includes review, experimental setup. Review is done on performance of flat plate solar collector from 2012 to 2017.and experimental setup is assembled which includes component like glass cover, collector, tubes and also brought nanoparticle from laboratory. Some part of research work is still remaining is which preparation of Nanofluid and calculation part and also simulation work. After preparation of Nanofluid, experiments will perform on flat plate solar collector. Calculation and comparison between different efficiency is the next step after experiment

9 References

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